DATA BOOKLET

SCIENCE

MANJUNATH.R

Science Data Booklet

"The only true wisdom is in knowing you know nothing."

— Socrates

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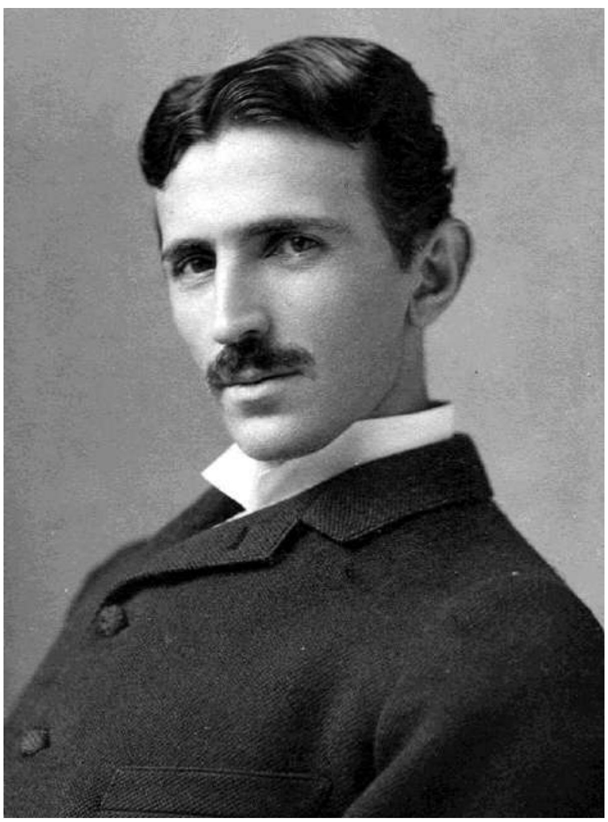
Science is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the nature. This booklet is designed to place less emphasis on factual material and greater emphasis on the understanding and application of scientific concepts and principles. This booklet has been designed in recognition of the need for students to develop skills that will be of long term value in an increasingly technological world rather than focusing on large quantities of factual material which may have only short term relevance.



My brain is only a receiver, in the Universe there is a core from which we obtain knowledge, strength and inspiration. I have not penetrated into the secrets of this core, but I know that it exists.

— Nikola Tesla

Laws of Exponents

- $1^n = 1$
- $0^n = 0$, for $n > 0$
- $x^1 = x$
- $x^0 = 1$
- $x^{½} = \sqrt{x}$
- $x^{1/n} = \sqrt[n]{x}$
- $x^{-1} = \frac{1}{x}$
- $x^m x^n = x^{m+n}$
- $\frac{x^m}{x^n} = x^{m-n}$, if $m > n$
- $\frac{x^m}{x^n} = 1$, if $m = n$
- $\frac{x^m}{x^n} = \frac{1}{x^{n-m}}$, if $m < n$; $x \in R$, $x \neq 0$
- $(x^m)^n = x^{mn}$
- $(x\,y)^n = x^n y^n$
- $(x / y)^n = \frac{x^n}{y^n}$
- $x^{-n} = \frac{1}{x^n}$
- $x^{m/n} = \sqrt[n]{x^m}$
- $(x^m y^n)^p = x^{mp} y^{np}$

- $(x^{m} / y^{n})^{p} = \frac{x^{mp}}{y^{np}}$
- If n is even, $(-1)^{n} = 1$
- If n is odd, $(-1)^{n} = -1$

Important Formulas in Algebra

- $(a + b)^{2} = a^2 + 2ab + b^2$
- $a^2 + b^2 = (a + b)^2 - 2ab$
- $(a - b)^2 = a^2 - 2ab + b^2$
- $a^2 + b^2 = (a - b)^2 + 2ab$
- $(a + b + c)^{2} = a^2 + b^2 + c^2 + 2(ab + bc + ca)$
- $(a + b)^{3} = a^3 + b^3 + 3ab(a + b)$
- $a^3 + b^3 = (a + b)^{3} - 3ab(a + b)$
- $(a - b)^3 = a^3 - b^3 - 3ab(a - b)$
- $a^3 - b^3 = (a - b)^{3} + 3ab(a - b)$
- $a^2 - b^2 = (a + b)(a - b)$
- $a^3 - b^3 = (a - b)(a^2 + ab + b^2)$
- $a^3 + b^3 = (a + b)(a^2 - ab + b^2)$
- $a^4 - b^4 = (a^2 - b^2)(a^2 + b^2) = (a + b)(a + b)(a^2 + b^2)$
- $a^4 + b^4 = (a^2 + b^2)^{2} - 2a^2 b^2 = (a^2 + \sqrt{2}ab + b^2)(a^2 - \sqrt{2}ab + b^2)$
- $a^5 + b^5 = (a + b)(a^4 - a^3b + a^2b^2 - ab^3 + b^4)$
- $a^5 - b^5 = (a - b)(a^4 + a^3b + a^2b^2 + ab^3 + b^4)$
- $a^n - b^n = (a - b)(a^{n-1} + a^{n-2} b + a^{n-3} b^2 + \cdots + b^{n-1}n-1)$

- $(a + b + c)^2 = a^2 + b^2 + c^2 + 2(ab + bc + ca)$
- $a^3 + b^3 + c^3 - 3abc = (a + b + c)(a^2 + b^2 + c^2 - ab - bc - ca)$

  If $a + b + c = 0$, then the above identity reduces to $a^3 + b^3 + c^3 = 3abc$

Roots of Quadratic Equation

For a quadratic equation $ax^2 + bx + c$ where $a \neq 0$, the roots will be given by the equation as:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

- $\Delta = b^2 - 4ac$ is called the discrimination
- For real and distinct roots, $\Delta > 0$
- For real and coincident roots, $\Delta = 0$
- For non-real roots, $\Delta < 0$
- If α and β are the two roots of the equation $ax^2 + bx + c$ then,

$$\alpha + \beta = \frac{-b}{a}$$

$$\alpha \times \beta = \frac{c}{a}$$

- If the roots of a quadratic equation are α and β, the equation will be $(x - \alpha)(x - \beta) = 0$

TRIGONOMETRY FORMULAS

$$\cos^2(x) + \sin^2(x) = 1 \qquad 1 + \tan^2(x) = \sec^2(x) \qquad \cot^2(x) + 1 = \csc^2(x)$$

$$\cos(x \pm y) = \cos(x)\cos(y) \mp \sin(x)\sin(y)$$
$$\sin(x \pm y) = \sin(x)\cos(y) \pm \cos(x)\sin(y)$$

$$\tan(x \pm y) = \frac{\tan(x) \pm \tan(y)}{1 \mp \tan(x)\tan(y)}$$

$$\sin(2x) = 2\sin(x)\cos(x)$$

$$\cos(2x) = \begin{cases} \cos^2(x) - \sin^2(x) \\ 2\cos^2(x) - 1 \\ 1 - 2\sin^2(x) \end{cases}$$

$$\tan(2x) = \frac{2\tan(x)}{1-\tan^2(x)}$$

$$c^2 = a^2 + b^2 - 2ab\cos(C)$$

$$\frac{\sin(A)}{a} = \frac{\sin(B)}{b} = \frac{\sin(C)}{c}$$

$$\sin^2(x) = \frac{1-\cos(2x)}{2}$$

$$\cos^2(x) = \frac{1+\cos(2x)}{2}$$

$$\tan^2(x) = \frac{1-\cos(2x)}{1+\cos(2x)}$$

$$\cos\left(\frac{x}{2}\right) = \pm\sqrt{\frac{1+\cos(x)}{2}}$$

$$\sin\left(\frac{x}{2}\right) = \pm\sqrt{\frac{1-\cos(x)}{2}}$$

$$\tan\left(\frac{x}{2}\right) = \pm\sqrt{\frac{1-\cos(x)}{1+\cos(x)}}$$

$$\sin(x)\sin(y) = \tfrac{1}{2}[\cos(x-y) - \cos(x+y)]$$

$$\cos(x)\cos(y) = \tfrac{1}{2}[\cos(x-y) + \cos(x+y)]$$

$$\sin(x)\cos(y) = \tfrac{1}{2}[\sin(x+y) + \sin(x-y)]$$

$$\cos(x)\sin(y) = \tfrac{1}{2}[\sin(x+y) - \sin(x-y)]$$

$$\sin(x) + \sin(y) = 2\sin\left(\frac{x+y}{2}\right)\cos\left(\frac{x-y}{2}\right)$$

$$\sin(x) - \sin(y) = 2\sin\left(\frac{x-y}{2}\right)\cos\left(\frac{x+y}{2}\right)$$

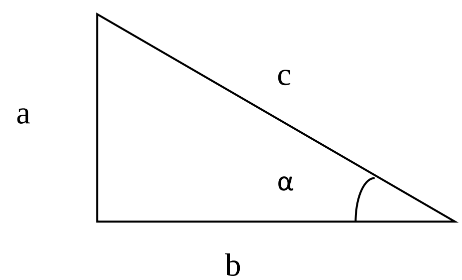
$$\cos(x) + \cos(y) = 2\cos\left(\frac{x+y}{2}\right)\cos\left(\frac{x-y}{2}\right)$$

$$\cos(x) - \cos(y) = -2\sin\left(\frac{x+y}{2}\right)\sin\left(\frac{x-y}{2}\right)$$

- $\sin(-x) = -\sin(x)$
- $\csc(-x) = -\csc(x)$
- $\cos(-x) = \cos(x)$

- $\sec(-x) = \sec(x)$
- $\tan(-x) = -\tan(x)$
- $\cot(-x) = -\cot(x)$

Pythagorean Theorem



$$a^2 + b^2 = c^2$$

$$c = \sqrt{a^2 + b^2}$$

- $\sin\alpha = \frac{a}{c} = \frac{\text{opposite}}{\text{hypotenuse}}$
- $\cos\alpha = \frac{b}{c} = \frac{\text{adjacent}}{\text{hypotenuse}}$
- $\tan\alpha = \frac{a}{b} = \frac{\text{opposite}}{\text{adjacent}}$
- $\cot\alpha = \frac{1}{\tan\alpha}$
- $\sec\alpha = \frac{1}{\cos\alpha}$
- $\operatorname{cosec}\alpha = \frac{1}{\sin\alpha}$
- The length of the **longest side** can never be greater than the sum of the two other sides.

- The length of the **shortest side** can never be less than the positive difference of the other two sides.
- A "**Pythagorean Triple**" is a set of positive integers, a, b and c that fits the rule:

$$a^2 + b^2 = c^2$$

  The smallest Pythagorean Triple is 3, 4 and 5.

Hyperbolic Functions

- $\sinh x = -\sinh(-x)$
- $\operatorname{sech} x = \operatorname{sech}(-x)$
- $\cosh x = \cosh(-x)$
- $\operatorname{cosech} x = -\operatorname{cosech}(-x)$
- $\tanh x = -\tanh(-x)$
- $\coth x = -\coth(-x)$
- $\cosh ix = \cos x$
- $\cos ix = \cosh x$
- $\sinh ix = i \sin x$
- $\sin ix = i \sinh x$
- $\tanh x = \frac{\sinh x}{\cosh x}$
- $\coth x = \frac{\cosh x}{\sinh x}$
- $\operatorname{sech} x = \frac{1}{\cosh x}$
- $\operatorname{cosech} x = \frac{1}{\sinh x}$
- $\cosh^2 x - \sinh^2 x = 1$
- $\cosh x = \frac{1}{2}(e^x + e^{-x}) = 1 + \frac{x^2}{2!} + \frac{x^4}{4!} + \ldots$ valid for all x

- $\sinh x = \frac{1}{2}(e^x - e^{-x}) = x + \frac{x^3}{3!} + \frac{x^5}{5!} + \ldots$ valid for all x

  For large positive x:

  $\cosh x \approx \sinh x \rightarrow \frac{e^x}{2}$

  $\tanh x \rightarrow 1$

  For large negative x:

  $\cosh x \approx -\sinh x \rightarrow \frac{e^{-x}}{2}$

  $\tanh x \rightarrow -1$

Inverse functions

- $\sinh^{-1}\frac{x}{a} = \ln\left(\frac{x+\sqrt{x^2+a^2}}{a}\right)$ for $-\infty < x < \infty$
- $\cosh^{-1}\frac{x}{a} = \ln\left(\frac{x+\sqrt{x^2-a^2}}{a}\right)$ for $x \geq a$
- $\tanh^{-1}\frac{x}{a} = \frac{1}{2}\ln\left(\frac{a+x}{a-x}\right)$ for $x^2 < a^2$
- $\coth^{-1}\frac{x}{a} = \frac{1}{2}\ln\left(\frac{x+a}{x-a}\right)$ for $x^2 > a^2$
- $\operatorname{sech}^{-1}\frac{x}{a} = \ln\left(\frac{a}{x} + \sqrt{\frac{a^2}{x^2} - 1}\right)$ for $0 < x \leq a$
- $\operatorname{cosech}^{-1}\frac{x}{a} = \ln\left(\frac{a}{x} + \sqrt{\frac{a^2}{x^2} + 1}\right)$ for $x \neq 0$

Natural Numbers

{1, 2, 3, 4 ....}

Whole numbers

{0, 1, 2, 3 .... }

0 is neither positive nor negative

Integers

{.....–3, –2, –1, 0, 1, 2, 3….}

Type of Integers

- Non negative integers { 0, 1, 2, 3,......... }
- Negative integers {.......... –3, –2, –1}
- Non positive integers {.......... –3, –2 –1, 0}
- Positive integers {1, 2, 3.......... }

Rational Numbers

A number is called rational if it can be expressed in the form $\frac{p}{q}$ where p and q are integers (q>0).

Example:

$$\frac{4}{3} = 1.\overline{3} = 1.333.........$$

Irrational numbers

A number is called irrational if it cannot be expressed in the form $\frac{p}{q}$ where p and q are integers (q> 0).

Example:

$$\sqrt{2} = 1.414.............$$

Real Numbers

Real → Rational + Irrational

Prime Numbers

Numbers which are divisible by 1 or itself

{2, 3, 5, 7, 11, 13 ....}

1 is not a prime. 2 is the smallest prime and the only even prime.

Composite Numbers

Numbers which are multiples of prime are called composite numbers

{4, 6, 8, 9 ....}

Coprime

21 and 22 are coprime:

- The factors of 21 are 1, 3, 7 and 21
- The factors of 22 are 1, 2, 11 and 22

(The only common factor is 1)

But 21 and 24 are NOT coprime:

- The factors of 21 are 1, 3, 7 and 21
- The factors of 24 are 1, 2, 3, 4, 6, 8, 12 and 24

(The common factors are 1 and 3)

Twin primes

The prime numbers which having the difference of 2

e.g. (5, 3), (7, 5), (13, 11)............

1 is neither a prime nor a composite number

Order of Operations: **PEMDAS**

(Parentheses / Exponents / Multiply / Divide / Add / Subtract)

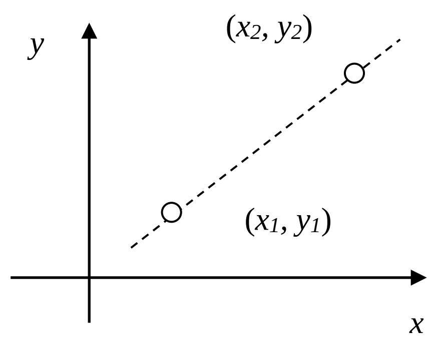
Euclid's Division Lemma: If two positive integers **a** and **b**, then there exists unique integers **q** and **r** such that which satisfies the condition **a** = **b**q + r where $0 \le r \le b$. If r = 0, then b is divisor of a.

Coordinate Geometry

Any line can be represented by $y = mx + b$, where m is the slope and b is the y-intercept. This is called slope-intercept form.

$$\text{Distance between two points } (x_1, y_1), (x_2, y_2) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

$$\text{Midpoint of two points } (x_1, y_1), (x_2, y_2) = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}\right)$$



The slope of the line passing through the points (x_1, y_1) and (x_2, y_2) is $\frac{y_2 - y_1}{x_2 - x_1}$

Differentiation Formulas

1. $\frac{d}{dx}(x^n) = nx^{n-1}$

2. $\frac{d}{dx}(\sin x) = \cos x$

3. $\frac{d}{dx}(\cos x) = -\sin x$

4. $\frac{d}{dx}(\tan x) = \sec^2 x$

5. $\frac{d}{dx}(\cot x) = -\csc^2 x$

6. $\frac{d}{dx}(\sec x) = \sec x \tan x$

7. $\frac{d}{dx}(\csc x) = -\csc x \cot x$

8. $\frac{d}{dx}(e^x) = e^x$

9. $\frac{d}{dx}(a^x) = a^x \ln a$

10. $\frac{d}{dx}(\ln x) = \frac{1}{x}$

11. $\frac{d}{dx}(Arc\sin x) = \frac{1}{\sqrt{1-x^2}}$

12. $\frac{d}{dx}(Arc\tan x) = \frac{1}{1+x^2}$

13. $\frac{d}{dx}(Arc\sec x) = \frac{1}{|x|\sqrt{x^2-1}}$

14. $\frac{dy}{dx} = \frac{dy}{dx} \times \frac{du}{dx}$

15. $\frac{d}{dx}[c] = 0$

16. $\frac{d}{dx}[cu] = c\frac{du}{dx}$

17. $\dfrac{d}{dx}[u \pm v] = \dfrac{du}{dx} \pm \dfrac{dv}{dx}$

18. $\dfrac{d}{dx}[uv] = u\dfrac{dv}{dx} + v\dfrac{du}{dx}$

19. $\dfrac{d}{dx}\left[\dfrac{u}{v}\right] = \dfrac{v\dfrac{du}{dx} - u\dfrac{dv}{dx}}{v^2}$

20. $\dfrac{d}{dx}[x] = 1$

Integration Formulas

1. $\int a\,dx = ax + C$

2. $\int x^n\,dx = \dfrac{x^{n+1}}{n+1} + C, \quad n \neq -1$

3. $\int \dfrac{1}{x}\,dx = \ln|x| + C$

4. $\int e^x\,dx = e^x + C$

5. $\int a^x dx = \dfrac{a^x}{\ln a} + C$

6. $\int \ln x\,dx = x\ln x - x + C$

7. $\int \sin x\,dx = -\cos x + C$

8. $\int \cos x\,dx = \sin x + C$

9. $\int \tan x\,dx = \ln|\sec x| + C$ or $-\ln|\cos x| + C$

10. $\int \cot x\,dx = \ln|\sin x| + C$

11. $\int \sec x\, dx = \ln\left|\sec x + \tan x\right| + C$

12. $\int \csc x \ dx = \ln\left|\csc x - \cot x\right| + C = -\ln\left|\csc x + \cot x\right| + C$

13. $\int \sec^2 x\, dx = \tan x + C$

14. $\int \sec x \tan x\, dx = \sec x + C$

15. $\int \csc^2 x\, dx = -\cot x + C$

16. $\int \csc x \cot x\, dx = -\csc x + C$

17. $\int \tan^2 x\, dx = \tan x - x + C$

18. $\int \frac{dx}{a^2 + x^2} = \frac{1}{a} Arc\tan\left(\frac{x}{a}\right) + C$

19. $\int \frac{dx}{\sqrt{a^2 - x^2}} = Arc\sin\left(\frac{x}{a}\right) + C$

20. $\int \frac{dx}{x\sqrt{x^2 - a^2}} = \frac{1}{a} Arc\sec\frac{|x|}{a} + C = \frac{1}{a} Arc\cos\left|\frac{a}{x}\right| + C$

21. $\int u\ dv = uv - \int v\ du$

HCF (Highest common factor)

- HCF (a, b) =1. Then a and b are co primes
- HCF (a, b) × LCM (a, b) = a × b

Vector Algebra

If i, j, k are orthonormal vectors and $A = A_x i + A_y j + A_z k$ then $|A|^2 = A_x^2 + A_y^2 + A_z^2$.

- **Scalar product**

  $A \cdot B = |A|\,|B| \cos\theta$ where θ is the angle between the vectors.

  Scalar multiplication is commutative: $A \cdot B = B \cdot A$.

- **Vector product**

  $A \times B = n\,|A|\,|B| \sin\theta$, where θ is the angle between the vectors and n is a unit vector normal to the plane containing A and B in the direction for which A, B, n form a right-handed set of axes.

  Vector multiplication is not commutative: $A \times B = -B \times A$.

- **Scalar triple product**

$$A \times B \cdot C = A \cdot B \times C$$

- **Vector triple product**

$$A \times (B \times C) = (A \cdot C)\,B - (A \cdot B)\,C$$

$$(A \times B) \times C = (A \cdot C)\,B - (B \cdot C)\,A$$

- Angles on the inside of any triangle add up to 180◦
- The **length of one side of any triangle** is always less than the sum and more than the difference of the lengths of the other two sides.
- If two lines intersect, the sum of the resulting four angles equals 360.

Average formula:

Let a_1, a_2, a_3... a_n be a set of numbers, average = $\frac{a_1 + a_2 + a_3 + ... + a_n}{n}$

Fractions formulas:

- $\frac{a}{b} + \frac{c}{d} = \frac{ad+bc}{bd}$
- $\frac{a}{b} - \frac{c}{d} = \frac{ad-bc}{bd}$
- $\frac{a}{b} \times \frac{c}{d} = \frac{ac}{bd}$
- $\frac{a}{b} \div \frac{c}{d} = \frac{a}{b} \times \frac{d}{c} = \frac{ad}{bc}$
- $\frac{a}{b} = \frac{c}{d} \longrightarrow ad = bc$

Geometry formulas:

Perimeter:

- **Perimeter of a square:** s + s + s + s

  s: length of one side

- **Perimeter of a rectangle:** l + w + l + w

  l: length

  w: width

- **Perimeter of a triangle:** a + b + c
- a, b, and c: lengths of the 3 sides

Area:

- **Area of a square:** $s \times s$

  s: length of one side

- **Area of a rectangle:** $l \times w$

  l: length

  w: width

- **Area of a triangle:** $\frac{b \times h}{2}$

  b: length of base

  h: length of height

- **Area of a trapezoid:** $(b_1 + b_2) \times \frac{h}{2}$

  b_1 and b_2: parallel sides or the bases

  h: length of height

Volume:

- **Volume of a cube:** $s \times s \times s$

  s: length of one side

- **Volume of a box:** $l \times w \times h$

  l: length

  w: width

  h: height

- **Volume of a sphere:** $\frac{4}{3} \times \pi \times r^3$

  π: 3.14159265359

  r: radius of sphere

- **Volume of a triangular prism:** area of triangle × height of the triangular prism
- **Volume of a cylinder:** $\pi \times r^2 \times h$

  r: radius of the circle of the base

  h: height of the cylinder

Quadrilaterals

- The diagonals of a square bisect one another, forming four 90 degree angles
- The diagonals of a rhombus bisect one another, forming four 90 degree angles
- The perimeter of a rectangle is twice its height plus twice its length (or, the sum of all its sides).
- The area of a parallelogram can be found multiplying base × height (the base always forms a right angle with the height).

Circles:

Area = πr^2

Circumference = $2\pi r$

A circle has 360 degrees. An arc is the portion of the circumference of a circle in *x* degrees of the circle.

Arc length = $\frac{x}{360} \times 2\pi r$

Area of sector = $\frac{x}{360} \times \pi r^2$

Basic Identities

- $a + 0 = a$
- $a + (-a) = 0$
- $(a + b) + c = a + (b + c)$
- $a + b = b + a$
- $a - b = a + (-b)$
- $a * 1 = a$
- $a * \frac{1}{a} = 1 \quad (a \neq 0)$
- $a * 0 = 0$
- $(a * b) * c = a * (b * c)$
- $a * b = b * a$
- $a\,(b + c) = ab + ac$
- $\frac{a}{b} = a\,(\frac{1}{b})$

Negative exponents:

$$x^{-2} = \frac{1}{x^2}$$

Negative bases:

$(-2)^4 = -2 \times -2 \times -2 \times -2 = 16$

$(-2)^5 = -2 \times -2 \times -2 \times -2 \times -2 = 32$

Perfect Squares:

Perfect Square	Factors

1	1 * 1
4	2 * 2
9	3 * 3
16	4 * 4
25	5 * 5
36	6 * 6
49	7 * 7
64	8 * 8
81	9 * 9
100	10 * 10
121	11 * 11
144	12 * 12
169	13 * 13
196	14 * 14
225	15 * 15
256	16 * 16
289	17 * 17
324	18 * 18
361	19 * 19

400	20 * 20

Inequalities:

- If w < x and x < y, then w < y.
- If a < b and c < d, then a + c < b + d. However, this does not hold for subtracting, multiplying, or dividing.

Probabilities

Probability is a representation of the odds of something happening. A probability of 1 is guaranteed to happen. A probability of 0 will never happen. 0.5 = there is a 50/50 chance the event will occur.

- **Probability of an outcome happening** = $\frac{\text{number of desired outcomes}}{\text{total number of possible outcomes}}$

Probability of two independent outcomes both happening is

Probability of event A * probability of event B

e.g., Event A has a probability of $\frac{1}{4}$ and event B has a probability of $\frac{1}{8}$. The probability of both events happening is: $\frac{1}{4} * \frac{1}{8} = \frac{1}{32}$. There is a 1 in 32 chance of both events A and event B happening.

Combinations

- **Possible combinations =** number of element A * number of element B * number of element C….

e.g., In a cafeteria, there are 3 different dessert options, 2 different entree options, and 4 drink options. How many different lunch combinations are possible, using one drink, one, dessert, and one entree?

- **The total combinations possible** = 3 * 2 * 4 = 24

Fundamental Counting Principle:

If an event can happen in N ways, and another, independent event can happen in M ways, and then both events together can happen in N × M ways.

Combinations:

$$^{n}C_{r} = \frac{n!}{r!(n-r)!}$$

$$^{5}C_{3} = \frac{5!}{3!\ (2!)} = 10$$

Permutations:

$$^{n}P_{r} = \frac{n!}{(n-r)!}$$

Probability that event A will happen:

$$P\ (A) = \frac{\text{Number of outcomes where A occurs}}{\text{Total number of outcomes}}$$

P (event happens) + P (event does not happen) = 1

Mutually exclusive events:

Two events are mutually exclusive if they can't happen together: P (A and B) = 0

Events A and B (if they are independent events):

$$P\ (A \text{ and } B) = P\ (A) \times P\ (B)$$

Events A or B:

A happens, B happens, or both A and B happen.

$$P\ (A \text{ or } B) = P\ (A) + P\ (B) - P\ (A \text{ and } B)$$

Events A and B (if A and B are dependent events):

$$P\ (A \text{ and } B) = P\ (A) \times P\ (B \mid A)$$

P (B | A) is the probability that B occurs given that A occurs.

Number of ways to follow a rule = number of ways to ignore the rule – number of ways to break the rule.

Percents:

$$\text{part} = \frac{\text{percent}}{100} \times \text{whole}$$

- **mode** = value in the list that appears most often
- **median** = middle value in the list

  median of {3, 9, 10, 27, 50} = 10

  median of $\{3, 9, 10, 27\} = \frac{9 + 10}{2} = 9.5$

  Range = Greatest value – least value

Polygons

- **Total degrees =** $180\,(n-2)$ where n = number of sides
- **Average degrees per side =** $\frac{180\,(n-2)}{n}$

Distance, Rate, and Time

- Distance = Rate × Time
- Rate = $\frac{\text{Distance}}{\text{Time}}$
- Time = $\frac{\text{Distance}}{\text{Rate}}$
- Average speed = $\frac{\text{Total Distance Traveled}}{\text{Total Time}}$

Standard deviation:

If you're given a set of n numbers a, b, c … with a mean m:

$$\text{SD} = \sqrt{\frac{(\text{a}-\text{m})^2 + (\text{b}-\text{m})^2 + (\text{c}-\text{m})^2 + \ldots}{\text{n}}}$$

Variance = SD^2

Integer series

- $1 + 2 + 3 + \ldots.. + n = \frac{n\,(n+1)}{2}$
- $1^2 + 2^2 + 3^2 + \ldots.. + n^2 = \frac{n\,(n+1)\,(2n+1)}{6}$
- $1^3 + 2^3 + 3^3 + \ldots.. + n^3 = \frac{n^2(n+1)^2}{4}$

- $1^4 + 2^4 + 3^4 + \ldots.. + n^4 = \frac{n(n+1)(2n+1)(3n^2+3n-1)}{30}$

- $1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \ldots.. = \ln 2$

- $1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \ldots.. = \frac{\pi}{4}$

- $1 - \frac{1}{4} + \frac{1}{9} - \frac{1}{16} + \ldots.. = \frac{\pi^2}{6}$

- $1.2.3 + 2.3.4 + \ldots + n(n+1)(n+2) = \frac{n(n+1)(n+2)(n+3)}{4}$

Arithmetic and Geometric progressions

A.P. $S_n = a + (a + d) + (a + 2d) + \ldots + [a + (n - 1)d] = \frac{n}{2}[2a + (n-1)d]$

G.P. $S_n = a + ar + ar^2 + \ldots + ar^{n-1} = a\frac{1-r^n}{1-r}$, $\left(S_\infty = \frac{a}{1-r}\right.$ for $|r| < 1)$

Convergence of series: the ratio test

$S_n = u_1 + u_2 + u_3 + \ldots..+ u_n$ converges as $n \rightarrow \infty$ if $\lim_{n\to\infty} \left|\frac{u_{n+1}}{u_n}\right| < 1$

Convergence of series: the comparison test

If each term in a series of positive terms is less than the corresponding term in a series known to be convergent, then the given series is also convergent.

Power series with real variables

- $e^x = 1 + x + \frac{x^2}{2!} + \ldots.. + \frac{x^n}{n!} + \ldots\ldots$ valid for all x

- $\ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} + \ldots + (-1)^{n+1}\frac{x^n}{n!} + \ldots$ valid for $-1 < x \le 1$
- $\cos x = \frac{e^{ix} + e^{-ix}}{2} = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \ldots\ldots$ valid for all values of x
- $\sin x = \frac{e^{ix} - e^{-ix}}{2i} = x - \frac{x^3}{3!} + \frac{x^5}{5!} + \ldots\ldots$ valid for all values of x
- $\tan x = x + \frac{1}{3}x^3 + \frac{2}{15}x^5 + \ldots$ valid for $-\frac{\pi}{2} < x < \frac{\pi}{2}$
- $\tan^{-1}x = x - \frac{x^3}{3} + \frac{x^5}{5} - \ldots$ valid for $-1 \le x \le 1$
- $\sin^{-1}x = x + \frac{1}{2}\frac{x^3}{3} + \frac{1.3}{2.4}\frac{x^5}{5} + \ldots$ valid for $-1 < x < 1$

Complex numbers

The complex number $z = x + iy = r\,(cos\theta + i\ sin\theta) = r\ e^{\ i\ (\theta+2n\pi)}$, where $i^2 = -1$ and n is an arbitrary integer.

The complex conjugate of z is $z^* = x - iy = r\,(cos\theta - i\ sin\theta) = re^{-i\theta}$; $zz^* = |z|^2 = x^2 + y^2$

De Moivre's theorem

$$(\cos\theta + i \sin\theta)^n = e^{in\theta} = \cos n\theta + i \sin n\theta$$

Power series for complex variables

$e^z = 1 + z + \frac{z^2}{2!} + \ldots\ldots + \frac{z^n}{n!} + \ldots$ convergent for all finite z

$\sin z = z - \frac{z^3}{3!} + \frac{z^5}{5!} - \ldots\ldots$ convergent for all finite z

$\cos z = 1 - \frac{z^2}{2!} + \frac{z^4}{4!} - \ldots\ldots$ convergent for all finite z

$\ln(1 + z) = z - \frac{z^2}{2} + \frac{z^3}{3} - \ldots\ldots$ principal value of $\ln(1 + z)$

- Sum of first n odd numbers = n^2
- Sum of first n even numbers = n (n + 1)

Profit, Loss and Discount

- Profit or Gain = Selling Price – Cost Price
- Profit % = $\frac{\text{Profit}}{\text{Cost Price}} \times 100$
- Selling Price = $\frac{100 + \text{Profit \%}}{100} \times$ Cost Price
- Cost Price = $\frac{100}{100 + \text{Profit \%}} \times$ Selling Price
- Loss = Cost Price – Selling Price
- Loss % = $\frac{\text{Loss}}{\text{Cost Price}} \times 100$
- Selling Price = $\frac{100 - \text{loss \%}}{100} \times$ Cost Price
- Cost Price = $\frac{100}{100 - \text{loss \%}} \times$ Selling Price
- Discount % = $\frac{\text{Marked Price} - \text{Selling Price}}{\text{Marked Price}} \times 100$
- Effective Discount after successive discount of a% and b% is $\left(a + b - \frac{ab}{100}\right)$. Effective Discount when you buy x goods and get y goods free is $\frac{y}{x + y} \times 100$

LCM and HCF

- Product of two numbers = Their H. C. F. × Their L. C. M.
- LCM of Co-prime Numbers = Product of the Numbers
- HCF of Fractions = $\frac{\text{HCF of Numerator}}{\text{LCM of denominator}}$
- LCM of Fractions = $\frac{\text{LCM of Numerator}}{\text{HCF of denominator}}$

Percentages

- To find what percentage of x is y: $\frac{y}{x} \times 100$
- Increase N by S % = N(1+ $\frac{S}{100}$)
- Decrease N by S % = N (1$-\frac{S}{100}$)

Time and Work

- If A can do a piece of work in *n* days, then A's 1 day's work = $\frac{1}{n}$
- If A's 1 day's work = $\frac{1}{n}$, then A can finish the work in *n* days.
- If A is thrice as good a workman as B, then:

  Ratio of work done by A and B = 3 : 1

  Ratio of times taken by A & B to finish a work = 1 : 3

Pipes and Cisterns

- If a pipe can fill a tank in 'x' hours and another pipe can empty the full tank in 'y' hours (where y > x), then on opening both the pipes, the net part of the tank filled in 1 hour is ($\frac{1}{x} - \frac{1}{y}$)

Time and Distance

- Suppose a man covers a distance at 'x' kmph and an equal distance at 'y' kmph, then average speed during his whole journey is [$\frac{2xy}{x+y}$] kmph

Trains

- Lengths of trains are 'x' km and 'y' km, moving at 'u' kmph and 'v' kmph (where u > v) in the same direction, then the time taken y the over-taker train to cross the slower train is [$\frac{x + y}{u - v}$] hrs

- Time taken to cross each other is $\left[\frac{x + y}{u + v}\right]$ hrs
- If two trains start at the same time from two points *A* and *B* towards each other and after crossing they take *a* and *b* hours in reaching *B* and *A* respectively. Then, A's speed : B's speed = $(\sqrt{b} : \sqrt{a})$.

Boats and Streams

- If the speed of a boat in still water is *u* km/hr and the speed of the stream is *v* km/hr, then:

Speed downstream = $(u + v)$ km/hr.

Speed upstream = $(u - v)$ km/hr.

- If the speed downstream is *a* km/hr and the speed upstream is *b* km/hr, then:

Speed in still water = $\frac{1}{2}(a + b)$ km/hr.

Rate of stream = $\frac{1}{2}(a - b)$ km/hr.

Mixtures and Alligations

- **Alligation:** It is the rule that enables us to find the ratio in which two or more ingredients at the given price must be mixed to produce a mixture of desired price.
- **Mean Price:** The cost of a unit quantity of the mixture is called the mean price.
- **Rule of Alligation:**

  If two ingredients are mixed, then

$$\frac{\text{Quantity of cheaper}}{\text{Quantity of dearer}} = \frac{\text{Cost Price of dearer} - \text{Mean Price}}{\text{Mean price} - \text{Cost Price of cheaper}}$$

- Where a is the original quantity, b is the quantity that is replaced and n is the number of times the replacement process is carried out, then

$$\frac{\text{Quantity of original entity after n operation}}{\text{Quantity of mixture}} = \left(\frac{a-b}{a}\right)^n$$

Inequalities

If $a > b$ and $c > 0$,

- $a + c > b + c$
- $a - c > b - c$
- $ac > bc$
- $\frac{a}{c} > \frac{b}{c}$

If $a, b \geq 0$, then $a^n > b^n$ and $\frac{1}{a^n} < \frac{1}{b^n}$, where n is positive.

- $a < b$ and $x > 0$, then $\frac{a+x}{b+x} > \frac{a}{b}$
- $a > b$ and $x > 0$, then $\frac{a+x}{b+x} < \frac{a}{b}$

1. $n(n+1)(2n+1)$ is always divisible by 6.
2. 3^{2n} leaves remainder = 1 when divided by 8
3. $n^3 + (n+1)^3 + (n+2)^3$ is always divisible by 9
4. $10^{2n+1} + 1$ is always divisible by 11
5. $n(n^2-1)$ is always divisible by 6
6. $n^2 + n$ is always even
7. $2^{3n}-1$ is always divisible by 7
8. $15^{2n-1} + 1$ is always divisible by 16
9. $n^3 + 2n$ is always divisible by 3
10. $3^{4n} - 4^{3n}$ is always divisible by 17
11. Product of n consecutive numbers is always divisible by n!
12. If n is a positive integer and p is a prime, then $n^p - n$ is divisible by p.
13. $|x| = x$ if $x \geq 0$ and $|x| = -x$ if $x \leq 0$.
14. Dividend = Quotient × Divisor + Remainder
15. A number is divisible by 2, if its unit’s place digit is 0, 2, 4, or 8
16. A number is divisible by 3, if the sum of its digits is divisible by 3
17. A number is divisible by 4, if the number formed by its last two digits is

divisible by 4

18. A number is divisible by 8, if the number formed by its last three digits is divisible by 8
19. A number is divisible by 9, if the sum of its digits is divisible by 9
20. If the population of a town is 'P' in a year, then its population after 'N' years is $P(1+\frac{R}{100})^{N}$
21. If the population of a town is 'P' in a year, then its population 'N' years ago is $P/[(1+\frac{R}{100})^{N}]$
22. The equality of two ratios is called a proportion. If a : b = c : d, we write a : b :: c : d and we say that a, b, c, d are in proportion. In a proportion, the first and fourth terms are known as extremes, while the second and third are known as means.
23. Product of extremes = Product of means
24. Mean proportion between a and b is $\sqrt{ab}$
25. The *compounded ratio* of the ratios (a : b), (c : d), (e : f) is (ace : bdf)
26. $a^2 : b^2$ is a duplicate ratio of a : b
27. $\sqrt{a} : \sqrt{b}$ is a sub-duplicate ration of a : b
28. $a^3 : b^3$ is a triplicate ratio of a : b
29. $a^{1/3} : b^{1/3}$ is a sub-triplicate ratio of a : b
30. If $\frac{a}{b} = \frac{c}{d}$, then, $\frac{(a+b)}{b} = \frac{(c+d)}{d}$, which is called the *componendo*.
31. If $\frac{a}{b} = \frac{c}{d}$, then, $\frac{(a-b)}{b} = \frac{(c-d)}{d}$, which is called the *dividendo*.
32. If $\frac{a}{b} = \frac{c}{d}$, then, $\frac{(a+b)}{(a-b)} = \frac{(c+d)}{(c-d)}$, which is called the *componendo and dividendo*.
33. Variation: We say that x is directly proportional to y if x = ky for some constant k and we write, $x \propto y$. Also, we say that x is inversely proportional to y if $x = \frac{k}{y}$ for some constant k and we write $x \propto \frac{1}{y}$
34. The cost of articles is directly proportional to the number of articles.
35. The work done is directly proportional to the number of men working at it.

$$n = m \times 10^P$$

If n = 12345:

$$\boxed{12345 = 1.2345 \times 10^4}$$

- Any single digit number written (P −1) times is divisible by P, where P is a prime number >5.
- If log x = y, then antilog y = x.
- Logarithms to the base 10 are known as **common logarithms.**

Characteristic and Mantissa in Logarithms:

$$\log_{10} 15 = 1.176 = 1 + 0.176$$

Characteristic

(Integral part)

Mantissa

(Decimal part)

When the **number** is greater than 1

$\log_{10} x =$ **y**

- $\log_{10} 15 = 1.176 = 1 + 0.176$
- $\log_{10} 250 = 2.397 = 2 + 0.397$
- $\log_{10} 4000 = 3.602 = 3 + 0.602$
- $\log_{10} 50000 = 4.698 = 4 + 0.698$

When the **number** is less than 1

$\log_{10} x =$ **y**

- $\log_{10} 0.5 = -0.301 = -1 + 0.699$
- $\log_{10} 0.\ 08 = -1.096 = -2 + 0.904$
- $\log_{10} 0.005 = -2.3010 = -3 + 0.699$

Fermat's Last Theorem:

No 3 positive integers a, b and c satisfy the equation:

$a^n + b^n = c^n$ for any integer value of n > 2.

Fermat's little theorem:

If p is a prime number and a is any integer not divisible by p, then p divides $a^{p-1} - 1$.

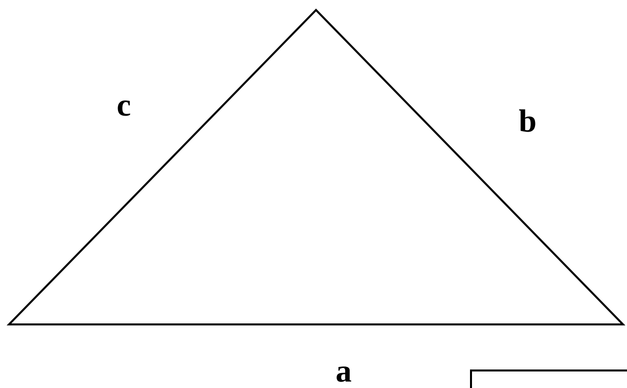
Fraction	Percentage	Fraction	Percentage
$\frac{1}{2}$	50%	$\frac{1}{9}$	11.11%
$\frac{1}{3}$	33.33%	$\frac{1}{10}$	10%
$\frac{1}{4}$	25%	$\frac{1}{11}$	9.09%
$\frac{1}{5}$	20%	$\frac{1}{12}$	8.33%
$\frac{1}{6}$	16.66%	$\frac{1}{13}$	7.69%
$\frac{1}{7}$	14.28%	$\frac{1}{14}$	7.14%
$\frac{1}{8}$	12.5%	$\frac{1}{15}$	6.66%

If N = $(2)^a (y)^b (z)^c$ where x, y, z are prime factors

- Number of even factors of N = (a) (b+1) (c+1)
- Number of odd factors of N = (b+1) (c+1)

Triangle inequality:

The sum of the lengths of any two sides of a triangle is greater than the length of the third side.



$$a + b > c$$

$$a + c > b$$

$$b + c > a$$

For a triangle with the side lengths:

7, 9, 13

- The sum of 7 and 9 is 16 and 16 is greater than 13
- The sum of 9 and 13 is 21 and 21 is greater than 7
- The sum of 7 and 13 is 20 and 20 is greater than 9

Modulus inequalities or Absolute value inequalities:

- If $|x| < a$, then $-a < x < a$
- If $|x| > a$, then either $x > a$ or $x < -a$
- If $|x - l| < a$, then $l - a < x < l + a$
- If $|x - l| > a$, then either $x > l + a$ or $x < l - a$.

Properties of inequalities:

Let x, y, and z be real numbers

Addition property:

If $x < y$, then $x + z < y + z$

Subtraction property:

If $x < y$, then $x - z < y - z$

Multiplication property:

If $x < y$ and $z > 0$, then $xz < yz$

If $x < y$ and $z < 0$, then $xz > yz$

Division property:

If $x < y$ and $z > 0$, then $\frac{x}{z} < \frac{x}{y}$

If $x < y$ and $z < 0$, then $\frac{x}{z} > \frac{x}{y}$

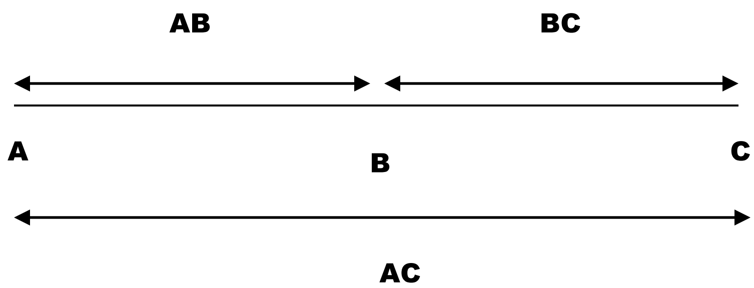
Transitive property:

If $x < y$ and $y < z$, then $x < z$

Comparison property:

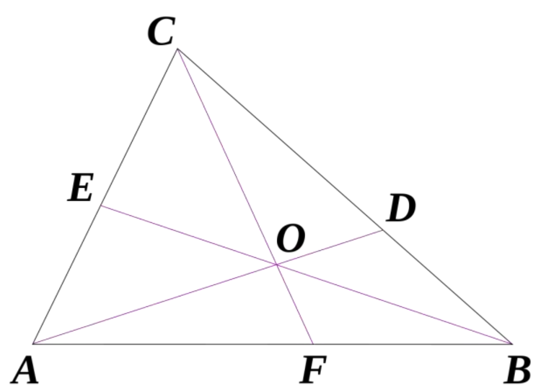
If $x = y + z$ and $z > 0$, then $x > y$

Segment Addition Postulate:



If AB + BC = AC, then B is between A and C

Ceva's theorem:



If $\frac{AF}{FB} \times \frac{BD}{DC} \times \frac{CE}{EA} = 1$, then the line AD, CF, BE forms a concurrent point at O.

- **Decimal** (Base 10) — Represent any number using 10 digits [0–9]
- **Binary** (Base 2) — Represent any number using 2 digits [0–1]
- **Octal** (Base 8) — Represent any number using 8 digits [0–7]
- **Hexadecimal** (Base 16) — Represent any number using 10 digits and 6 characters [0–9, A, B, C, D, E, F]

- **Decimal, hexadecimal, octal, and binary values**

Decimal	Hexadecimal	Octal	Binary
0	0	0	0
1	1	1	1
2	2	2	10
3	3	3	11
4	4	4	100
5	5	5	101
6	6	6	110
7	7	7	111
8	8	10	1000
9	9	11	1001
10	A	12	1010
11	B	13	1011
12	C	14	1100
13	D	15	1101
14	E	16	1110
15	F	17	1111
16	10	20	10000
17	11	21	10001
18	12	22	10010
19	13	23	10011
20	14	24	10100
21	15	25	10101
22	16	26	10110
23	17	27	10111
24	18	30	11000
25	19	31	11001
26	1A	32	11010
27	1B	33	11011
28	1C	34	11100
29	1D	35	11101
30	1E	36	11110
31	1F	37	11111
32	20	40	100000
33	21	41	100001
34	22	42	100010
35	23	43	100011
36	24	44	100100

37	25	45	100101
38	26	46	100110
39	27	47	100111
40	28	50	101000
41	29	51	101001
42	2A	52	101010
43	2B	53	101011
44	2C	54	101100
45	2D	55	101101
46	2E	56	101110
47	2F	57	101111
48	30	60	110000
49	31	61	110001
50	32	62	110010
51	33	63	110011
52	34	64	110100
53	35	65	110101
54	36	66	110110
55	37	67	110111
56	38	70	111000
57	39	71	111001
58	3A	72	111010
59	3B	73	111011
60	3C	74	111100
61	3D	75	111101
62	3E	76	111110
63	3F	77	111111
64	40	100	1000000
65	41	101	1000001
66	42	102	1000010
67	43	103	1000011
68	44	104	1000100
69	45	105	1000101
70	46	106	1000110
71	47	107	1000111
72	48	110	1001000
73	49	111	1001001
74	4A	112	1001010
75	4B	113	1001011
76	4C	114	1001100

77	4D	115	1001101
78	4E	116	1001110
79	4F	117	1001111
80	50	120	1010000
81	51	121	1010001
82	52	122	1010010
83	53	123	1010011
84	54	124	1010100
85	55	125	1010101
86	56	126	1010110
87	57	127	1010111
88	58	130	1011000
89	59	131	1011001
90	5A	132	1011010
91	5B	133	1011011
92	5C	134	1011100
93	5D	135	1011101
94	5E	136	1011110
95	5F	137	1011111
96	60	140	1100000
97	61	141	1100001
98	62	142	1100010
99	63	143	1100011
100	64	144	1100100
101	65	145	1100101
102	66	146	1100110
103	67	147	1100111
104	68	150	1101000
105	69	151	1101001
106	6A	152	1101010
107	6B	153	1101011
108	6C	154	1101100
109	6D	155	1101101
110	6E	156	1101110
111	6F	157	1101111
112	70	160	1110000
113	71	161	1110001
114	72	162	1110010
115	73	163	1110011
116	74	164	1110100

117	75	165	1110101
118	76	166	1110110
119	77	167	1110111
120	78	170	1111000
121	79	171	1111001
122	7A	172	1111010
123	7B	173	1111011
124	7C	174	1111100
125	7D	175	1111101
126	7E	176	1111110
127	7F	177	1111111
128	80	200	10000000
129	81	201	10000001
130	82	202	10000010
131	83	203	10000011
132	84	204	10000100
133	85	205	10000101
134	86	206	10000110
135	87	207	10000111
136	88	210	10001000
137	89	211	10001001
138	8A	212	10001010
139	8B	213	10001011
140	8C	214	10001100
141	8D	215	10001101
142	8E	216	10001110
143	8F	217	10001111
144	90	220	10010000
145	91	221	10010001
146	92	222	10010010
147	93	223	10010011
148	94	224	10010100
149	95	225	10010101
150	96	226	10010110
151	97	227	10010111
152	98	230	10011000
153	99	231	10011001
154	9A	232	10011010
155	9B	233	10011011
156	9C	234	10011100

157	9D	235	10011101
158	9E	236	10011110
159	9F	237	10011111
160	A0	240	10100000
161	A1	241	10100001
162	A2	242	10100010
163	A3	243	10100011
164	A4	244	10100100
165	A5	245	10100101
166	A6	246	10100110
167	A7	247	10100111
168	A8	250	10101000
169	A9	251	10101001
170	AA	252	10101010
171	AB	253	10101011
172	AC	254	10101100
173	AD	255	10101101
174	AE	256	10101110
175	AF	257	10101111
176	B0	260	10110000
177	B1	261	10110001
178	B2	262	10110010
179	B3	263	10110011
180	B4	264	10110100
181	B5	265	10110101
182	B6	266	10110110
183	B7	267	10110111
184	B8	270	10111000
185	B9	271	10111001
186	BA	272	10111010
187	BB	273	10111011
188	BC	274	10111100
189	BD	275	10111101
190	BE	276	10111110
191	BF	277	10111111
192	C0	300	11000000
193	C1	301	11000001
194	C2	302	11000010
195	C3	303	11000011
196	C4	304	11000100

197	C5	305	11000101
198	C6	306	11000110
199	C7	307	11000111
200	C8	310	11001000
201	C9	311	11001001
202	CA	312	11001010
203	CB	313	11001011
204	CC	314	11001100
205	CD	315	11001101
206	CE	316	11001110
207	CF	317	11001111
208	D0	320	11010000
209	D1	321	11010001
210	D2	322	11010010
211	D3	323	11010011
212	D4	324	11010100
213	D5	325	11010101
214	D6	326	11010110
215	D7	327	11010111
216	D8	330	11011000
217	D9	331	11011001
218	DA	332	11011010
219	DB	333	11011011
220	DC	334	11011100
221	DD	335	11011101
222	DE	336	11011110
223	DF	337	11011111
224	E0	340	11100000
225	E1	341	11100001
226	E2	342	11100010
227	E3	343	11100011
228	E4	344	11100100
229	E5	345	11100101
230	E6	346	11100110
231	E7	347	11100111
232	E8	350	11101000
233	E9	351	11101001
234	EA	352	11101010
235	EB	353	11101011
236	EC	354	11101100

237	ED	355	11101101
238	EE	356	11101110
239	EF	357	11101111
240	F0	360	11110000
241	F1	361	11110001
242	F2	362	11110010
243	F3	363	11110011
244	F4	364	11110100
245	F5	365	11110101
246	F6	366	11110110
247	F7	367	11110111
248	F8	370	11111000
249	F9	371	11111001
250	FA	372	11111010
251	FB	373	11111011
252	FC	374	11111100
253	FD	375	11111101
254	FE	376	11111110
255	FF	377	11111111

- Any prime number greater than 3 can be written as $6k\pm1$.
- The product of 'n' consecutive natural numbers is always divisible by n!
- Square of any natural number can be written in the form of 3n or 3n+1. Also, square of any natural number can be written in the form of 4n or 4n+1.
- Any two digit number 'pq' can effectively be written as 10p + q and a three digit number 'pqr' can effectively be written as 100p + 10q + r.
- Number of ways N can be written as product of two factors = $\frac{P}{2}$ or $\frac{(P+1)}{2}$ if P is even or odd respectively
- The number of ways in which a composite number can be resolved into two co-prime factors is 2^{m-1}, where m is the number of different prime factors of the number.

- $(x + a)(x + b)(x + c) = x^3 + (a + b + c)x^2 + (ab + bc + ac)x + abc$

- $(x - a)(x - b)(x - c) = x^3 - (a + b + c)x^2 + (ab + bc + ac)x - abc$

- Arithmetic Mean = $(a_1 + a_2 + a_3 \ldots. a_n) / n$

- Geometric Mean = $\sqrt[n]{a_1 a_2 \ldots\ldots a_n}$

- Harmonic Mean = $n / \left(\frac{1}{x_1} + \frac{1}{x_2} + \ldots + \frac{1}{x_n} \right)$

- For two numbers a and b

$$AM = \frac{(a + b)}{2}$$

$$GM = \sqrt{ab}$$

$$HM = \frac{2ab}{a+b}$$

- AM ≥ GM ≥ HM is always true. They will be equal if all elements are equal to each other. If there are just two values then $GM^2 = AM \times HM$
- Absolute Growth = Final Value – Initial Value
- Growth rate for one year period = $\frac{\text{Final Value} - \text{Initial Value}}{\text{Initial Value}} \times 100$
- Compound Annual Growth Rate = $\left(\frac{\text{Final Value}}{\text{Initial Value}}\right)^{\frac{1}{no.\ of\ years}} - 1$
- Average Annual Growth Rate = $\frac{\text{Final Value} - \text{Initial Value}}{\text{Number of years}} \times 100$
- **Linear Races**
  Winner's distance = Length of race
  Loser's distance = Winner's distance – (beat distance + start distance)
  Winner's time = Loser's time – (beat time + start time)

  Circular Races

Two people are running on a circular track of length L with speeds a and b in the same direction

Time for 1^{st} meeting = $\frac{L}{a-b}$

They meet at a – b distinct points (reduced ratio)

Time for 1st meeting at the starting point = LCM $(\frac{L}{a}, \frac{L}{b})$

Two people are running on a circular track of length L with speeds a and b in the opposite direction

Time for 1^{st} meeting = $\frac{L}{a+b}$

They meet at a + b distinct points (reduced ratio)

Time for 1st meeting at the starting point = LCM $(\frac{L}{a}, \frac{L}{b})$

Three people are running on a circular track of length L with speeds a, b and c in the same direction

Time for 1st meeting = LCM $(\frac{L}{a-b}, \frac{L}{a-c})$

Time for 1st meeting at the starting point = LCM $(\frac{L}{a}, \frac{L}{b}, \frac{L}{c})$

- If a and b are positive quantities, then

$$\frac{a+b}{2} \geq \sqrt{ab}$$

- If a, b, c, d are positive quantities, then

$$\frac{a}{b} + \frac{b}{c} + \frac{c}{d} + \frac{d}{a} \geq 4$$

$$a^4 + b^4 + c^4 + d^4 \geq 4abcd$$

- For any positive integer n, $2 \leq (1+\frac{1}{n})^n \leq 3$
- $(n!)^2 \geq n^n$
- $\frac{a^m + b^m}{2} > (\frac{a+b}{2})^m$ [$m \leq 0$ or $m \geq 1$]
- $\frac{a^m + b^m}{2} < (\frac{a+b}{2})^m$ [$0 < m < 1$]

- **Simple Interest Formula**

$$\text{Simple interest} = P \times i \times n$$

where:

P = principal amount
i = interest rate
n = term of the loan

- **Compound Interest Formula**

The formula for calculating compound interest in a year is:

$$\text{Compound interest} = [P\,(1 + i)^{n}] - P$$

where:

P = principal amount
i = interest rate in percentage terms
n = number of compounding periods for a year

$$\text{Total value with compound interest} = \left[P\left(\frac{1+i}{n}\right)^{nt}\right] - P$$

where:

P = principal amount

i = interest rate in percentage terms

n = number of compounding periods per year

t = total number of years for the investment or loan

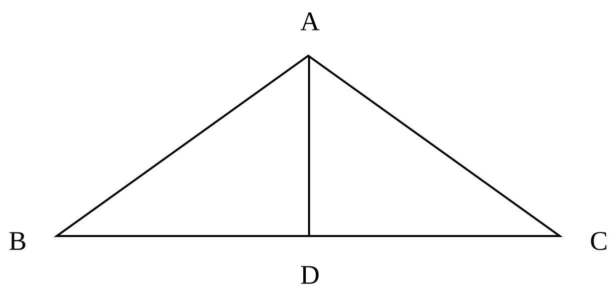
- **The formulas for obtaining the** future value (FV) **and** present value (PV) **are as follows:**

$$FV = PV \times \left(\frac{1+i}{n}\right)^{nt}$$

$$PV = \frac{FV}{\left(\frac{1+i}{n}\right)^{nt}}$$

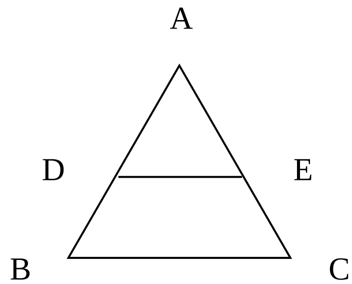
Theorems

- **Mid Point Theorem**: The line joining the midpoint of any two sides is parallel to the third side and is half the length of the third side.
- **Apollonius' Theorem:**



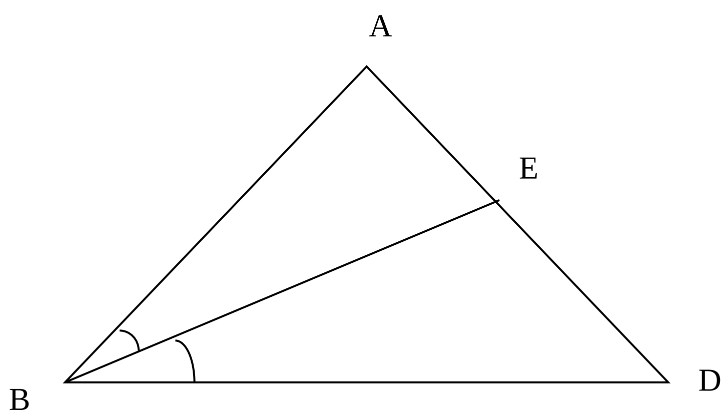
$$AB^2 + AC^2 = 2\,(AD^2 + BD^2)$$

- **Basic Proportionality Theorem:**



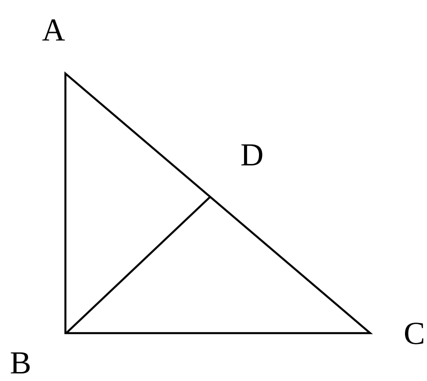
If DE || BC, then $\frac{AD}{DB} = \frac{AE}{EC}$

- **Interior Angle Bisector Theorem:**



$$\frac{AE}{ED} = \frac{BA}{BD}$$

- **Right Angled Triangle:**



$\Delta ABC \approx \Delta ADB \approx \Delta BDC$

$BD^2 = AD \times DC$

$AB \times BC = BD \times AC$

Fundamental Theorem of Arithmetic:

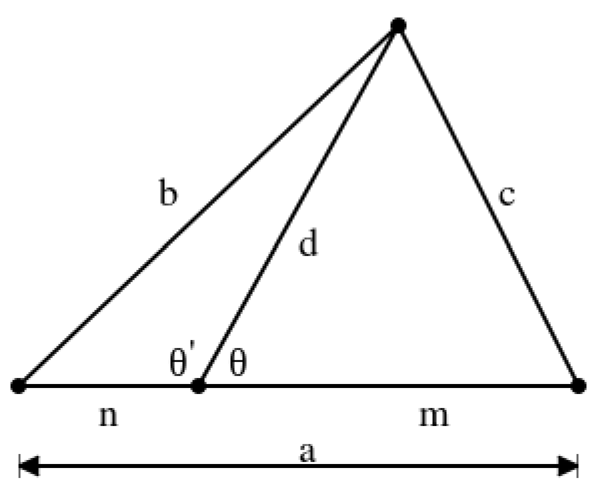
Every integer greater than 1 can be factored uniquely into a product of prime numbers

For example:

$$4312 = 2 \times 2 \times 2 \times 7 \times 7 \times 11$$

Euclid's lemma: If a prime number divides a product of two numbers, it must divide at least one of the numbers.

Stewart's Theorem:



If a, b and c are the lengths of the sides of a triangle. If d is the length of the cevian of the side of the length **a**. Suppose this cevian divides the side '**a**' into 2 segments of the length m and n, where m is adjacent to the side c and whereas n is adjacent to the side b, then

$$b^2m + c^2n = a\,(d^2 + mn)$$

The Square Root of 2 is Called "Pythagoras' Constant."

0 is the Only Number That Can't Be Represented In Roman Numerals

0 is an Even Number

6 is the Smallest Perfect Number

The Number Pi (the ratio of the circumference to the diameter of a circle) is Irrational

If we multiply a number by 9 and add all the digits of the new number together, the sum will always add up to 9. For example:

$8 \times 9 = 72$

$7 + 2 = 9$

$4 \times 9 = 36$

$3 + 6 = 9$

Number	Square	Cube	Square Root	Cubic Root
1	1	1	1.000	1.000
2	4	8	1.414	1.260
3	9	27	1.732	1.442
4	16	64	2.000	1.587
5	25	125	2.236	1.710
6	36	216	2.449	1.817
7	49	343	2.646	1.913
8	64	512	2.828	2.000
9	81	729	3.000	2.080
10	100	1000	3.162	2.154
11	121	1331	3.317	2.224
12	144	1728	3.464	2.289
13	169	2197	3.606	2.351
14	196	2744	3.742	2.410
15	225	3375	3.873	2.466
16	256	4096	4.000	2.520
17	289	4913	4.123	2.571
18	324	5832	4.243	2.621
19	361	6859	4.359	2.668
20	400	8000	4.472	2.714
21	441	9261	4.583	2.759
22	484	10648	4.690	2.802
23	529	12167	4.796	2.844
24	576	13824	4.899	2.884
25	625	15625	5.000	2.924
26	676	17576	5.099	2.962

27	729	19683	5.196	3.000
28	784	21952	5.292	3.037
29	841	24389	5.385	3.072
30	900	27000	5.477	3.107
31	961	29791	5.568	3.141
32	1024	32768	5.657	3.175
33	1089	35937	5.745	3.208
34	1156	39304	5.831	3.240
35	1225	42875	5.916	3.271
36	1296	46656	6.000	3.302
37	1369	50653	6.083	3.332
38	1444	54872	6.164	3.362
39	1521	59319	6.245	3.391
40	1600	64000	6.325	3.420
41	1681	68921	6.403	3.448
42	1764	74088	6.481	3.476
43	1849	79507	6.557	3.503
44	1936	85184	6.633	3.530
45	2025	91125	6.708	3.557
46	2116	97336	6.782	3.583
47	2209	103823	6.856	3.609
48	2304	110592	6.928	3.634
49	2401	117649	7.000	3.659
50	2500	125000	7.071	3.684
51	2601	132651	7.141	3.708
52	2704	140608	7.211	3.733
53	2809	148877	7.280	3.756

54	2916	157464	7.348	3.780
55	3025	166375	7.416	3.803
56	3136	175616	7.483	3.826
57	3249	185193	7.550	3.849
58	3364	195112	7.616	3.871
59	3481	205379	7.681	3.893
60	3600	216000	7.746	3.915
61	3721	226981	7.810	3.936
62	3844	238328	7.874	3.958
63	3969	250047	7.937	3.979
64	4096	262144	8.000	4.000
65	4225	274625	8.062	4.021
66	4356	287496	8.124	4.041
67	4489	300763	8.185	4.062
68	4624	314432	8.246	4.082
69	4761	328509	8.307	4.102
70	4900	343000	8.367	4.121
71	5041	357911	8.426	4.141
72	5184	373248	8.485	4.160
73	5329	389017	8.544	4.179
74	5476	405224	8.602	4.198
75	5625	421875	8.660	4.217
76	5776	438976	8.718	4.236
77	5929	456533	8.775	4.254
78	6084	474552	8.832	4.273
79	6241	493039	8.888	4.291
80	6400	512000	8.944	4.309

81	6561	531441	9.000	4.327
82	6724	551368	9.055	4.344
83	6889	571787	9.110	4.362
84	7056	592704	9.165	4.380
85	7225	614125	9.220	4.397
86	7396	636056	9.274	4.414
87	7569	658503	9.327	4.431
88	7744	681472	9.381	4.448
89	7921	704969	9.434	4.465
90	8100	729000	9.487	4.481
91	8281	753571	9.539	4.498
92	8464	778688	9.592	4.514
93	8649	804357	9.644	4.531
94	8836	830584	9.695	4.547
95	9025	857375	9.747	4.563
96	9216	884736	9.798	4.579
97	9409	912673	9.849	4.595
98	9604	941192	9.899	4.610
99	9801	970299	9.950	4.626
100	10000	1000000	10.000	4.642

Logarithm Table

x	$\log_{10}x$	$\log_2 x$	$\log_e x$
0	undefined	undefined	undefined

0.0001	−4	−13.287712	−9.210340
0.001	−3	−9.965784	−6.907755
0.01	−2	−6.643856	−4.605170
0.1	−1	−3.321928	−2.302585
1	0	0	0
2	0.301030	1	0.693147
3	0.477121	1.584963	1.098612
4	0.602060	2	1.386294
5	0.698970	2.321928	1.609438
6	0.778151	2.584963	1.791759
7	0.845098	2.807355	1.945910
8	0.903090	3	2.079442
9	0.954243	3.169925	2.197225
10	1	3.321928	2.302585
20	1.301030	4.321928	2.995732
30	1.477121	4.906891	3.401197
40	1.602060	5.321928	3.688879
50	1.698970	5.643856	3.912023

60	1.778151	5.906991	4.094345
70	1.845098	6.129283	4.248495
80	1.903090	6.321928	4.382027
90	1.954243	6.491853	4.499810
100	2	6.643856	4.605170
200	2.301030	7.643856	5.298317
300	2.477121	8.228819	5.703782
400	2.602060	8.643856	5.991465
500	2.698970	8.965784	6.214608
600	2.778151	9.228819	6.396930
700	2.845098	9.451211	6.551080
800	2.903090	9.643856	6.684612
900	2.954243	9.813781	6.802395
1000	3	9.965784	6.907755
10000	4	13.287712	9.210340

1 is Not a Prime Number

Six Weeks = 10! Seconds

10 × 9 × 8 × 7 × 6 × 5 × 4 × 3 × 2 × 1 = 3,628,800 seconds = 60,480 minutes = 1,008 hours = 42 days = 6 weeks

Multiplication Table

×	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	1	2	3	4	5	6	7	8	9	10	11	12
2	0	2	4	6	8	10	12	14	16	18	20	22	24
3	0	3	6	9	12	15	18	21	24	27	30	33	36
4	0	4	8	12	16	20	24	28	32	36	40	44	48
5	0	5	10	15	20	25	30	35	40	45	50	55	60
6	0	6	12	18	24	30	36	42	48	54	60	66	72
7	0	7	14	21	28	35	42	49	56	63	70	77	84
8	0	8	16	24	32	40	48	56	64	72	80	88	96
9	0	9	18	27	36	45	54	63	72	81	90	99	108
10	0	10	20	30	40	50	60	70	80	90	100	110	120
11	0	11	22	33	44	55	66	77	88	99	110	121	132
12	0	12	24	36	48	60	72	84	96	108	120	132	144

$$1^3 + 5^3 + 3^3 = 153$$

$$16^3 + 50^3 + 33^3 = 16\mathbf{50}33$$

$$166^3 + 500^3 + 333^3 = 166\mathbf{500}333$$

$$1666^3 + 5000^3 + 3333^3 = 1666\mathbf{5000}3333$$

$$1 \times 8 + 1 = 9$$
$$12 \times 8 + 2 = 98$$
$$123 \times 8 + 3 = 987$$
$$1234 \times 8 + 4 = 9876$$
$$12345 \times 8 + 5 = 98765$$
$$123456 \times 8 + 6 = 987654$$
$$1234567 \times 8 + 7 = 9876543$$
$$12345678 \times 8 + 8 = 98765432$$
$$123456789 \times 8 + 9 = 987654321$$

Metric Units of Measurement

Prefix Name	**Prefix Symbol**	**Value**	
yotta	Y	10^{24}	Septillion
zetta	Z	10^{21}	Sextillion
exa	E	10^{18}	Quintillion
peta	P	10^{15}	Quadrillion
tera	T	10^{12}	Trillion
giga	G	10^{9}	Billion
mega	M	10^{6}	Million
kilo	k	10^{3}	Thousand
hecto	h	10^{2}	Hundred
deka	da	10^{1}	Ten
		10^{0}	One
deci	d	10^{-1}	Tenth
centi	c	10^{-2}	Hundredth
milli	m	10^{-3}	Thousandth
micro	μ	10^{-6}	Millionth

nano	n	10^{-9}	Billionth
pico	p	10^{-12}	Trillionth
femto	f	10^{-15}	Quadrillionth
atto	a	10^{-18}	Quintillionth
zepto	z	10^{-21}	Sextillionth
yocto	y	10^{-24}	Septillionth

From 0 to 1000, the only number that has the letter "a" in it is "one thousand".

Units of Length	
10 millimeter (mm)	1 centimeter (cm)
10 centimeter	1 decimeter (dm) = 100 millimeters
10 decimeter	1 meter (m) = 1000 millimeters
10 meter	1 decameter (dam)
10 decameter	1 hectometer (hm) = 100 meters
10 hectometer	1 kilometer (km) = 1000 meters

The numbers on opposite sides of a dice always add up to seven

Units of Area	
100 square millimeter (mm^2)	1 square centimeter (cm^2)
100 square centimeter	1 square decimeter (dm^2)
100 square decimeter	1 square meter (m^2)
100 square meter	1 square decameter (dam^2) = 1 are
100 square decameter	1 square hectometer (hm^2) = 1 hectare (ha)
100 square hectometer	1 square kilometer (km^2)

Units of Liquid Volume	
10 milliliters (mL)	1 centiliter (cL)
10 centiliters	1 deciliter (dL) = 100 milliliters
10 deciliters	1 liter = 1000 milliliters
10 liters	1 decaliter (daL)
10 decaliter	1 hectoliter (hL) = 100 liters
10 hectoliters	1 kiloliter (kL) = 1000 liters

The number 0.999999..... is exactly equal to 1

Units of Volume	
1000 cubic millimeter (mm^3)	1 cubic centimeter (cm^3)
1000 cubic centimeter	1 cubic decimeter (dm^3) 1 000 000 cubic millimeter
1000 cubic decimeter	1 cubic meter (m^3) 1 000 000 cubic centimeter 1 000 000 000 cubic millimeter

Dividing by zero once put a US Navy Warship out of action

Units of Mass	
10 milligrams (mg)	1 centigram (cg)
10 centigrams	1 decigram (dg) = 100 milligrams
10 decigrams	1 gram (g) = 1000 milligrams
10 grams	1 dekagram (dag)
10 decagrams	1 hectogram (hg) = 100 grams
10 hectograms	1 kilogram (kg) = 1000 grams
1000 kilograms	1 megagram (Mg) or 1 metric ton (t)

Physical constants

Symbol	Quantity	Value
c	speed of light in vacuum	299792458 $m \cdot s^{-1}$
h	Planck constant	$6.62607015 \times 10^{-34}$ $J \cdot Hz^{-1}$
$\hbar$	reduced Planck constant	$1.054571817... \times 10^{-34}$ $J \cdot s$
G	Newtonian constant of gravitation	$6.67430(15) \times 10^{-11}$ $m^3 \cdot kg^{-1} \cdot s^{-2}$
$\varepsilon_0 = \frac{1}{\mu_0 c^2}$	vacuum electric permittivity	$8.8541878128(13) \times 10^{-12}$ $F \cdot m^{-1}$
μ_0	vacuum magnetic permeability	$1.25663706212(19) \times 10^{-6}$ $N \cdot A^{-2}$
$Z_0 = \mu_0 c$	characteristic impedance of vacuum	376.730313668(57) Ω
e	elementary charge	$1.602176634 \times 10^{-19}$ C
$\Delta \upsilon_{Cs}$	hyperfine transition frequency of ^{133}Cs	9192631770 Hz
N_A	Avogadro constant	$6.02214076 \times 10^{23}$ mol^{-1}
k_B	Boltzmann constant	1.380649×10^{-23} $J \cdot K^{-1}$
$G_0 = \frac{2e^2}{h}$	conductance quantum	$7.748091729... \times 10^{-5}$ S

$K_J = \dfrac{2e}{h}$	Josephson constant	$483597.8484... \times 10^{9}$ Hz·V^{-1}
$\dfrac{1}{4\pi\varepsilon_0}$	Coulomb constant	$8.9875517923(14) \times 10^{9}$ kg·m^{3}·s^{-2}·C^{-2}
$R_K = \dfrac{h}{e^2}$	von Klitzing constant	25812.80745... Ω
$\Phi_0 = \dfrac{h}{2e}$	magnetic flux quantum	$2.067833848... \times 10^{-15}$ Wb
$\dfrac{1}{G_0}$	inverse conductance quantum	12906.40372... Ω
$\mu_B = \dfrac{e\hbar}{2m_e}$	Bohr magneton	$9.2740100783(28) \times 10^{-24}$ J·T^{-1}
$\mu_N = \dfrac{e\hbar}{2m_p}$	nuclear magneton	$5.0507837461(15) \times 10^{-27}$ J·T^{-1}
$\alpha = \dfrac{e^2}{4\pi\varepsilon_0 \hbar c}$	fine-structure constant	$7.2973525693(11) \times 10^{-3}$
α^{-1}	inverse fine-structure constant	137.035999084(21)
m_e	electron mass	$9.1093837015(28) \times 10^{-31}$ kg
m_p	proton mass	$1.67262192369(51) \times 10^{-27}$ kg
m_n	neutron mass	$1.67492749804(95) \times 10^{-27}$ kg
$a_0 = \dfrac{\hbar}{\alpha m_e c}$	Bohr radius	$5.29177210903(80) \times 10^{-11}$ m

$r_e = \frac{e^2}{4\pi\varepsilon_0 m_e c^2}$	classical electron radius	$2.8179403262(13)\times10^{-15}$ m
g_e	electron *g*-factor	$-2.00231930436256(35)$
$\mathbf{G_F} / (\hbar c)^3$	Fermi coupling constant	$1.1663787(6)\times10^{-5}$ GeV^{-2}
$E_h = 2R_\infty hc$	Hartree energy	$4.3597447222071(85)\times10^{-18}$ J
$\frac{h}{2m_e}$	quantum of circulation	$3.6369475516(11)\times10^{-4}$ m$^2\cdot$s^{-1}
$R_\infty = \frac{\alpha^2 m_e c}{2h}$	Rydberg constant	$10973731.568160(21)$ m^{-1}
$\sigma_e = \frac{8\pi r_e^2}{3}$	Thomson cross section	$6.6524587321(60)\times10^{-29}$ m^2
$\frac{m_W}{m_Z}$	W-to-Z mass ratio	0.88153(17)
$\sin^2\theta_W = 1 - (\frac{m_W}{m_Z})^2$	weak mixing angle	0.22290(30)
m_u = 1Da	atomic mass constant	$1.66053906660(50)\times10^{-27}$ kg
$F = N_A e$	Faraday constant	96485.33212... C$\cdot$mol^{-1}
$R = N_A k_B$	molar gas constant	8.314462618... J$\cdot$mol$^{-1}\cdot$K^{-1}
$M_u = M(^{12}C)/12$	molar mass constant	$0.99999999965(30)\times10^{-3}$ kg$\cdot$mol^{-1}
$\sigma = \frac{\pi^2 k_B^4}{60\hbar^3 c^2}$	Stefan–Boltzmann constant	$5.670374419...\times10^{-8}$ W$\cdot$m$^{-2}\cdot$K^{-4}

$c_1 = 2\pi hc^2$	first radiation constant	$3.741771852... \times 10^{-16}$ W·m^2
$c_{1L} = \dfrac{c_1}{\pi}$	first radiation constant for spectral radiance	$1.191042972... \times 10^{-16}$ W·m^2·sr^{-1}
$M\,(^{12}C) = N_A\, m\,(^{12}C)$	molar mass of carbon-12	$11.9999999958(36) \times 10^{-3}$ kg·mol^{-1}
$N_A h$	molar Planck constant	$3.990312712... \times 10^{-10}$ J·Hz^{-1}·mol^{-1}
$c_2 = \dfrac{hc}{k_B}$	second radiation constant	$1.438776877... \times 10^{-2}$ m·K
b	Wien wavelength displacement law constant	$2.897771955... \times 10^{-3}$ m·K
b'	Wien frequency displacement law constant	$5.878925757... \times 10^{10}$ Hz·K^{-1}
$b_{entropy}$	Wien entropy displacement law constant	$3.002916077... \times 10^{-3}$ m·K

111111111 × 111111111 = 12345678987654321

Euler's identity:

$i = \sqrt{-1}$

$$\boxed{e^{i\pi} + 1 = 0}$$

Euler's number − the base of natural logarithms

Planetary Fact Sheet

Data about the planets of our solar **system (Planetary facts taken from NASA's Planetary Fact Sheet–Metric)**.

		Name	Mass (10^{24} kg)	Diameter (km)	Density (kg/m^3)	Gravity (m/s^2)	Length of day (hours)	Distance from Sun (10^6 km)	Mean temperature (°C)	Number of moons
Terrestrial planets		**Mercury**	0.330	4,879	5427	3.7	4222.6	57.9	167	0
		Venus	4.87	12,104	5243	8.9	2802.0	108.2	464	0
		Earth	5.97	12,756	5514	9.8	24.0	149.6	15	1
		Mars	0.642	6,792	3933	3.7	24.7	227.9	−65	2
Jovian planets	Gas giants	**Jupiter**	1898	142,984	1326	23.1	9.9	778.6	−110	67
		Saturn	568	120,536	687	9.0	10.7	1433.5	−140	62
	Ice giants	**Uranus**	86.8	51,118	1271	8.7	17.2	2872.5	−195	27
		Neptune	102	49,528	1638	11.0	16.1	4495.1	−200	14
Dwarf planets		**Pluto**	0.0146	2,370	2095	0.7	153.3	5906.4	−225	5

Sun Reference Data

Diameter:	1.4 million km (870,000 miles)		**Age:**	4.5 billion years
Mass:	330,000 × Earth		**Distance from Earth:**	149.6 million km (93 million miles)
Density:	1.41 (water =1)		**Distance to Nearest Star:**	4.3 light years
Solar Wind Speed:	3 million km/hr.		**Luminosity:**	390 billion billion megawatts
Solar Cycle:	8 - 11 years		**Temperature at surface:**	5,500 °C (9,932 °F)
Temperature at Core:	14 million °C (22.5 million °F)		**Temperature of Sunspots:**	4,000 °C (7,232 °F)
Rotation Period at Equator:	25 Earth days		**Rotation Period at Poles:**	35 Earth days

Mercury and Venus are the only 2 planets in our solar system that have no moons.

The hottest planet in our solar system is Venus.

Enceladus − one of Saturn's smaller moons, reflects 90% of the Solar radiation.

A light-year is the distance covered by light in a single year.

The Milky Way galaxy is 105,700 light-years wide.

The Sun weighs about 330,000 times more than Earth.

Footprints left on the Moon won't disappear as there is no wind.

The Sun makes a full rotation once every 25 – 35 days.

Earth is the only planet not named after a God.

Pluto is smaller than the United States.

He is like the fox, who effaces his tracks in the sand with his tail.

{Describing the writing style of famous mathematician **Carl Friedrich Gauss**}

— Niels Henrik Abel

There are more volcanoes on Venus than any other planet in our solar system.

Neptune's moon [Triton] orbits the planet backwards.

There are more stars in space than there are grains of sand in the world.

Neptune takes nearly 165 Earth years to make one orbit of the Sun.

Pluto's largest moon [Charon] is half the size of Pluto.

A day on Pluto is lasts for 153.6 hours long.

Any free-moving liquid in outer space will shape itself into a sphere.

Only 5% of the universe is visible from Earth.

Light travels from the Sun to the Earth in less than 10 minutes.

The Earth's rotation is slowing slightly as time goes on.

There are three main types of galaxies:

- elliptical
- spiral
- irregular

There are approximately 100 thousand million stars in the Milky Way.

<table>
<tr><th>Essential Amino Acids</th><th>Nonessential Amino Acids</th></tr>
<tr><td>These cannot be synthesized or produced by the body and are required from food supplements

• Leucine
• Isoleucine
• Histidine
• Lysine
• Methionine
• Threonine
• Phenylalanine
• Tryptophan
• Valine</td><td>These are produced or synthesized by our bodies and are not taken up as food supplements

• Arginine
• Alanine
• Aspartic acid
• Asparagine
• Cysteine
• Glutamine
• Glutamic acid
• Proline
• Glycine
• Serine
• Tyrosine</td></tr>
<tr><th colspan="2">Conditional Amino Acids</th></tr>
<tr><td colspan="2">These are usually not essential but in times of illness and stress – may become essential

• Cysteine
• Arginine
• Tyrosine
• Glutamine
• Ornithine
• Glycine
• Serine
• Proline</td></tr>
</table>

Common Amino Acids

Name	Abbr.		Molecular Weight	Molecular Formula
Alanine	Ala	A	89.10	$C_3H_7NO_2$
Arginine	Arg	R	174.20	$C_6H_{14}N_4O_2$
Asparagine	Asn	N	132.12	$C_4H_8N_2O_3$
Aspartic acid	Asp	D	133.11	$C_4H_7NO_4$
Cysteine	Cys	C	121.16	$C_3H_7NO_2S$
Glutamic acid	Glu	E	147.13	$C_5H_9NO_4$
Glutamine	Gln	Q	146.15	$C_5H_{10}N_2O_3$
Glycine	Gly	G	75.07	$C_2H_5NO_2$
Histidine	His	H	155.16	$C_6H_9N_3O_2$
Hydroxyproline	Hyp	O	131.13	$C_5H_9NO_3$
Isoleucine	Ile	I	131.18	$C_6H_{13}NO_2$
Leucine	Leu	L	131.18	$C_6H_{13}NO_2$
Lysine	Lys	K	146.19	$C_6H_{14}N_2O_2$
Methionine	Met	M	149.21	$C_5H_{11}NO_2S$
Phenylalanine	Phe	F	165.19	$C_9H_{11}NO_2$
Proline	Pro	P	115.13	$C_5H_9NO_2$
Pyroglutamatic	Glp	U	139.11	$C_5H_7NO_3$
Serine	Ser	S	105.09	$C_3H_7NO_3$
Threonine	Thr	T	119.12	$C_4H_9NO_3$
Tryptophan	Trp	W	204.23	$C_{11}H_{12}N_2O_2$
Tyrosine	Tyr	Y	181.19	$C_9H_{11}NO_3$
Valine	Val	V	117.15	$C_5H_{11}NO_2$

With our naked eye, we can see 3 – 7 different galaxies from Earth.

The closest galaxy to us is the **Andromeda Galaxy** – it's estimated at 2.5 million light-years away.

The distance between the Sun and Earth is defined as an Astronomical Unit.

On Venus, it snows metal and rains sulfuric acid.

Space is completely silent.

Astronauts can grow approximately two inches in height when in space.

The first artificial satellite in space was called **Sputnik**

Exoplanets are planets that orbit around other stars.

The center of the Milky Way smells like rum and tastes like raspberries.

Particles and their Properties

Particle name	Mass (MeV/c^2)	Average lifetime (s)
Leptons		
Electron	0.511	Stable
Electron neutrino	≈0	Stable
Muon	105.7	2.20×10^{-6}
Muon neutrino	≈0	Stable
Tau	1784	$<4\times10^{-13}$
Tau neutrino	≈0	Stable
Hadrons		
Proton	938.3	Stable
Neutron	939.6	920
Lambda	1115.6	2.6×10^{-10}
Sigma	1189.4	0.80×10^{-10}
Xi	1315	2.9×10^{-10}
Omega	1672	0.82×10^{-10}
Pion	139.6	2.60×10^{-8}
π-Zero	135.0	0.83×10^{-16}
Kaon	493.7	1.24×10^{-8}
k-Short	497.6	0.89×10^{-10}
k-Long	497.6	5.2×10^{-8}
J/ψ	3100	7.1×10^{-21}
Upsilon	9460	1.2×10^{-20}

Composition of Earth's Atmosphere	
Nitrogen	78.1%
Oxygen	20.9%
Argon	0.9%
Carbon dioxide, Methane, Rare (inert) gases	0.1%

Base Planck units			
Name	**Dimension**	**Expression**	**Value (SI units)**
Planck length	Length (L)	$l_P = \sqrt{\frac{\hbar G}{c^3}}$	$1.616255(18) \times 10^{-35}$ m
Planck mass	Mass (M)	$m_P = \sqrt{\frac{\hbar c}{G}}$	$2.176435(24) \times 10^{-8}$ kg
Planck time	Time (T)	$t_P = \sqrt{\frac{\hbar G}{c^5}}$	$5.391247(60) \times 10^{-44}$ s
Planck temperature	Temperature (Θ)	$T_P = \sqrt{\frac{\hbar c^5}{G k_B^2}}$	$1.416785(16) \times 10^{32}$ K
Planck charge	Electric charge (Q)	$q_P = \sqrt{4\pi\varepsilon_0 \hbar c}$	$1.875545956(41) \times 10^{-18}$ C

Abundances of the Elements in the Earth's Crust

Element	Approximate % by weight
Oxygen	46.6
Silicon	27.7
Aluminum	8.1
Iron	5.0
Calcium	3.6
Sodium	2.8
Potassium	2.6
Magnesium	2.1
All others	1.5

Element Abundance in the Solar System

Element	Symbol	Mass Number A	Mass fraction in parts per million	Atom fraction in parts per million
Hydrogen-1	H	1	705700	909964
Helium-4	He	4	275200	88714
Oxygen-16	O	16	5920	477
Carbon-12	C	12	3032	326
Nitrogen-14	N	14	1105	102
Neon-20	Ne	20	1548	100
Silicon-28	Si	28	653	30
Magnesium-24	Mg	24	513	28
Iron-56	Fe	56	1169	27
Sulfur-32	S	32	396	16

Helium-3	He	3	35	15
Hydrogen-2	H	2	23	15
Neon-22	Ne	22	208	12
Magnesium-26	Mg	26	79	4
Carbon-13	C	13	37	4
Magnesium-25	Mg	25	69	4
Aluminum-27	Al	27	58	3
Argon-36	Ar	36	77	3
Calcium-40	Ca	40	60	2
Sodium-23	Na	23	33	2
Iron-54	Fe	54	72	2
Silicon-29	Si	29	34	2
Nickel-58	Ni	58	49	1
Silicon-30	Si	30	23	1
Iron-57	Fe	57	28	1

Composition of the Sun

Element	**Abundance (percentage of total number of atoms)**	**Abundance (percentage of total mass)**
Hydrogen	91.2	71.0
Helium	8.7	27.1
Oxygen	0.078	0.97
Carbon	0.043	0.40
Nitrogen	0.0088	0.096
Silicon	0.0045	0.099
Magnesium	0.0038	0.076
Neon	0.0035	0.058

Iron	0.0030	0.14
Sulfur	0.0015	0.040

Speed of Sound

Gases	
Material	**v (m/s)**
Hydrogen (0°C)	1286
Helium (0°C)	972
Air (20°C)	343
Air (0°C)	331
Liquids at 25°C	
Material	**v (m/s)**
Glycerol	1904
Sea water	1533
Water	1493
Mercury	1450
Kerosene	1324
Methyl alcohol	1143
Carbon tetrachloride	926
Solids	
Material	**v (m/s)**
Diamond	12000
Pyrex glass	5640
Iron	5130
Aluminum	5100
Brass	4700
Copper	3560
Gold	3240
Lucite	2680
Lead	1322
Rubber	1600

Our moon is moving away from Earth at a rate of 4 cm per year.

Pluto is named after the Roman god of the underworld.

The first living mammal to go into space was a dog named "Laika" from Russia.

Saturn is the only planet that could float in water.

A sunset on Mars is blue.

Astronauts can grow approximately two inches in height when in space.

The Earth weighs about 81 times more than the **Moon**

Asteroids are the byproducts of formations in the solar system, more than 4 billion years ago.

Molecule	Bond Energy (kJ/mol)
H—H	432
H—F	565
H—Cl	427
H—Br	363
H—I	295
C—H	413
C—C	347
C—N	305
C—O	358
C—F	485
C—Cl	339
C—Br	276
C—I	240.
C—S	259
N—H	391
N—N	160.
N—F	272
N—Cl	200.
N—Br	243
N—O	201
O—H	467
O—O	146
O—F	190.
O—Cl	203

O—I	234
F—F	154
F—Cl	253
F—Br	237
Cl—Cl	239
Cl—Br	218
Br—Br	193
I—I	149
I—Cl	208
I—Br	175
S—H	347
S—F	327
S—Cl	253
S—Br	218
S—S	266
Si—Si	340
Si—H	393
Si—C	360
Si—O	452
C = C	614
C ≡ C	839
O = O	495
C = O	799
C ≡ O	1072
N = O	607

N = N	418
N ≡ N	941
C ≡ N	891
C = N	615

Electron Affinities of the Main-Group Elements

Electron Affinities in kJ/mole

	IA	IIIA	IVA	VA	VIA	VIIA
Period 1	H					
	-73					
Period 2	Li	B	C	N	O	F
	-60	-27	-122	0	-141	-328
Period 3	Na	Al	Si	P	S	Cl
	-53	-44	-134	-72	-200	-349
Period 4	K	Ga	Ge	As	Se	Br
	-48	-30	-120	-77	-195	-325
Period 5	Rb	In	Sn	Sb	Te	I
	-47	-30	-121	-101	-190	-295
Period 6	Cs	Tl	Pb	Bi	Po	At
	-45	-30	-110	-110	-180	-270

Work function of elements (eV)					
Ag	4.26 – 4.74	**Al**	4.06 – 4.26	**As**	3.75

Au	5.10 - 5.47	**B**	~4.45	**Ba**	2.52 - 2.70
Be	4.98	**Bi**	4.31	**C**	~5
Ca	2.87	**Cd**	4.08	**Ce**	2.9
Co	5	**Cr**	4.5	**Cs**	1.95
Cu	4.53 - 5.10	**Eu**	2.5	**Fe:**	4.67 - 4.81
Ga	4.32	**Gd**	2.90	**Hf**	3.90
Hg	4.475	**In**	4.09	**Ir**	5.00 - 5.67
K	2.29	**La**	3.5	**Li**	2.9
Lu	~3.3	**Mg**	3.66	**Mn**	4.1
Mo	4.36 - 4.95	**Na**	2.36	**Nb**	3.95 - 4.87
Nd	3.2	**Ni**	5.04 - 5.35	**Os**	5.93
Pb	4.25	**Pd**	5.22 - 5.60	**Pt**	5.12 - 5.93
Rb	2.261	**Re**	4.72	**Rh**	4.98

Ru	4.71	**Sb**	4.55 – 4.70	**Sc**	3.5
Se	5.9	**Si**	4.60 – 4.85	**Sm**	2.7
Sn	4.42	**Sr**	~2.59	**Ta**	4.00 – 4.80
Tb	3.00	**Te**	4.95	**Th**	3.4
Ti	4.33	**Tl**	~3.84	**U**	3.63 – 3.90
V	4.3	**W**	4.32 – 5.22	**Y**	3.1
Yb	2.60	**Zn**	3.63 – 4.9	**Zr**	4.05

Fermi Energies, Fermi Temperatures, and Fermi Velocities

Element	**Fermi Energy eV**	**Fermi Temperature 10^4 K**	**Fermi Velocity 10^6 m/s**
Li	4.74	5.51	1.29
Na	3.24	3.77	1.07
K	2.12	2.46	0.86
Rb	1.85	2.15	0.81
Cs	1.59	1.84	0.75
Cu	7.00	8.16	1.57
Ag	5.49	6.38	1.39
Au	5.53	6.42	1.40
Be	14.3	16.6	2.25
Mg	7.08	8.23	1.58

Ca	4.69	5.44	1.28
Sr	3.93	4.57	1.18
Ba	3.64	4.23	1.13
Nb	5.32	6.18	1.37
Fe	11.1	13.0	1.98
Mn	10.9	12.7	1.96
Zn	9.47	11.0	1.83
Cd	7.47	8.68	1.62
Hg	7.13	8.29	1.58
Al	11.7	13.6	2.03
Ga	10.4	12.1	1.92
In	8.63	10.0	1.74
Tl	8.15	9.46	1.69
Sn	10.2	11.8	1.90
Pb	9.47	11.0	1.83
Bi	9.90	11.5	1.87
Sb	10.9	12.7	1.96

Radioactive Nuclide	**Half-Life (years)**
^{50}V	6.0×10^{15}
^{144}Nd	2.4×10^{15}
^{174}Hf	2.0×10^{15}
^{192}Pt	1×10^{15}
^{115}In	6.0×10^{14}
^{152}Gd	1.08×10^{14}
^{123}Te	1.2×10^{13}
^{190}Pt	6.9×10^{11}

^{138}La	1.12×10^{11}
^{147}Sm	1.06×10^{11}
^{87}Rb	4.88×10^{10}
^{187}Re	4.3×10^{10}
^{176}Lu	3.5×10^{10}
^{232}Th	1.40×10^{10}
^{238}U	4.47×10^{9}
^{40}K	1.25×10^{9}
^{235}U	7.04×8^{10}
^{244}Pu	8.2×10^{7}
^{146}Sm	7.0×10^{7}
^{205}Pb	3.0×10^{7}
^{236}U	2.39×10^{7}
^{129}I	1.7×10^{7}
^{247}Cm	1.60×10^{7}
^{182}Hf	9.0×10^{6}
^{107}Pd	7×10^{6}
^{53}Mn	3.7×10^{6}
^{135}Cs	3.0×10^{6}
^{97}Tc	2.6×10^{6}
^{237}Np	2.14×10^{6}
^{150}Gd	2.1×10^{6}
^{10}Be	1.6×10^{6}
^{93}Zr	$1.5.0\times10^{6}$
^{98}Tc	1.5×10^{6}

^{153}Dy	1×10^6

- **Standard Electrode Potentials in Aqueous Solution at 25°C**

Cathode (Reduction) Half-Reaction	Standard Potential E° (volts)
$Li^+(aq) + e^- \rightarrow Li(s)$	-3.04
$K^+(aq) + e^- \rightarrow K(s)$	-2.92
$Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$	-2.76
$Na^+(aq) + e^- \rightarrow Na(s)$	-2.71
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	-2.38
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	-1.66
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	-0.83
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	-0.76
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	-0.74
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	-0.41
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$	-0.40
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	-0.23
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	-0.14
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	-0.13
$Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$	-0.04
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	0.15
$Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)$	0.16
$ClO_4^-(aq) + H_2O(l) + 2e^- \rightarrow ClO_3^-(aq) + 2OH^-(aq)$	0.17
$AgCl(s) + e^- \rightarrow Ag(s) + Cl^-(aq)$	0.22
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	0.34
$ClO_3^-(aq) + H_2O(l) + 2e^- \rightarrow ClO_2^-(aq) + 2OH^-(aq)$	0.35
$IO^-(aq) + H_2O(l) + 2e^- \rightarrow I^-(aq) + 2OH^-(aq)$	0.49

$Cu^{+}(aq) + e^{-} \rightarrow Cu(s)$	0.52
$I_2(s) + 2e^{-} \rightarrow 2I^{-}(aq)$	0.54
$ClO_2^{-}(aq) + H_2O(l) + 2e^{-} \rightarrow ClO^{-}(aq) + 2OH^{-}(aq)$	0.59
$Fe^{3+}(aq) + e^{-} \rightarrow Fe^{2+}(aq)$	0.77
$Hg_2^{2+}(aq) + 2e^{-} \rightarrow 2Hg(l)$	0.80
$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$	0.80
$Hg^{2+}(aq) + 2e^{-} \rightarrow Hg(l)$	0.85
$ClO^{-}(aq) + H_2O(l) + 2e^{-} \rightarrow Cl^{-}(aq) + 2OH^{-}(aq)$	0.90
$2Hg^{2+}(aq) + 2e^{-} \rightarrow Hg_2^{2+}(aq)$	0.90
$NO_3^{-}(aq) + 4H^{+}(aq) + 3e^{-} \rightarrow NO(g) + 2H_2O(l)$	0.96
$Br_2(l) + 2e^{-} \rightarrow 2Br^{-}(aq)$	1.07
$O_2(g) + 4H^{+}(aq) + 4e^{-} \rightarrow 2H_2O(l)$	1.23
$Cr_2O_7^{2-}(aq) + 14H^{+}(aq) + 6e^{-} \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	1.33
$Cl_2(g) + 2e^{-} \rightarrow 2Cl^{-}(aq)$	1.36
$Ce^{4+}(aq) + e^{-} \rightarrow Ce^{3+}(aq)$	1.44
$MnO_4^{-}(aq) + 8H^{+}(aq) + 5e^{-} \rightarrow Mn^{2+}(aq) + 4H_2O(l)$	1.49
$H_2O_2(aq) + 2H^{+}(aq) + 2e^{-} \rightarrow 2H_2O(l)$	1.78
$Co^{3+}(aq) + e^{-} \rightarrow Co^{2+}(aq)$	1.82
$S_2O_8^{2-}(aq) + 2e^{-} \rightarrow 2SO_4^{2-}(aq)$	2.01
$O_3(g) + 2H^{+}(aq) + 2e^{-} \rightarrow O_2(g) + H_2O(l)$	2.07
$F_2(g) + 2e^{-} \rightarrow 2F^{-}(aq)$	2.87

- **Astronomy Data**

1 light-year = 9.47×10^{15} m

1 AU (astronomical unit) = 1.50×10^{11} m

- **Distilled Water at Room Temperature (25°C) and Standard Pressure (101.325 kPa)**

Volume	Mass	Density
1.0 mL or 1.0 cm^3	1.0 g	1.0 g/cm^3
1.0 L or 1.0 dm^3	1.0 kg	1.0 kg/dm^3

- **Melting and Boiling points of Selected Compounds**

Compound	Formula	Boiling Point	Melting Point
pentane	$CH_3(CH_2)_3CH_3$	36°C	−130°C
hexane	$CH_3(CH_2)_4CH_3$	69°C	−95°C
heptane	$CH_3(CH_2)_5CH_3$	98°C	−91°C
octane	$CH_3(CH_2)_6CH_3$	126°C	−57°C
nonane	$CH_3(CH_2)_7CH_3$	151°C	−54°C
decane	$CH_3(CH_2)_8CH_3$	174°C	−30°C
tetramethylbutane	$(CH_3)_3C\text{-}C(CH_3)_3$	106°C	+100°C

- **Flame Colour of Elements**

Element	Symbol	Colour
barium	Ba	yellowish-green
calcium	Ca	yellowish red
cesium	Cs	violet
copper	Cu	blue to green
lead	Pb	blue-white
lithium	Li	red
potassium	K	violet
rubidium	Rb	violet
sodium	Na	yellow

strontium	Sr	scarlet red

- **Prefixes for Molecular Compounds**

1 = *mono-*	6 = *hexa-*
2 = *di-*	7 = *hepta-*
3 = *tri-*	8 = *octa-*
4 = *tetra-*	9 = *ennea- (nona-)*
5 = *penta-*	10 = *deca-*

- **Properties of alkanes**

Alkane	**Formula**	**Boiling point [°C]**	**Melting point [°C]**	**Density [kg/m^3] (at 20 °C)**
Methane	CH_4	-162	-182	0.656 (gas)
Ethane	C_2H_6	-89	-183	1.26 (gas)
Propane	C_3H_8	-42	-188	2.01 (gas)
Butane	C_4H_{10}	0	-138	2.48 (gas)
Pentane	C_5H_{12}	36	-130	626 (liquid)
Hexane	C_6H_{14}	69	-95	659 (liquid)
Heptane	C_7H_{16}	98	-91	684 (liquid)
Octane	C_8H_{18}	126	-57	703 (liquid)

Nonane	C_9H_{20}	151	−54	718 (liquid)
Decane	$C_{10}H_{22}$	174	−30	730 (liquid)
Undecane	$C_{11}H_{24}$	196	−26	740 (liquid)
Dodecane	$C_{12}H_{26}$	216	−10	749 (liquid)
Tridecane	$C_{13}H_{28}$	235	−5.4	756 (liquid)
Tetradecane	$C_{14}H_{30}$	253	5.9	763 (liquid)
Pentadecane	$C_{15}H_{32}$	270	10	769 (liquid)
Hexadecane	$C_{16}H_{34}$	287	18	773 (liquid)
Heptadecane	$C_{17}H_{36}$	303	22	777 (solid)
Octadecane	$C_{18}H_{38}$	317	28	781 (solid)
Nonadecane	$C_{19}H_{40}$	330	32	785 (solid)
Icosane	$C_{20}H_{42}$	343	37	789 (solid)
Triacontane	$C_{30}H_{62}$	450	66	810 (solid)
Tetracontane	$C_{40}H_{82}$	525	82	817 (solid)
Pentacontane	$C_{50}H_{102}$	575	91	824 (solid)
Hexacontane	$C_{60}H_{122}$	625	100	829 (solid)
Heptacontane	$C_{70}H_{142}$	653	109	869 (solid)

Quantity	Unit Name	Symbol	Definition
Time	minute hour day year (annum)	min h d a	1min = 60s 1h = 3,600s 1d = 86,400s 1a = 31,557,600s
Area	hectare	ha	1ha = 10,000 m^2
Volume	litre	L	1L = 1,000 cm^3
Mass	metric ton or tonne	t	1t = 1,000 kg = 1 Mg
Pressure	standard atmosphere	atm	1atm = 101.325 kPa

- **Color of Transition Metal Ions in Aqueous Solution**

Transition Metal Ion	Color
Co^{2+}	pink
Cu^{2+}	blue-green
Fe^{2+}	olive green
Ni^{2+}	bright green
Fe^{3+}	brown to yellow
CrO_4^{2-}	orange
$Cr_2O_7^{2-}$	yellow
Ti^{3+}	purple
Cr^{3+}	violet
Mn^{2+}	pale pink
Zn^{2+}	colorless

- **DNA Nitrogen Bases**

Nitrogen Base	Abbreviation
adenine	A

cytosine	C
guanine	G
thymine	T

- **Acid–Base Indicators at 25°C**

Indicator	pH Range	Colour Change as pH Increases
methyl violet	0.0 – 1.6	yellow to blue
thymol blue	1.2 – 2.8	red to yellow
thymol blue	8.0 – 9.6	yellow to blue
orange IV	1.4 – 2.8	red to yellow
methyl orange	3.2 – 4.4	red to yellow
bromocresol green	3.8 – 5.4	yellow to blue
litmus	4.5 – 8.3	red to blue
methyl red	4.8 – 6.0	red to yellow
chlorophenol red	5.2 – 6.8	yellow to red
bromothymol blue	6.0 – 7.6	yellow to blue
phenol red	6.6 – 8.0	yellow to red
phenolphthalein	8.2 – 10.0	colourless to pink
thymolphthalein	9.4 – 10.6	colourless to blue
alizarin yellow R	10.1 – 12.0	yellow to red
indigo carmine	11.4 – 13.0	blue to yellow
1,3,5-trinitrobenzene	12.0 – 14.0	colourless to orange

- **Activity Series for 1.0 mol/L Solution at 25 °C and 101.325 kPa**

Increasing strength of reactant as an oxidizing agent (↑)

Reduction Half-Reaction
$Au^{3+}(aq) + 3\,e^- \rightarrow Au(s)$
$Hg^{2+}(aq) + 2\,e^- \rightarrow Hg(l)$
$Ag^{+}(aq) + e^- \rightarrow Ag(s)$
$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$
$2\,H^{+}(aq) + 2\,e^- \rightarrow H_2(g)$
$Pb^{2+}(aq) + 2\,e^- \rightarrow Pb(s)$
$Sn^{2+}(aq) + 2\,e^- \rightarrow Sn(s)$
$Ni^{2+}(aq) + 2\,e^- \rightarrow Ni(s)$
$Cd^{2+}(aq) + 2\,e^- \rightarrow Cd(s)$
$Fe^{2+}(aq) + 2\,e^- \rightarrow Fe(s)$
$Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$
$Cr^{2+}(aq) + 2\,e^- \rightarrow Cr(s)$
$Al^{3+}(aq) + 3\,e^- \rightarrow Al(s)$
$Mg^{2+}(aq) + 2\,e^- \rightarrow Mg(s)$
$Na^{+}(aq) + e^- \rightarrow Na(s)$
$Ca^{2+}(aq) + 2\,e^- \rightarrow Ca(s)$
$Li^{+}(aq) + e^- \rightarrow Li(s)$

Increasing strength of reactant as a reducing agent (↓)

- **Symbols in Chemical Equations**

Symbol	Meaning
+	used to separate one reactant or product from another
$\rightarrow$	used to separate the reactants from the products - it is pronounced "yields" or "produces" when the equation is read
$\leftrightarrow$	used when the reaction can proceed in both directions - this is called an equilibrium arrow and will be used later in the course
(g)	indicates that the substance is in a gaseous state
$\uparrow$	an alternative way of representing a substance in a gaseous state
(s)	indicates that the substance is in a solid state

$\downarrow$	an alternative way of representing a substance in a solid state
(aq)	indicates that the substance is dissolved in water - the aq comes from aqueous
$\xrightarrow{\Delta}$	indicates that heat is applied to make the reaction proceed
(l)	indicates that the substance is in a liquid state
$\xrightarrow{hv}$	The reaction undergoes photolysis (catalyzed with light/radiation)
$\xrightarrow{Fe_{(s)}}$	Catalyzed by iron (solid).
$\xrightarrow{4^oC}$	The reaction occurs at 4°C

- **Geological time scale**

Era	Period	Epoch	Plant and Animal Development
Cenozoic	Quaternary	Holocene (.01)	Humans develop
		Pleistocene (1.8)	
	Tertiary	Pliocene (5.3)	
		Miocene (23.8)	
		Oligocene (33.7)	"Age of mammals"
		Eocene (54.8)	
		Paleocene (65.0)	Extinction of dinosaurs and many other species.
Mesozoic	Cretaceous (144)	"Age of Reptiles"	First flowering plants
	Jurassic (206)		First birds
	Triassic (248)		Dinosaurs dominant.
Paleozoic	Permian (290)	"Age of Amphibians"	Extinction of trilobites and many other marine animals
	Carboniferous: Pennyslvanian (323)		
	Carboniferous:		

	Mississippian (354)		First reptiles Large coal swamps Large Amphibians abundant.
	Devonian (417)	"Age of Fishes"	First insect fossils
	Silurian (443)		Fishes dominant First land plants
	Ordovician (490)	"Age of Invertebrates"	First fishes
	Cambrian (540)		Trilobites dominant First organisms with shells
Precambrian - comprises about 88% of geologic time (4500)			First multicelled organisms First one-celled organisms Origin of Earth

prefix	number of carbons	alkyl group
meth-	1	methyl
eth-	2	ethyl

prop-	3	propyl
but-	4	butyl
pent-	5	pentyl
hex-	6	hexyl
hept-	7	heptyl
oct-	8	octyl
non-	9	nonyl
dec-	10	decyl

- **The suffix associated with various functional groups**

Functional group	suffix
alkane	-ane
alkene	-ene
alkyne	-yne
alcohol	-ol
aldehyde	-al
ketone	-one

carboxylic acid	-oic acid
ester	-oate

- **Heat Capacities of Selected Substances at 1 atm and 25°C**

Substance	**Specific Heat Capacity** (J/g°C)
air	1.012
aluminum	0.89
argon	0.5203
copper	0.385
granite	0.790
graphite	0.710
helium	5.1932
iron	0.450
lead	0.129
lithium	3.58
mercury	0.14
methanol	2.14
sodium	1.228
steel	0.466
titanium	0.523
water (ice, O°C)	2.09
water	4.184
water (steam, 100°C)	2.03

- **Thermodynamic Properties of Selected Compounds**

Compound	Melting Point (°C)	Boiling Point (°C)	Heat of Fusion (kJ/mol)	Heat of Vaporization (kJ/mol)
water	0.00	100.00	6.01	40.66
hexane	−95.35	68.73	13.08	28.85
ethanol	−114.14	78.29	4.93	38.56
methanol	−97.53	64.6	3.22	35.21
toluene	−94.95	110.63	6.64	33.18

- **Standard Heats of Formation of Selected Compounds at 25°C**

Compound	Standard heat of formation (kJ/mol)
ammonia	−45.9
benzene	+49.1
butane	−125.7
calcium carbonate	−1207.6
calcium hydroxide	−985.2
carbon dioxide	−393.5
carbon monoxide	−110.5
ethane	−84.0
ethanoic acid (acetic acid)	−484.3
ethanol	−277.6
ethene (ethylene)	+52.4
ethyne (acetylene)	+227.4
glucose	−1273.3
hydrogen sulfide	−20.6
methane	−74.6

methanol	−239.2
nitrogen dioxide	+33.2
nitrogen monoxide	+91.3
octane	−250.1
pentane	−173.5
propane	−103.8
sucrose	−2226.1
sulfur dioxide	−296.8
sulfur trioxide	−395.7
water (liquid)	−285.8
water (gas)	−241.8

Note:

Negative sign (–) denotes exothermic change.

Positive sign (+) denotes endothermic change.

1.00 kilowatt hour = 1.00 kW·h = 3.60×10^6 J

- **Elements for Radioactive Dating**

Radioisotope (Parent Nuclide)	Final Decay Nuclide	Approximate Half-Life (annum—a)
carbon-14	nitrogen-14	5.73×10^3
potassium-40	argon-40	1.26×10^9
rubidium-87	strontium-87	4.88×10^{10}
uranium-235	lead-207	7.04×10^8
uranium-238	lead-206	4.47×10^9

- **Types of Reactions**

Formation (Synthesis)

element + element → compound

Decomposition

compound → element + element

Single Replacement

compound + element → new compound + new element

Double Replacement

compound + compound → new compound + new compound

Complete Hydrocarbon Combustion

hydrocarbon + oxygen → carbon dioxide + water

Addition

alkene or alkyne + excess hydrogen → alkane

alkene or alkyne + halogen → halogenated hydrocarbon

Cracking

large hydrocarbon → small hydrocarbons

Polymerization

monomer + monomer → polymer

Esterification

alcohol + carboxylic acid → ester + water

- **Table of Polyatomic Ions**

Name	Formula
ammonium	NH_4^+
nitrite	NO_2^-
nitrate	NO_3^-
sulfite	SO_3^{2-}
sulfate	SO_4^{2-}
hydrogen sulfate (bisulfate)	HSO_4^-
thiosulfate	$S_2O_3^{2-}$
oxalate	$C_2O_4^{2-}$
hydroxide	OH^-
phosphite	PO_3^{3-}
phosphate	PO_4^{3-}
hydrogen phosphate	HPO_4^{2-}
dihydrogen phosphate	$H_2PO_4^-$
perchlorate	ClO_4^-
chlorate	ClO_3^-

chlorite	ClO_2^-
hypochlorite	ClO^-
bromate	BrO_3^-
iodate	IO_3^-
acetate acetate	CH_3COO^- $C_2H_3O_2^-$
carbonate	CO_3^{2-}
hydrogen carbonate (bicarbonate)	HCO_3^-
chromate	CrO_4^{2-}
dichromate	$Cr_2O_7^{2-}$
permanganate	MnO_4^-
peroxide	O_2^{2-}
cyanide	CN^-
cyanate	OCN^-
thiocyanate	SCN^-

- **Standard index of refraction measurements taken at the "yellow doublet" sodium D line with a wavelength of 589 nm**

MATERIAL	INDEX OF REFRACTION	STATE	
Vacuum	1		(by definition)
Helium	1.000036	Gas	(0°C and 1 atm)
Hydrogen	1.000132	Gas	(0°C and 1 atm)
Air	1.000277	Gas	(at STP*)
Air	1.000293	Gas	(0°C and 1 atm)
Carbon Dioxide	1.001	Gas	(0°C and 1 atm)
Liquid Helium	1.025	Liquid	(at -270°C)
Water Ice	1.31	Solid	(at 0°C)
Water	1.330	Liquid	(at 20°C)
Acetone	1.36	Liquid	(at 20°C)
Ethanol	1.361	Liquid	(at 20°C)
Kerosene	1.39	Liquid	(at 20°C)
Corn Oil	1.47	Liquid	(at 20°C)
Glycerol	1.4729	Liquid	(at 20°C)
Acrylic Glass	1.490–1.492	Solid	(at 20°C)
Benzene	1.501	Liquid	(at 20°C)
Crown Glass (pure)	1.50–1.54	Solid	(at 20°C)
Plate Glass (window glass)	1.52	Solid	(at 20°C)
Sodium Chloride (table salt)	1.544	Solid	(at 20°C)
Amber	1.55	Solid	(at 20°C)
Polycabonate	1.60	Solid	(at 20°C)
Flint Glass (pure)	1.60–1.62	Solid	(at 20°C)
Bromine	1.661	Liquid	(at 20°C)
Sapphire	1.762–1.778	Solid	(at 20°C)
Cubic Zirconia	2.15–2.18	Solid	(at 20°C)
Diamond	2.417	Solid	(at 20°C)
Silicon	3.42–3.48	Solid	(at 20°C)
Germanium	4.05–4.01	Solid	(at 20°C)

- STP is defined as a temperature of 273.15 K (0 °C, 32 °F) and an absolute pressure of exactly 105 Pa (100 kPa, 1 bar).

- **Solubility Products for Selected Ionic Substances at 25°C**

Solid	**Color**	K_{sp}	**Solid**	**Color**	K_{sp}
Acetates			**Iodides**		
$Ca(O_2CCH_3)_2 \cdot 3H_2O$	white	4×10^{-3}	Hg_2I_2	yellow	5.2×10^{-29}
Bromides			PbI_2	yellow	9.8×10^{-9}
AgBr	off-white	5.35×10^{-13}	**Oxalates**		
Hg_2Br_2	yellow	6.40×10^{-23}	$Ag_2C_2O_4$	white	5.40×10^{-12}
Carbonates			$MgC_2O_4 \cdot 2H_2O$	white	4.83×10^{-6}
$CaCO_3$	white	3.36×10^{-9}	PbC_2O_4	white	4.8×10^{-10}
$PbCO_3$	white	7.40×10^{-14}	**Phosphates**		
Chlorides			Ag_3PO_4	white	8.89×10^{-17}
AgCl	white	1.77×10^{-10}	$Sr_3(PO_4)_2$	white	4.0×10^{-28}
Hg_2Cl_2	white	1.43×10^{-18}	$FePO_4 \cdot 2H_2O$	pink	9.91×10^{-16}
$PbCl_2$	white	1.70×10^{-5}	**Sulfates**		
Chromates			Ag_2SO_4	white	1.20×10^{-5}
$CaCrO_4$	yellow	7.1×10^{-4}	$BaSO_4$	white	1.08×10^{-10}
$PbCrO_4$	yellow	2.8×10^{-13}	$PbSO_4$	white	2.53×10^{-8}
Fluorides			**Sulfides**		
BaF_2	white	1.84×10^{-7}	Ag_2S	black	6.3×10^{-50}
PbF_2	white	3.3×10^{-8}	CdS	yellow	8.0×10^{-27}
Hydroxides			PbS	black	8.0×10^{-28}
$Ca(OH)_2$	white	5.02×10^{-6}	ZnS	white	1.6×10^{-24}
$Cu(OH)_2$	pale blue	1×10^{-14}			
$Mn(OH)_2$	light pink	1.9×10^{-13}			
$Cr(OH)_3$	gray-green	6.3×10^{-31}			
$Fe(OH)_3$	rust red	2.79×10^{-39}			

20 Amino Acids In Human Protein:

Table of DNA Base Triplets, RNA Codons and Anticodons

Amino Acid	**DNA Base Triplets**	**M-RNA Codons**	**T-RNA Anticodons**
alanine	CGA, CGG, CGT, CGC	GCU, GCC, GCA, GCG	CGA, CGG, CGU, CGC
arginine	GCA, GCG, GCT, GCC TCT, TCC	CGU, CGC, CGA, CGG AGA, AGG	GCA, GCG, GCU, GCC UCU, UCC
asparagine	TTA, TTG	AAU, AAC	UUA, UUG
aspartate	CTA, CTG	GAU, GAC	CUA, CUG
cysteine	ACA, ACG	UGU, UGC	ACA, ACG
glutamate	CTT, CTC	GAA, GAG	CUU, CUC
glutamine	GTT, GTC	CAA, CAG	GUU, GUC
glycine	CCA, CCG, CCT, CCC	GGU, GGC, GGA, GGG	CCA, CCG, CCU, CCC
histidine	GTA, GTG	CAU, CAC	GUA, GUG
isoleucine	TAA, TAG, TAT	AUU, AUC, AUA	UAA, UAG, UAU
leucine	AAT, AAC, GAA, GAG GAT, GAC	UUA, UUG, CUU, CUC CUA, CUG	AAU, AAC, GAA, GAG GAU, GAC
lysine	TTT, TTC	AAA, AAG	UUU, UUC
methionine	TAC	AUG	UAC
phenylalanine	AAA, AAG	UUU, UUC	AAA, AAG
proline	GGA, GGG, GGT, GGC	CCU, CCC, CCA, CCG	GGA, GGG, GGU, GGC
serine	AGA, AGG, AGT, AGC TCA, TCG	UCU, UCC, UCA, UCG AGU, AGC	AGA, AGG, AGU, AGC UCA, UCG
Stop	ATG, ATT, ACT	UAA, UAG, UGA	AUG, AUU, ACU
threonine	TGA, TGG, TGT, TGC	ACU, ACC, ACA, ACG	UGA, UGG, UGU, UGC
tryptophan	ACC	UGG	ACC
tyrosine	ATA, ATG	UAU, UAC	AUA, AUG
valine	CAA, CAG, CAT, CAC	GUU, GUC, GUA, GUG	CAA, CAG, CAU, CAC

Element	Symbol	Relative atomic mass	Density (g / cm^3)	Date of Discovery
Actinium	Ac	227	10·1	1899
Aluminium	Al	27	2·70	1825
Americium	Am	243	13·7	1944
Antimony	Sb	122	6·68	Ancient
Argon	Ar	40	0·0018	1894
Arsenic	As	75	5·78	~1250
Astatine	At	210	unknown	1940
Barium	Ba	137·5	3·62	1808
Berkelium	Bk	247	14·8	1949
Beryllium	Be	9	1·85	1798
Bismuth	Bi	209	9·79	1753
Boron	B	11	2·47	1808
Bromine	Br	80	3·12	1826
Cadmium	Cd	112·5	8·69	1817
Calcium	Ca	40	1·54	1808
Californium	Cf	251	unknown	1950
Carbon	C	12	*	Prehistoric
Cerium	Ce	140	6·77	1803
Caesium	Cs	133	1·93	1860
Chlorine	Cl	35·5	0·0032	1774
Chromium	Cr	52	7·15	1797
Cobalt	Co	59	8·86	1739
Copper	Cu	63·5	8·96	Ancient
Curium	Cm	247	13·3	1944
Dysprosium	Dy	162·5	8·55	1886
Einsteinium	Es	252	unknown	1952
Erbium	Er	167·5	9·07	1843
Europium	Eu	152	5·24	1896
Fluorine	F	19	0·0017	1886
Francium	Fr	223	unknown	1939
Gadolinium	Gd	157	7·90	1880
Gallium	Ga	69·5	5·91	1875
Germanium	Ge	72·5	5·32	1886
Gold	Au	197	19·3	Ancient
Hafnium	Hf	178·5	13·3	1923
Helium	He	4	0·0002	1868
Holmium	Ho	165	8·80	1879
Hydrogen	H	1	0·00009	1766
Indium	In	115	7·31	1863
Iodine	I	127	4·95	1811
Iridium	Ir	192	22·5	1803
Iron	Fe	56	7·87	Ancient
Krypton	Kr	84	0·0037	1898
Lanthanum	La	139	6·15	1839
Lead	Pb	207	11·3	Ancient
Lithium	Li	7	0·53	1817

Lutetium	Lu	175	9·84	1907
Magnesium	Mg	24·5	1·74	1808
Manganese	Mn	55	7·47	1774
Mercury	Hg	200·5	13·5	Ancient
Molybdenum	Mo	96	10·2	1778
Neodymium	Nd	144	7·01	1885
Neon	Ne	20	0·0009	1898
Neptunium	Np	237	20·2	1940
Nickel	Ni	58·5	8·90	1751
Niobium	Nb	93	8·57	1801
Nitrogen	N	14	0.0013	1772
Osmium	Os	190	22·6	1803
Oxygen	O	16	0·0014	1774
Palladium	Pd	106·5	12·0	1803
Phosphorus	P	31	1·82	1669
Platinum	Pt	195	21·5	1735
Plutonium	Pu	244	19·7	1941
Polonium	Po	209	9·20	1898
Potassium	K	39	0·89	1807
Praseodymium	Pr	141	6·77	1885
Promethium	Pm	145	7·26	1944
Protactinium	Pa	231	15·4	1913
Radium	Ra	226	5·00	1898
Radon	Rn	222	0·0097	1900
Rhenium	Re	186	20·8	1925
Rhodium	Rh	103	12·4	1803
Rubidium	Rb	85·5	1·53	1861
Ruthenium	Ru	101	12·1	1844
Samarium	Sm	150·5	7·52	1853
Scandium	Sc	45	2·99	1879
Selenium	Se	79	4·81	1817
Silicon	Si	28	2·33	1824
Silver	Ag	108	10·5	Ancient
Sodium	Na	23	0·97	1807
Strontium	Sr	87·5	2·64	1790
Sulfur	S	32	2·09	Ancient
Tantalum	Ta	181	16·4	1802
Technetium	Tc	98	11	1937
Tellurium	Te	127·5	6·25	1782
Terbium	Tb	159	8·23	1843
Thallium	Tl	204·5	11·8	1861
Thorium	Th	232	11·7	1828
Thulium	Tm	169	9·32	1879
Tin	Sn	118·5	7·26	Ancient
Titanium	Ti	48	4·51	1791
Tungsten	W	184	19·3	1783
Uranium	U	238	19·1	1789
Vanadium	V	51	6·00	1801

Xenon	Xe	131·5	0·0059	1898
Ytterbium	Yb	173	6·90	1878
Yttrium	Y	89	4·47	1789
Zinc	Zn	65·5	7·14	Ancient
Zirconium	Zr	91	6·52	1789

- **Solubilities of Selected Compounds in Water**

vs	means very soluble	(a solubility greater than 10 gl^{-1})
s	means soluble	(a solubility of between 1 and 10 gl^{-1})
i —	means insoluble no data	(a solubility of less than 1 gl^{-1})

	bromide	carbonate	chloride	iodide	nitrate	phosphate	sulfate	oxide	hydroxide
aluminium	vs	—	vs	vs	vs	i	vs	i	i
ammonium	vs	vs	vs	vs	vs	vs	vs	—	—
barium	vs	i	vs	vs	vs	i	i	vs	vs
calcium	vs	i	vs	vs	vs	i	s	s	s
copper(II)	vs	i	vs	—	vs	i	vs	i	i
iron(II)	vs	i	vs	vs	vs	i	vs	i	i
iron(III)	vs	—	vs	—	vs	i	vs	i	i
lead(II)	s	i	s	i	vs	i	i	i	i
lithium	vs	vs	vs	vs	vs	i	vs	vs	vs
magnesium	vs	i	vs	vs	vs	i	vs	i	i
nickel	vs	i	vs	vs	vs	i	vs	i	i
potassium	vs	vs	vs	vs	vs	vs	vs	vs	vs
silver	i	i	i	i	vs	i	s	i	—
sodium	vs	vs	vs	vs	vs	vs	vs	vs	vs
tin(II)	vs	i	vs	s	—	i	vs	i	i
zinc	vs	i	vs	vs	vs	i	vs	i	i

Bond	Bond length (pm)	Bond energy (kJ/mol)
H–H	74	436
C–C	154	348
N–N	145	170
O–O	148	145
F–F	142	158
Cl–Cl	199	243
Br–Br	228	193
I–I	267	151
C–C	154	348
C–N	147	308
C–O	143	360
C–S	182	272
C–F	135	488
C–Cl	177	330
C–Br	194	288
C–I	214	216
H–C	109	413
H–N	101	391
H–O	96	366
H–F	92	568
H–Cl	127	432
H–Br	141	366
H–I	161	298
C–C	154	348
C=C	134	614
C≡C	120	839
O–O	148	145
O=O	121	498
N–N	145	170
N≡N	110	945

We cannot taste anything without saliva.

- Blue is the color of liquid oxygen.
- Every hydrogen atom in our body is likely 13.5 billion years old because they were created at the birth of the universe.

Gallium has a melting point of 29.76 degrees centigrade and can melt on the palm of our hand.

If we pour a handful of salt into a glass of water, the water level will go down

When we freeze seawater or saltwater, we get freshwater ice.

More than 78% of human brain consists of water.

The rarest naturally-occurring element in the Earth's crust is astatine

- **Spectrochemical series**

Ligands can be arranged in a spectrochemical series according to the energy difference they produce between the two sets of d-orbitals in an octahedral complex.

$$I^{-} < Br^{-} < S^{2-} < Cl^{-} < F^{-} < OH^{-} < H_2O < SCN^{-} < NH_3 < CN^{-} \approx CO$$

- **Values of the ionization constant of water**

Temperature (^oC)	**K_w value**
0	0.113×10^{-14}
5	0.185×10^{-14}
10	0.292×10^{-14}
15	0.453×10^{-14}
20	0.684×10^{-14}
25	1.00×10^{-14}
30	1.47×10^{-14}
35	2.09×10^{-14}
40	2.92×10^{-14}
45	4.02×10^{-14}
50	5.43×10^{-14}
55	7.24×10^{-14}
60	9.55×10^{-14}
65	12.4×10^{-14}
70	15.9×10^{-14}
75	20.1×10^{-14}
80	25.2×10^{-14}
85	31.3×10^{-14}
90	38.3×10^{-14}
95	46.6×10^{-14}
100	56.0×10^{-14}

- **Specific Gravity of Liquids**

Liquid	Temperature	kg/m^3
1,1,2-Trichlorotrifluoroethane	25 °C	1564.00
1,2,4-Trichlorobenzene	20 °C	1454.00
1,4-Dioxane	20 °C	1033.60
2-Methoxyethanol	20 °C	964.60
Acetic Acid	25 °C	1049.10
Acetone	25 °C	784.58
Acetonitrile	20 °C	782.20
Alcohol, ethyl	25 °C	785.06
Alcohol, methyl	25 °C	786.51
Alcohol, propyl	25 °C	799.96
Ammonia (aqua)	25 °C	823.35
Analine	25 °C	1018.93
Automobile oils	15 °C	880 - 940
Beer (varies)	10 °C	1010
Benzene	25 °C	873.81
Benzil	25 °C	1079.64
Brine	15 °C	1230
Bromine	25 °C	3120.40
Butyric Acid	20 °C	959
Butane	25 °C	599.09
n-Butyl Acetate	20 °C	879.60
n-Butyl Alcohol	20 °C	809.70
n-Butyl Chloride	20 °C	886.20
Caproic acid	25 °C	921.06
Carbolic acid	15 °C	956.30
Carbon disulfide	25 °C	1260.97
Carbon tetrachloride	25 °C	1584.39
Carene	25 °C	856.99
Castor oil	25 °C	956.14
Chloride	25 °C	1559.88
Chlorobenzene	20 °C	1105.80
Chloroform	20 °C	1489.20
Chloroform	25 °C	1464.73
Citric acid	25 °C	1659.51
Coconut oil	15 °C	924.27
Cotton seed oil	15 °C	925.87
Cresol	25 °C	1023.58
Creosote	15 °C	1066.83

Crude oil, 48° API	60 °F	790
Crude oil, 40° API	60 °F	825
Crude oil, 35.6° API	60 °F	847
Crude oil, 32.6° API	60 °F	862
Crude oil, California	60 °F	915
Crude oil, Mexican	60 °F	973
Crude oil, Texas	60 °F	873
Cumene	25 °C	860.19
Cyclohexane	20 °C	778.50
Cyclopentane	20 °C	745.40
Decane	25 °C	726.28
Diesel fuel oil 20 to 60	15 °C	820 - 950
Diethyl ether	20 °C	714
o-Dichlorobenzene	20 °C	1305.80
Dichloromethane	20 °C	1326.00
Diethylene glycol	15 °C	1120
Dichloromethane	20 °C	1326.00
Dimethyl Acetamide	20 °C	941.50
N,*N*-Dimethylformamide	20 °C	948.70
Dimethyl Sulfoxide	20 °C	1100.40
Dodecane	25 °C	754.63
Ethane	-89 °C	570.26
Ether	25 °C	72.72
Ethylamine	16 °C	680.78
Ethyl Acetate	20 °C	900.60
Ethyl Alcohol	20 °C	789.20
Ethyl Ether	20 °C	713.30
Ethylene Dichloride	20 °C	1253.00
Ethylene glycol	25 °C	1096.78
Fluorine refrigerant R-12	25 °C	1310.95
Formaldehyde	45 °C	812.14
Formic acid 10% concentration	20 °C	1025
Formic acid 80% concentration	20 °C	1221
Freon - 11	21 °C	1490
Freon - 21	21 °C	1370
Fuel oil	60 °F	890.13
Furan	25 °C	1416.03
Furforol	25 °C	1154.93
Gasoline, natural	60 °F	711.22
Gasoline, Vehicle	60 °F	737.22

Gas oils	60 °F	890
Glucose	60 °F	1350 - 1440
Glycerin	25 °C	1259.37
Glyme	20 °C	869.10
Glycerol	25 °C	1126.10
Heptane	25 °C	679.50
Hexane	25 °C	654.83
Hexanol	25 °C	810.53
Hexene	25 °C	671.17
Hydrazine	25 °C	794.52
Iodine	25 °C	4927.28
Ionene	25 °C	932.27
Isobutyl Alcohol	20 °C	801.60
Iso-Octane	20 °C	691.90
Isopropyl Alcohol	20 °C	785.40
Isopropyl Myristate	20 °C	853.20
Kerosene	60 °F	817.15
Linolenic Acid	25 °C	898.64
Linseed oil	25 °C	929.07
Methane	-164 °C	464.54
Methanol	20 °C	791.30
Methyl Isoamyl Ketone	20 °C	888.00
Methyl Isobutyl Ketone	20 °C	800.80
Methyl *n*-Propyl Ketone	20 °C	808.20
Methyl *t*-Butyl Ether	20 °C	740.50
N-Methylpyrrolidone	20 °C	1030.40
Methyl Ethyl Ketone (MEK)	20 °C	804.90
MEK	25 °C	802.52
Milk	15 °C	1020 - 1050
Naphtha	15 °C	664.77
Naphtha, wood	25 °C	959.51
Napthalene	25 °C	820.15
Ocimene	25 °C	797.72
Octane	15 °C	917.86
Olive oil	20 °C	800 - 920
Oxygen (liquid)	-183 °C	1140
Palmitic Acid	25 °C	850.58
Pentane	20 °C	626.20
Pentane	25 °C	624.82
Petroleum Ether	20 °C	640.00

Petrol, natural	60 ºF	711.22
Petrol, Vehicle	60 ºF	737.22
Phenol	25 ºC	1072.28
Phosgene	0 ºC	1377.59
Phytadiene	25 ºC	823.35
Pinene	25 ºC	856.99
Propane	-40 ºC	583.07
Propane, R-290	25 ºC	493.53
Propanol	25 ºC	804.13
Propylene Carbonate	20 ºC	1200.60
Propylene	25 ºC	514.35
n-Propyl Alcohol	20 ºC	803.70
Propylene glycol	25 ºC	965.27
Pyridine	25 ºC	978.73
Pyrrole	25 ºC	965.91
Rape seed oil	20 ºC	920
Resorcinol	25 ºC	1268.66
Rosin oil	15 ºC	980
Sabiname	25 ºC	812.14
Sea water	25 ºC	1025.18
Silane	25 ºC	717.63
Sodium Hydroxide (caustic soda)	15 ºC	1250
Sorbaldehyde	25 ºC	895.43
Soya bean oil	15 ºC	924 - 928
Stearic Acid	25 ºC	890.63
Sulphuric Acid 95% conc.	20 ºC	1839
Sugar solution 68 brix	15 ºC	1338
Sunflower oil	20 ºC	920
Styrene	25 ºC	903.44
Terpinene	25 ºC	847.38
Tetrahydrofuran	20 ºC	888.00
Toluene	20 ºC	866.90
Toluene	25 ºC	862.27
Triethylamine	20 ºC	727.60
Trifluoroacetic Acid	20 ºC	1489.00
Turpentine	25 ºC	868.20
Water, pure	4 ºC	1000.00
Water, sea	77 ºF	1021.98
Whale oil	15 ºC	925
o-Xylene	20 ºC	880.20

Bromine and mercury are the only elements that can stay liquid at room temperature.

- DNA is a flame retardant
- There is about 250 g of table salt (**NaCl**) in an average adult human body.

Air becomes liquid at −190°C

Frogs don't drink water because they can absorb it through their skin

Helium and Hydrogen account for 98% of all matter.

The chemical elements are organized in order of their increasing atomic numbers.

Mars is red because of iron oxide

Molecular formula	Compound name
Ac_2O_3	Actinium(III) oxide
$AgBF_4$	Silver tetrafluoroborate
$AgBr$	silver bromide
$AgBrO$	silver hypobromite
$AgBrO_2$	silver bromite
$AgBrO_3$	silver bromate
$AgBrO_4$	silver perbromate
$AgCl$	silver chloride
$AgCl_3Cu_2$	dicopper silver trichloride
$AgClO_3$	silver chlorate
$AgClO_4$	silver perchlorate
$AgCN$	silver cyanide
$AgCNO$	silver fulminate
AgF	silver fluoride
AgF_2	silver(II) fluoride
AgI	silver iodide
$AgIO$	silver hypoiodite
$AgIO_2$	silver iodite
$AgIO_3$	silver iodate
$AgIO_4$	silver periodate
$AgMnO_4$	silver permanganate
AgN_3	silver azide
$AgNO_3$	silver nitrate
AgO	silver monoxide
$AgONC$	silver cyanate
$AgPF_6$	silver hexafluorophosphate
$AgSNC$	silver thiocyanate
Ag_2C_2	silver acetylide
Ag_2CO_3	silver(I) carbonate
$Ag_2C_2O_4$	silver oxalate
Ag_2Cl_2	silver(II) dichloride
Ag_2CrO_4	silver chromate
$Ag_2Cr_2O_7$	silver dichromate
Ag_2F	silver subfluoride
Ag_2MoO_4	silver molybdate
Ag_2O	silver(I) oxide
Ag_2S	silver sulfide
Ag_2SO_4	silver sulfate
Ag_2Se	silver selenide

Ag_2SeO_3	silver selenite
Ag_2SeO_4	silver selenate
Ag_2Te	silver(I) telluride
Ag_3Br_2	silver dibromide
Ag_3Br_3	silver tribromide
Ag_3Cl_3	silver(III) trichloride
Ag_3I_3	silver(III) triiodide
Ag_3PO_4	silver phosphate
AlBO	aluminium boron oxide
$AlBO_3$	aluminium borate
AlBr	aluminium monobromide
$AlBr_3$	aluminium tribromide
AlCl	aluminium monochloride
AlClF	aluminium chloride fluoride
$AlCl_{2<F}$	aluminium chloride fluoride
AlClO	aluminium chloride oxide
$AlCl_2H$	Dichloroalumane
$AlCl_3$	aluminium chloride
$AlCl_2F$	aluminium chloride fluoride
$AlCl_3$	aluminium trichloride
$AlCl_4Cs$	aluminium caesium tetrachloride
$AlCl_4K$	potassium tetrachloroaluminate
$AlCl_4Na$	sodium tetrachloroaluminate
$AlCl_4Rb$	aluminium rubidium tetrachloride
$AlCl_6K_3$	potassium hexachloroaluminate
$AlCl_6Na_3$	sodium hexachloroaluminate
AlF	aluminium monofluoride
AlFO	aluminium monofluoride monoxide
AlF_2	aluminium difluoride
AlF_2O	aluminium difluoride oxide
AlF_3	aluminium trifluoride
AlF_4K	potassium tetrafluoroaluminate
AlF_4Li	lithium tetrafluoroaluminate
AlF_6K_3	potassium hexafluoraluminate
AlF_6Li_3	lithium hexafluoroaluminate
AlF_6Na_3	cryolite
AlGaInP	aluminium-gallium-indium phosphide
$Al(OH)_3$	aluminium hydroxide
AlI	aluminium monoiodide
AlI_3	aluminium triiodide

$AlLiO_2$	lithium aluminate
AlN	aluminium nitride
$Al(NO_2)_3$	aluminium nitrite
$Al(NO_3)_3$	aluminium nitrate
$AlNaO_2$	sodium aluminate
AlO	aluminium monoxide
$AlOSi$	aluminium silicon monoxide
AlO_2	Aluminium(IV) oxide
AlP	aluminium monophosphide
$AlPO_4$	aluminium phosphate
$AlTe$	aluminium monotelluride
$AlTe_2$	monoaluminium ditelluride
Al_2BeO_4	beryllium aluminium oxide
Al_2Br_6	dialuminium hexabromide
$Al_2(CO_3)_3$	aluminium carbonate
$Al_2Cl_9K_3$	potassium aluminium chloride
Al_2CoO_4	cobalt blue
Al_2F_6	aluminium fluoride
Al_2I_6	aluminium iodide
Al_2MgO_4	magnesium aluminium oxide
Al_2O	dialuminium monoxide
Al_2O_2	dialuminium dioxide
Al_2O_3	aluminium oxide
Al_2O_5Si	aluminium silicate
Al_2O_5Si	aluminium silicate
Al_2O_5Si	andalusite
$Al_2O_7Si_2$	aluminium silicate
Al_2S	dialuminium monosulfide
Al_2S_3	aluminium sulfide
$Al_2(SO_4)_3$	aluminium sulphate
Al_2Se	dialuminium selenide
$Al_2Si_2O_5(OH)_4$	kaolin
Al_2Te	dialuminium telluride
$Al_3F_{14}Na_5$	chiolite
Al_4C_3	aluminium carbide
Al_6BeO_{10}	beryllium aluminium oxide
$Al_6O_{13}Si_2$	mullite
$ArClF$	argon chloride fluoride
$ArClH$	argon chloride hydride
$ArFH$	argon fluoride hydride

AsBrO	arsenic oxybromide
$AsBr_3$	arsenic tribromide
AsClO	arsenic monoxide monochloride
$AsCl_3$	arsenic trichloride
$AsCl_3O$	arsenic oxychloride
$AsCl_4F$	arsenic tetrachloride fluoride
AsF_3	arsenic trifluoride
AsF_5	arsenic pentafluoride
AsH_3	arsine
AsI_3	arsenic triiodide
AsO	arsenic monoxide
AsO_2	arsenic dioxide
AsP	arsenic monophosphide
AsP_3	arsenic triphosphide
AsTl	thallium arsenide
As_2I_4	arsenic diiodide
As_2O_3	arsenic trioxide
As_2P_2	arsenic diphosphide
As_2O_5	arsenic pentoxide
As_2S_4	arsenic tetrasulfide
As_2S_5	arsenic pentasulfide
As_2Se	arsenic hemiselenide
As_2Se_3	arsenic triselenide
As_2Se_5	arsenic pentaselenide
As_3O_4	arsenic tetraoxide
As_3P	arsenic(III) phosphide
As_4O_3	tetraarsenic trioxide
As_4O_5	tetraarsenic pentaoxide
As_4S_3	tetraarsenic trisulfide
As_4S_4	tetraarsenic tetrasulfide
AuBO	gold monoboride monoxide
AuBr	gold bromide
$AuBr_3$	gold tribromide
AuCN	gold cyanide
AuCl	gold chloride
$AuCl_3$	gold trichloride
AuF_3	gold trifluoride
AuI	gold iodide
AuI_3	gold(III) iodide
$Au(OH)_3$	gold hydroxide

AuTe	gold telluride
Au_2O_3	gold trioxide
Au_2S	gold sulfide
Au_2S_3	gold trisulfide
$Au_2(SeO_4)_3$	gold triselenate
Au_2Se_3	gold triselenide
BAs	boron arsenide
$BAsO_4$	boron(III) arsenate
BBr_3	boron tribromide
BCl_3	boron trichloride
BF_3	boron trifluoride
BI_3	boron iodide
BN	boron nitride
$c(NO_2)_3$	boron nitrite
$B(NO_3)_3$	boron nitrate
$B(OH)_3$	boric acid
BP	boron(III) phosphide
BPO_4	boron(III) orthophosphate
B_2Cl_4	boron chloride
B_2F_4	Diboron tetrafluoride
B_2H_6	boron hydride
B_2O_3	boron(III) oxide
B_2S_3	boron sulfide
B_2Se_3	boron selenide
$B_3N_3H_6$	borazine
B_4C	boron carbide
$Ba(AlO_2)_2$	barium aluminate
$Ba(AsO_3)_2$	barium arsenite
$Ba(AsO_4)_2$	barium arsenate
BaB_6	barium hexaboride
$Ba(BrO_3)_2 \cdot H_2O$	barium bromate monohydrate
$Ba(BrO_3)_2 \cdot 2H_2O$	barium bromate dihydrate
$BaBr_2$	barium bromide
$Ba(BrO)_2$	barium hypobromite
$Ba(BrO_2)_2$	barium bromite
$Ba(BrO_3)_2$	barium bromate
$Ba(BrO_4)_2$	barium perbromate
$Ba(CHO_2)_2$	barium formate
$Ba(C_2H_3O_2)_2$	barium acetate
$Ba(CN)_2$	barium cyanide

$BaHfO_3$	barium hafnate
$BaHgI_4$	barium tetraiodomercurate(II)
$Ba(HS)_2$	barium hydrosulfide
BaI_2	barium iodide
$Ba(IO)_2$	barium hypoiodite
$Ba(IO_2)_2$	barium iodite
$Ba(IO_3)_2$	barium iodate
$Ba(IO_4)_2$	barium periodate
$BaK_2(CrO_4)_2$	barium potassium chromate
$BaMnO_4$	barium manganate
$Ba(MnO_4)_2$	barium permanganate
$BaMoO_4$	barium molybdate
BaN_6	barium azide
$Ba(NO_2)_2$	barium nitrite
$Ba(NO_3)_2$	barium nitrate
$Ba(NbO_3)_2$	barium niobate
$BaNb_2O_6$	barium metaniobate
BaO	barium oxide
$Ba(OH)_2$	barium hydroxide baryta
BaO_2	barium peroxide
$Ba(PO_3)_2$	barium metaphosphate
BaS	barium sulfide
$Ba(SCN)_2$	barium thiocyanate
BaS_2O_3	barium thiosulfate
$BaSiF_6$	barium hexafluorosilicate
$BaSO_3$	barium sulfite
$BaSO_4$	barium sulfate barite
$BaSe$	barium selenide
$Ba(SeCN)_2$	barium selenocyanate
$BaSeO_3$	barium selenite
$BaSeO_4$	barium selenate
$BaSiO_3$	barium metasilicate
$BaSi_2$	barium silicide
$BaSi_2O_5$	barium disilicate
$BaSnO_3$	barium stannate
$BaTeO_3$	barium tellurite
$BaTeO_4 \cdot 3H_2O$	barium tellurate trihydrate
$BaTiO_3$	barium titanate barium metatitanate

BaU_2O_7	barium uranium oxide
$BaWO_4$	barium tungstate
$BaZrO_3$	barium zirconate
$Ba_2Na(NbO_3)_5$	barium sodium niobate
$Ba_2P_2O_7$	barium pyrophosphate
$Ba_2V_2O_7$	barium pyrovanadate
Ba_2XeO_6	barium perxenate
$Ba_3(CrO_4)_2$	barium chromate(V)
Ba_3N_2	barium nitride
$Ba_3(PO_4)_2$	barium orthophosphate
$Ba_3(VO_4)_2$	barium orthovandate
BeB_2	beryllium boride
$Be(BH_4)_2$	beryllium borohydride
$BeBr_2$	beryllium bromide
$Be(CHO_2)_2$	beryllium formate
$BeCO_3$	beryllium carbonate
$Be(C_2H_3O_2)_2$	beryllium acetate
$Be(C_5H_7O_2)_2$	beryllium acetylacetonate
$BeCl_2$	beryllium chloride
$Be(ClO)_2$	beryllium hypochlorite
$Be(ClO_3)_2$	beryllium chlorate
$Be(ClO_4)_2$	beryllium perchlorate
BeF_2	beryllium fluoride
BeI_2	beryllium iodide
$Be(NO_2)_2$	beryllium nitrite
$Be(NO_3)_2$	beryllium nitrate
BeO	beryllium oxide bromellite
$Be(OH)_2$	beryllium hydroxide
BeS	beryllium sulfide
$BeSO_3$	beryllium sulfite
$BeSO_4$	beryllium sulfate
Be_2C	beryllium carbide
$Be_3Al_2(SiO_3)_6$	beryl
Be_3N_2	beryllium nitride
$BiBO_3$	bismuth(III) orthoborate
$BiBr_3$	bismuth(III) bromide
$Bi(C_2H_3O_2)_3$	bismuth(III) acetate
$BiC_6H_5O_7$	bismuth(III) citrate
$BiCl_3$	bismuth(III) chloride
BiF_3	bismuth(III) fluoride

BiI_3	bismuth(III) iodide
$Bi(NO_3)_3 \cdot 5H_2O$	bismuth(III) nitrate pentahydrate
BiOCl	bismuth(III) oxychloride
BiOI	bismuth(III) oxyiodide
$(BiO)_2CO_3$	bismuth oxycarbonate
$BiPO_4$	bismuth(III) orthophosphate
$Bi(VO_3)_5$	bismuth(III) metavanadate
Bi_2Se_3	bismuth(III) selenide bismuth selenide
$Bi_2(MoO_4)_3$	bismuth(III) molybdate
Bi_2O_3	bismuth(III) oxide
Bi_2S_3	bismuth(III) sulfide bismuthinite
Bi_2Se_3	bismuth(III) selenide
BrCl	bromine chloride
$BrCl_3$	bromine trichloride
$BrCl_5$	bromine pentachloride
BrF	bromine monofluoride bromine fluoride
BrF_3	bromine trifluoride
BrF_5	bromine pentafluoride
BrO_3^-	bromate ion
Br_2	bromine
Br_2O_5	dibromine pentoxide
CCl_2F_2	dichlorodifluoromethane freon-12
CCl_4	carbon tetrachloride tetrachloromethane
$C(CN)_4$	tetracyanomethane
$CFCl_3$	freon-11
$CFCl_2CF_2Cl$	freon-13
$CHCl_3$	chloroform trichloromethane methyl trichloride
$CHClF_2$	chlorodifluoromethane
$CH(CN)_3$	cyanoform
CHO_2^-	formate ion
$CH_2CHCHCH_2$	1,3-butadiene
CH_2CO	ketene
CH_2CHOH	ethenol
$CH_2ClCOOH$	chloroacetic acid

CH_2Cl_2	dichloromethane
CH_2ClF	chlorofluoromethane
$CH_2(CN)_2$	malononitrile
CH_2O	formaldehyde
$CH_2(OH)_2$	methanediol
CH_2OHCH_2OH	ethylene glycol
CH_3CCH	propyne
CH_3CdCH_3	dimethylcadmium
$CH_3CHCHCH_3$	2-butene
CH_3CHCH_2	propene
CH_3CHO	acetaldehyde
CH_3CH_2Br	bromoethane
$CH_3CH_2CH_2CH_2OH$	butan-1-ol
$CH_3CH_2CH_2OH$	1-propanol propan-1-ol
$CH_3CH_2CONH_2$	propanamide
CH_3CH_2COOH	propionic acid
$CH_3CH_2OCH_2CH_3$	diethyl ether ethoxyethane
CH_3CH_2OH	ethanol
$CH_3(CH_2)_{16}COOH$	stearic acid
CH_3CN	acetonitrile
CH_3COCH_3	acetone
CH_3COOCH_3	methyl acetate
CH_3COCl	acetyl chloride
CH_3CONH_2	acetamide ethanamide
CH_3COO^-	acetate ion
$CH_3COOCHCH_2$	vinyl acetate
$CH_3COOCH_2C_6H_5$	benzyl acetate
$CH_3COO(CH_2)_2CH(CH_3)_2$	isoamyl acetate
CH_3COOH	acetic acid ethanoic acid
CH_3COONa	sodium acetate
CH_3COOK	potassium acetate
CH_3COORb	rubidium acetate
CH_3COOCs	caesium acetate
$(CH_3CO)_2O$	acetic anhydride
CH_3Cl	chloromethane methyl chloride
CH_3HgCH_3	dimethylmercury

CH_3I	iodomethane methyl iodide
CH_3OCH_3	dimethyl ether
CH_3NH_2	methylamine
CH_3NO	oxaziridine
CH_3OCs	caesium methoxide
CH_3OH	methanol
CH_3OK	potassium methoxide
CH_3OLi	lithium methoxide
CH_3ONa	sodium methoxide
CH_3ORb	rubidium methoxide
CH_3SCH_3	dimethyl sulfide DMS
CH_3SH	methanethiol
$(CH_3)_2CHOH$	isopropyl alcohol 2-propanol propan-2-ol isopropanol
$(CH_3)_2CO$	acetone
$(CH_3)_2C_2O_4$	dimethyl oxalate
$(CH_3)_2NNH_2$	dimethyl hydrazine
$(CH_3)_2NH$	dimethylamine
$(CH_3)_2S^+CH_2CH_2COO^-$	dimethylsulfoniopropionate DMSP
$(CH_3)_3CCl$	*t*-butyl chloride
$(CH)_3COH$	*t*-butyl alcohol
$(CH_3)_3COOC(CH_3)_3$	di-*t*-butyl peroxide DTBP
$(CH_3)_3N$	trimethylamine
CH_4	methane natural gas
$CH_4N_2O_2$	hydroxycarbamide
CH_5N_3	Guanidine
CN^-	cyanide ion
$(CN)_2$	cyanogen
$C(NH_2)_3NO_3$	guanidine nitrate
CNO^-	cyanate ion
CO	carbon monoxide
$COCl_2$	phosgene
CO_2	carbon dioxide
CO_3	carbon trioxide

CO_3^{2-}	carbonate ion
CS_2	carbon disulfide
C_2F_4	tetrafluoroethylene
C_2H_2	acetylene
$C_2H_2O_2$	glyoxal
C_2H_3Cl	vinyl chloride
C_2H_3NO	glycolonitrile
$C_2H_3O_2^-$	acetate ion
C_2H_4	ethylene
$C_2H_4Cl_2$	ethylene dichloride
$C_2H_4N_4$	3-amino-1,2,4-triazole
C_2H_4O	ethylene oxide
$C_2H_4O_2$	acetic acid
C_2H_5Br	bromoethane
$C_2H_5NH_2$	ethylamine
$C_2H_5NO_2$	glycine Gly
$C_2H_5O^-$	ethoxide ion
C_2H_5OH	ethanol ethyl alcohol
$(C_2H_5)_2NH$	diethylamine
C_2H_5OCs	caesium ethoxide
C_2H_5OK	potassium ethoxide
C_2H_5ONa	sodium ethoxide
C_2H_5ORb	rubidium ethoxide
C_2H_6	ethane
C_2H_6OS	dimethyl sulfoxide DMSO
C_2H_7NO	ethanolamine
$C_2H_7NO_2$	ammonium acetate
$C_2H_7NO_3S$	taurine
$C_2O_4^{2-}$	oxalate ion
$C_3H_3O_4^-$	malonate ion
C_3HN	cyanopolyyne
C_3H_3N	azete
$C_3H_4N_2$	imidazole
$C_3H_4N_2S$	aminothiazole
$C_3H_4O_3$	pyruvic acid
$C_3H_4O_4$	malonic acid
C_3H_5NO	acrylamide
$C_3H_5N_3$	3-amino-1H-pyrazole

$C_3H_5N_3O_9$	nitroglycerine
C_3H_6	cyclopropane
	propylene
$C_3H_6O_2$	ethyl formate
$C_3H_6O_2S$	2-Mercaptopropionic acid
$C_3H_6O_2S$	3-Mercaptopropionic acid
C_3H_7N	azetidine
$C_3H_7NO_2$	α-alanine
	β-alanine
$C_3H_7NO_2S$	cysteine Cys
$C_3H_7NO_3$	serine Ser
C_3H_8	propane
$C_3H_8NO_5P$	glyphosate
C_3H_8O	propanol 1-propanol
	2-propanol
$C_3H_8O_2$	propylene glycol
$C_3H_8O_2$	1,3-propanediol
$C_3H_8O_3$	glycerol
$C_3H_9N_3$	1,3,5-triazinane
$C_3N_3(OH)_3$	cyanuric acid
C_3N_{12}	cyanuric triazide
$C_4HCl_2FN_2$	2,6-dichloro-5-fluoroacil
C_4H_2	diacetylene
C_4I_2	diiodobutadiyne
$C_4H_2BrClN_2$	5-bromo-2-chloropyrimidine
$C_4H_2Cl_2N_2$	2,4-dichloropyrimidine
	4,6-dichloropyrimidine
$C_4H_3Cl_2N_3$	2-amino-4,6-dichloropyrimidine
$C_4H_3FN_2O_2$	fluorouracil
C_4H_4	vinylacetylene
$C_4H_4FN_3O$	flucytosine
$C_4H_4N_2O_2$	uracil
$C_4H_4N_4$	diaminomaleonitrile
$C_4H_4N_4$	3-aminopyrazole-4-carbonitrile
$C_4H_4N_4$	1,3,5,7-tetrazocine
C_4H_4O	furan
$C_4H_5N_3O$	cytosine
$C_4H_6N_2$	fomepizole

$C_4H_6N_2$	1-methylimidazole
$C_4H_6N_2$	4-methylimidazole
$C_4H_6N_2S$	methimazole
	2-amino-4-methylthiazole
$C_4H_6N_4O$	2,4-diamino-6-hydroxypyrimidine
$C_4H_6O_2$	1,4-Butynediol
$C_4H_6O_2$	gamma-Butyrolactone
$C_4H_6O_2$	crotonic acid
$C_4H_6O_2$	diacetyl
$C_4H_6O_2$	diepoxybutane
$C_4H_6O_2$	1,4-Dioxene
$C_4H_6O_2$	isocrotonic acid
$C_4H_6O_2$	methacrylic acid
$C_4H_6O_2$	methyl acrylate
$C_4H_6O_2$	succinaldehyde
$C_4H_6O_2$	vinyl acetate
$C_4H_6O_4$	succinic acid
$C_4H_7BrO_2$	2-bromobutyric acid
	4-bromobutyric acid
	α-bromoisobutyric acid
	ethyl bromoacetate
$C_4H_7KO_3$	potassium oxybate
$C_4H_7NaO_3$	sodium oxybate
$C_4H_7NO_2$	1-Aminocyclopropanecarboxylic acid
$C_4H_7NO_3$	aceturic acid
$C_4H_7NO_4$	aspartic acid Asp
C_4H_8	cyclobutane
$C_4H_8N_2O_3$	asparagine Asn
C_4H_8O	tetrahydrofuran THF
$C_4H_8O_2$	ethyl acetate
$C_4H_8O_3$	gamma-Hydroxybutyric acid
C_4H_9Li	n-butyllithium
$C_4H_9NO_2$	γ-aminobutyric acid
$C_4H_9NO_3$	threonine Thr
C_4H_9OH	butyl alcohol
C_4H_{10}	butane
	2-methylpropane

$C_4H_{10}O$	diethyl ether
$C_4H_{10}O_2$	1,2-Butanediol
$C_4H_{10}O_2$	1,3-Butanediol
$C_4H_{10}O_2$	1,4-Butanediol
$C_4H_{10}O_2$	2,3-Butanediol
$C_4H_{10}O_2$	tert-Butyl hydroperoxide
$C_4H_{10}O_2$	Dimethoxyethane
$C_4H_{10}O_2$	2-Ethoxyethanol
$C_4H_{10}O_2$	1-Methoxy-2-propanol
$C_4H_{10}O_3$	diethylene glycol
$C_4H_{11}NO_2$	diethanolamine
$C_5H_3BrN_2O_2$	2-bromo-5-nitropyridine
$C_5H_3Br_2N$	3,5-dibromopyridine
$C_5H_3ClN_2O_2$	2-chloro-5-nitropyridine
$C_5H_3ClN_4$	6-chloropurine
C_5H_4NCOOH	niacin
$C_5H_4N_2O_2$	pyrazinoic acid
$C_5H_4N_2O_4$	orotic acid
$C_5H_4N_4O$	allopurinol
	hypoxanthine
$C_5H_4N_4O_2$	xanthine
$C_5H_4N_4S$	mercaptopurine
C_5H_4O	cyclopentadienone
$C_5H_4O_2$	furfural
$C_5H_4O_2S$	b-thiophenic acid
$C_5H_5^-$	cyclopentadienyl anion
$C_5H_5BrN_2$	2-amino-5-bromopyridine
$C_5H_5ClN_2$	2-amino-4-chloropyridine
	2-amino-5-chloropyridine
	4-amino-2-chloropyridine
$C_5H_5IN_2$	2-amino-5-iodopyridine
C_5H_5N	pyridine
C_5H_5NO	2-pyridone
	3-pyridinol
$C_5H_5N_3O$	pyrazinamide
$C_5H_5N_3O_2$	2-amino-nitropyridine
$C_5H_5N_5$	adenine
$C_5H_5N_5O$	guanine
$C_5H_6BNO_2$	3-pyridinylboronic acid
$C_5H_6N_2$	1,2-diazepine

	1,3-diazepine
	1,4-diazepine
	1-vinylimidazole
	2-aminopyridine
	3-aminopyridine
	4-aminopyridine
	glutaronitrile
$C_5H_6N_2OS$	methylthiouracil
$C_5H_6N_2O_2$	thymine
C_5H_6O	cyclopentenone
$C_5H_6O_5$	α-Ketoglutaric acid
$C_5H_7N_3$	3,4-diaminopyridine
$C_5H_8O_2$	gamma-Valerolactone
$C_5H_9NO_2$	allylglycine
$C_5H_9NO_2$	proline Pro
$C_5H_9NO_4$	glutamic acid Glu
C_5H_{10}	cyclopentane
$C_5H_{10}N_2O_3$	glutamine Gln
$C_5H_{10}O_2$	pivalic acid
$C_5H_{10}O_2$	valeric acid
$C_5H_{10}O_2$	3-Methylbutanoic acid
$C_5H_{10}O_4$	deoxyribose
$C_5H_{11}NO_2$	valine Val
$C_5H_{11}NO_2S$	methionine Met
C_5H_{12}	pentane
$C_5H_{12}O_2$	neopentyl glycol
$C_5H_{12}O_4$	pentaerythritol
$C_5H_{12}O_5$	xylitol
C_6F_5COOH	pentafluorobenzoic acid
$C_6H_3Br_3O$	2,4,6-Tribromophenol
$C_6H_3Cl_3O$	2,4,6-Trichlorophenol
$C_6H_4BrNO_2$	5-bromonicotinic acid
$C_6H_4ClNO_2$	2-chloronicotinic acid
$C_6H_4ClN_3$	6-chloro-7-dezapurine
$C_6H_4ClNO_2$	6-chloro-2-pyridinecarboxylic acid
	6-chloronicotinic acid

$C_6H_4N_4$	tricyanoaminopropene
$C_6H_4O_2$	orthobenzoquinone
	parabenzoquinone quinone
C_6H_5Br	bromobenzene
C_6H_5CHO	benzaldehyde
$C_6H_5CH_2OH$	benzyl alcohol
C_6H_5Cl	chlorobenzene
C_6H_5COCl	benzoyl chloride
$C_6H_5COO^-$	benzoate ion
C_6H_5COOH	benzoic acid
C_6H_5F	fluorobenzene
C_6H_5I	iodobenzene
$C_6H_5NO_2$	picolinic acid
$C_6H_5NO_3$	4-nitrophenol
	6-hydroxyniacin
C_6H_5OH	phenol
$C_6H_5O_7^{3-}$	citrate ion
$(C_6H_5)_4Ge$	tetraphenylgermane
$(C_6H_5)_2O$	diphenyl ether
$(C_6H_5)_3N$	triphenylamine
$(C_6H_5)_3P$	triphenylphosphine
C_6H_6	benzene
$C_6H_6BClO_2$	4-chlorophenylboronic acid
$C_6H_6BFO_2$	4-fluorophenylboronic acid
C_6H_6IN	4-iodoaniline
$C_6H_6N_2O$	nicotinamide
$C_6H_6N_2O_2$	6-aminonicotinic acid
C_6H_6O	phenol
$C_6H_6O_2$	catechol
	hydroquinone
	resorcinol
$C_6H_6O_3$	hydroxymethylfurfural
$C_6H_7BO_2$	phenylboronic acid
$C_6H_7CsO_6$	caesium ascorbate
$C_6H_7KO_6$	potassium ascorbate
$C_6H_7LiO_6$	lithium ascorbate
$C_6H_7N_3O$	isoniazid
$C_6H_7NaO_6$	sodium ascorbate
$C_6H_7RbO_6$	rubidium ascorbate
$C_6H_8N_2$	2-amino-3-methylpyridine

	2-amino-4-methylpyridine
	2-amino-5-methylpyridine
	2-amino-6-methylpyridine
$C_6H_8N_2O_2S$	ethyl 2-aminothiazole-4-carboxylate
	sulfanilamide
$C_6H_8O_7$	citric acid
$C_6H_9N_3O_2$	histidine His
	ethyl 5-amino-1H-pyrazole-4-carboxylate
$C_6H_9N_3O_3$	metronidazole
$C_6H_{10}O_3$	4-acetylbutyric acid
	butyl glyoxylate
	ethyl acetoacetate
	2-hydroxypropyl acrylate
	pantolactone
	propyl pyruvate
$C_6H_{10}O_4$	aceburic acid
$C_6H_{10}O_4$	adipic acid
$C_6H_{10}O_4$	conduritol
$C_6H_{10}O_4$	dianhydrohexitol
$C_6H_{10}O_4$	ethylidene diacetate
$C_6H_{10}O_4$	glucal
$C_6H_{11}NO_2$	cycloleucine
	pipecolic acid
C_6H_{12}	cyclohexane
$C_6H_{12}O_3$	4-Hydroxy-4-methylpentanoic acid
$C_6H_{12}O_6$	fructose
	glucose
$C_6H_{13}NO$	*N*-ethylmorpholine
$C_6H_{13}NO_2$	aminocaproic acid
	isoleucine Ile
	leucine Leu
C_6H_{14}	hexane
$C_6H_{14}N_2O_2$	lysine Lys
$C_6H_{14}N_4O_2$	arginine Arg
$C_6H_{14}O_2$	1,6-hexanediol
$C_6H_{14}O_3$	dipropylene glycol

$C_6H_{14}O_3$	trimethylolpropane
$C_6H_{14}O_4$	triethylene glycol
$C_6H_{15}NO_3$	triethanolamine
C_6N_4	tetracyanoethylene
$C_7H_5Br_3O$	2,4,6-tribromoanisole
$C_7H_5Cl_3O$	2,4,6-trichloroanisole
$C_7H_5F_3O$	2,4,6-trifluoroanisole
$C_7H_5FO_2$	2-fluorobenzoic acid
$C_7H_5FO_2$	3-Fluorobenzoic acid
$C_7H_5FO_2$	4-fluorobenzoic acid
$C_7H_5NO_4$	quinolinic acid
	dipicolinic acid
$C_7H_5NS_2$	2-mercaptobenzothiazole
$C_7H_5N_3O_2$	7-nitroindazole
$C_7H_6N_2$	7-azaindole
$C_7H_6N_2$	Benzimidazole
C_7H_6O	tropone
$C_7H_6O_2$	benzoic acid
	4-hydroxybenzaldehyde
$C_7H_6O_3$	salicylic acid
	4-hydroxybenzoic acid
$C_7H_6O_4$	protocatechuic acid
	2,3-dihydroxybenzoic acid
$C_7H_6O_5$	gallic acid
$C_7H_7BO_4$	4-carboxyphenylboronic acid
$C_7H_7NO_2$	4-aminobenzoic acid
$C_7H_7NO_3$	mesalazine
$C_7H_7N_3$	benomyl metabolite
C_7H_8	toluene
$C_7H_8ClN_3O_4S_2$	hydrochlorothiazide
$C_7H_8N_4O_2$	theophylline
$C_7H_8N_4O_2$	theobromine
$C_7H_9BO_2$	4-methylphenylboronic acid
$C_7H_9BO_3$	4-boronoanisole
$C_7H_{10}N_2$	4-dimethylaminopyridine
$C_7H_{11}NO_5$	N-Acetylglutamic acid
$C_7H_{12}O_4$	diethyl malonate
$C_7H_{12}N_2O_4$	aceglutamide
$C_7H_{14}O_6$	bornesitol
C_7H_{16}	heptane

$C_8H_5F_3N_2OS$	riluzole
$C_8H_5NO_2$	isatin
C_8H_6BrN	5-bromoindole
	6-bromoindole
C_8H_6ClN	4-chloroindole
$C_8H_6Cl_2O_3$	2,4-dichlorophenoxyacetic acid
$C_8H_6N_2O$	4-quinazolinol
$C_8H_6N_2O_2$	indazolium-3-carboxylate
C_8H_7N	indole
C_8H_7NO	indol-4-ol
	oxindole
	5-hydroxyindole
C_8H_8	cubane
$C_8H_8N_2OS$	2-amino-6-methoxybenzothiazole
$C_8H_8O_3$	4-hydroxyphenylacetic acid
	isovanillin
$C_8H_8O_4$	vanillic acid
$C_8H_9NO_2$	acetaminophen
$C_8H_9NO_2$	aminomethylbenzoic acid
$C_8H_9NO_2$	hydroxydanaidal
$C_8H_9NO_2$	methyl anthranilate
$C_8H_{10}N_4O_2$	caffeine
$C_8H_{11}NO$	tyramine
$C_8H_{11}N_5O_3$	aciclovir
$C_8H_{16}O_2$	cyclohexanedimethanol
$C_8H_{16}O_6$	pinpollitol
$C_8H_{16}O_6$	viscumitol
$C_8H_{16}O_6$	Eleutheroside C ethyl galactoside
C_8H_{18}	octane
C_9H_6BrN	4-bromoisoquinoline
$C_9H_6N_2$	5-cyanoindole
$C_9H_6O_3$	umbelliferone
C_9H_6OS	thiochromone
C_9H_7NO	8-hydroxyquinoline
	indole-3-carboxaldehyde
$C_9H_7NO_2$	indole-2-carboxylic acid
	indole-3-carboxylic acid
$C_9H_8N_2$	5-aminoisoquinoline
	5-aminoquinoline
	6-aminoquinoline

	8-aminoquinoline
$C_9H_8O_2$	cinnamic acid
$C_9H_8O_3$	*o*-coumaric acid
	m-coumaric acid
	p-coumaric acid
$C_9H_8O_4$	aspirin acetylsalicylic acid
	caffeic acid
C_9H_9N	methylketol
	skatole
C_9H_9NO	4-methoxyindole
	5-methoxyindole
	6-methoxyindole
	indole-3-carbinol
$C_9H_9NO_3$	hippuric acid
$C_9H_{10}O$	chavicol
$C_9H_{10}O_3$	paeonol
$C_9H_{11}NO_2$	phenylanine LPA
	phenylanine DLPA
$C_9H_{10}O$	cinnamyl alcohol
$C_9H_{11}NO_3$	tyrosine Tyr
$C_9H_{11}NO_4$	L-DOPA
$C_9H_{17}NO_2$	gabapentin
$C_9H_{18}N_2O_2$	1-boc-piperazine
C_9H_{20}	nonane
$C_{10}H_7NO_2$	quinaldic acid
$C_{10}H_7N_3S$	tiabendazole
$C_{10}H_8$	azulene
$C_{10}H_8$	naphthalene
$C_{10}H_8O_3$	hymecromone
$C_{10}H_9NO_2$	indole-3-acetic acid
$C_{10}H_9N_5O$	kinetin
$C_{10}H_9NO_2$	5-methoxyindole-3-carboxaldehyde
$C_{10}H_{10}N_2O$	edaravone
$C_{10}H_{10}O_2$	safrole
$C_{10}H_{10}O_4$	ferulic acid
$C_{10}H_{11}N_3O_3S$	sulfamethoxazole
$C_{10}H_{12}N_2$	tryptamine

$C_{10}H_{12}O$	anethole
$C_{10}H_{12}O$	estragole
$C_{10}H_{12}O_2$	hinokitiol
$C_{10}H_{12}O_2$	eugenol
$C_{10}H_{12}O_2$	isoeugenol
$C_{10}H_{12}O_2$	pseudoisoeugenol
$C_{10}H_{12}O_3$	coniferyl alcohol
$C_{10}H_{13}N_5O_4$	adenosine
$C_{10}H_{14}O$	mentha spicata herb oil
$C_{10}H_{15}ON$	ephedrine
$C_{10}H_{16}$	limonene
$C_{10}H_{16}O$	camphor
$C_{10}H_{17}NO_3$	boc-4-piperidone
$C_{10}H_{19}NO_3$	1-boc-4-piperidinol
$C_{10}H_{20}N_2O_2$	boc-4-aminopiperidine
$C_{10}H_{22}$	decane
$C_{11}H_8O_2$	menadione
$C_{11}H_{11}NO_2$	3-indolepropionic acid
$C_{11}H_{12}N_2O_2$	tryptophan Trp
$C_{11}H_{12}O_3$	myristicin
$C_{11}H_{14}N_2O$	5-methoxytryptamine
$C_{11}H_{14}O_2$	methyl eugenol
$C_{11}H_{14}O_2$	methyl isoeugenol
$C_{11}H_{19}NO_4$	boc-isonipecotic acid
$C_{11}H_{24}$	undecane
$C_{12}H_4N_4$	tetracyanoquinodimethane
$C_{12}H_8O_4$	methoxsalen
$C_{12}H_{10}$	biphenyl
$C_{12}H_{10}ClN_2O_5S$	furosemide
$C_{12}H_{11}N_5$	6-benzylaminopurine
$C_{12}H_{11}N_7$	triamterene
$C_{12}H_{13}NO_2$	indole-3-butyric acid
$(C_{12}H_{14}CaO_{12})_n$	calcium alginate
$C_{12}H_{14}O_4$	apiole
$C_{12}H_{14}O_4$	dillapiole
$C_{12}H_{15}NO$	1-benzyl-4-piperidone
$C_{12}H_{16}N_2$	N,N-Dimethyltryptamine
$C_{12}H_{16}O_3$	asarone
$C_{12}H_{16}O_3$	elemicin
$C_{12}H_{16}O_3$	isoelemicin

$C_{12}H_{16}O_3$	oudenone
$C_{12}H_{16}O_4$	2,4,5-Trimethoxypropiophenone
$C_{12}H_{16}O_7$	arbutin
$C_{12}H_{18}O$	propofol
$C_{12}H_{22}O_{11}$	maltose
	sucrose
$C_{12}H_{26}$	dodecane
$C_{13}H_{10}O$	benzophenone
$C_{13}H_{12}F_2N_6O$	fluconazole
$C_{13}H_{12}O$	β-ionone
$C_{13}H_{12}O_2$	monobenzone
$C_{13}H_{14}N_2O$	harmaline
$C_{13}H_{16}N_2O_2$	melatonin
$C_{13}H_{18}O_2$	ibuprofen
$C_{13}H_{28}$	tridecane
$C_{14}H_{10}$	anthracene
$C_{14}H_{10}$	phenanthrene
$C_{14}H_{10}O_{14}$	benzoyl peroxide
$C_{14}H_{12}O_3$	resveratrol
$C_{14}H_{14}Cl_2N_2O$	enilconazole
$C_{14}H_{18}N_2O_5$	aspartame
$C_{14}H_{18}N_4O_3$	trimethoprim
$C_{14}H_{30}$	tetradecane
$C_{15}H_{10}O_4$	daidzein
$C_{15}H_{10}O_5$	apigenin
	emodin
	genistein
$C_{15}H_{10}O_6$	luteolin
$C_{15}H_{10}O_7$	quercetin
$C_{15}H_{12}N_2O$	carbamazepine
$C_{15}H_{12}N_2O_2$	phenytoin
$C_{15}H_{32}$	pentadecane
$C_{16}H_{14}O_3$	ketoprofen
$C_{16}H_{28}N_2O_6Zn$	zinc acexamate
$C_{16}H_{34}$	hexadecane
$C_{17}H_{13}ClN_4$	alprazolam
$C_{17}H_{14}F_3N_3O_2S$	celecoxib
$C_{17}H_{18}N_2O_6$	nifedipine
$C_{17}H_{19}N_3O_3S$	omeprazole
$C_{17}H_{21}NO_4$	cocaine

$C_{17}H_{22}O_2$	cicutoxin
$C_{17}H_{22}O_2$	oenanthotoxin
$C_{17}H_{24}O$	falcarinol
$C_{17}H_{24}O_9$	Eleutheroside B syringin
$C_{17}H_{36}$	heptadecane
$C_{18}H_{22}O_2$	estrone
$C_{18}H_{24}O_2$	estradiol
$C_{18}H_{24}O_3$	estriol
$C_{18}H_{24}O_4$	estetrol
$C_{18}H_{27}NO_3$	capsaicin
$C_{18}H_{32}O_2$	linoleic acid
$C_{18}H_{36}O_2$	stearic acid
$C_{18}H_{38}$	octadecane
$C_{19}H_{16}ClNO_4$	indometacin
$C_{19}H_{26}O_2$	androstenedione
$C_{19}H_{28}O_2$	dehydroepiandrosterone
$C_{19}H_{28}O_2$	testosterone
$C_{19}H_{30}O_2$	androstenediol
$C_{19}H_{30}O_2$	dihydrotestosterone
$C_{19}H_{40}$	nonadecane
$C_{20}H_{24}O_2N_2$	quinine
$C_{20}H_{27}NO_{11}$	amygdalin
$C_{20}H_{28}O_2$	tretinoin
$C_{20}H_{32}O_5$	prostacyclin
$C_{20}H_{32}O_5$	prostaglandin E2
$C_{20}H_{34}O_5$	dinoprost
$C_{20}H_{42}$	eicosane
$C_{21}H_{20}O_6$	curcumin
$C_{21}H_{30}O_2$	progesterone
$C_{21}H_{36}N_7O_{16}P_3S$	Coenzyme A
$C_{21}H_{30}O_2$	tetrahydrocannabinol
$C_{22}H_{23}ClN_2O_2$	loratadine
$C_{23}H_{19}ClF_3NO_3$	cyhalothrin
$C_{30}H_{19}NO_9$	Dynemicin A
$C_{34}H_{46}O_{18}$	Eleutheroside D
$C_{35}H_{60}O_6$	Eleutheroside A
$C_{40}H_{56}$	lycopene
$C_{44}H_{69}N_{15}O_9S$	adrenorphin
$C_{55}H_{74}IN_3O_{21}S_4$	calicheamicin
$C_{59}H_{80}N_4O_{22}S_4$	esperamicin

$C_{62}H_{89}CoN_{13}O_{15}P$	hydroxocobalamin
$C_{63}H_{88}CoN_{14}O_{14}P$	Vitamin B12
$C_{63}H_{88}CoN_{14}O_{14}P$	cyanocobalamin
$C_{63}H_{91}CoN_{13}O_{14}P$	methylcobalamin
$C_{72}H_{100}CoN_{18}O_{17}P$	adenosylcobalamin
$C_{77}H_{120}N_{18}O_{26}S$	alpha-Endorphin
$C_{83}H_{131}N_{19}O_{27}S$	gamma-Endorphin
$C_{131}H_{200}N_{30}O_{43}S_2$	amidorphin
$C_{158}H_{251}N_{39}O_{46}S$	beta-Endorphin
$C_{161}H_{236}N_{42}O_{48}$	leumorphin
$C_{164}H_{256}Na_2O_{68}S_2$	maitotoxin
$CaAl_2O_4$	calcium aluminate
CaB_6	calcium boride
$CaBr_2$	calcium bromide
$Ca(BrO)_2$	calcium hypobromite
$Ca(BrO_2)_2$	calcium bromite
$Ca(BrO_3)_2$	calcium bromate
$Ca(BrO_4)_2$	calcium perbromate
$Ca(CN)_2$	calcium cyanide
$CaCO_3$	calcium carbonate spent lime calcite limestone marble
CaC_2	calcium carbide
$Ca(CHO_2)_2$	calcium formate
$Ca(C_2H_3O_2)_2$	calcium acetate
CaC_2O_4	calcium oxalate
$CaCN_2$	calcium cyanamide
$CaCl_2$	calcium chloride
$Ca(ClO)_2$	calcium hypochlorite
$Ca(ClO_2)_2$	calcium chlorite
$Ca(ClO_3)_2$	calcium chlorate
$Ca(ClO_4)_2$	calcium perchlorate
CaF_2	calcium fluoride fluorite
CaH_2	calcium hydride
$CaHPO_4$	dicalcium phosphate
$Ca(H_2PO_2)_2$	calcium hypophosphite
$Ca(HS)_2$	calcium hydrosulfide
CaI_2	calcium iodide

$Ca(IO)_2$	calcium hypoiodite
$Ca(IO_2)_2$	calcium iodite
$Ca(IO_3)_2$	calcium iodate
$Ca(IO_4)_2$	calcium periodate
$CaMoO_4$	calcium molybdate
$Ca(NO_2)_2$	calcium nitrite
$Ca(NO_3)_2$	calcium nitrate
$Ca(NO_3)_2 \cdot 4H_2O$	Calcium nitrate tetrahydrate
$Ca(NbO_3)_2$	calcium metaniobate
CaO	quicklime calcium oxide burnt lime
$Ca(OH)_2$	calcium hydroxide slaked lime
CaO_2	calcium peroxide
CaP	calcium monophosphide
CaS	calcium sulfide hepar calcies sulfurated lime oldhamite
$CaSO_3$	calcium sulfite
$CaSO_4$	calcium sulfate
$CaSO_4 \cdot 0.5H_2O$	plaster of paris calcium sulfate hemihydrate
$CaSe$	calcium selenide
$CaSeO_3$	calcium selenite
$CaSeO_4$	calcium selenate
$CaSiO_3$	calcium metasilicate wollastonite
$CaTe$	calcium telluride
$CaTeO_3$	calcium tellurite
$CaTeO_4$	calcium tellurate
$CaTiO_3$	calcium titanate
$Ca(VO_3)_2$	calcium metavanadate
$Ca(VO_4)_2$	calcium orthovanadate
$CaWO_4$	calcium tungstate
$Ca_3(AsO_4)_2$	calcium arsenate
Ca_3N_2	calcium nitride
Ca_3P_2	calcium phosphide
$Ca_3(PO_4)_2$	tricalcium phosphate
$Ca_4(PO_4)_2O$	tetracalcium phosphate

$Ca_5(PO_4)_3F$	calcium fluorophosphate
$Ca_5(PO_4)_3(OH)$	hydroxyapatite
$CdBr_2$	cadmium bromide
$Cd(CN)_2$	cadmium cyanide
$CdCO_3$	cadmium carbonate
$Cd(C_2H_3O_2)_2$	cadmium acetate
CdC_2O_4	cadmium oxalate
$CdCl_2$	cadmium chloride
$CdCrO_4$	cadmium chromate
CdF_2	cadmium fluoride
CdI_2	cadmium iodide
$Cd(IO_3)_2$	cadmium iodate
$CdMoO_4$	cadmium molybdate
$Cd(NO_3)_2$	cadmium nitrate
$Cd(N_3)_2$	cadmium azide
CdO	cadmium oxide
$Cd(OH)_2$	cadmium hydroxide
CdS	cadmium sulfide greenockite
$CdSO_3$	cadmium sulfite
$CdSO_4$	cadmium sulfate
CdSb	cadmium antimonide
CdSe	cadmium selenide cadmoselite
$CdSeO_3$	cadmium selenite
$CdSiO_3$	cadmium metasilicate
$Cd(TaO_3)_2$	cadmium metatantalate
CdTe	cadmium telluride
$CdTeO_4$	cadmium tellurate
$CdTiO_3$	cadmium titanate
$CdWO_4$	cadmium tungstate
$CdZrO_3$	cadmium metazirconate
$Cd_2Nb_2O_7$	cadmium niobate
Cd_3As_2	cadmium arsenide
Cd_3P_2	cadmium phosphide
$Cd_3(PO_4)_2$	cadmium phosphate
CeB_6	cerium boride
$CeBr_3$	cerium(III) bromide
CeC	cerium carbide
$CeCl_3$	cerium(III) chloride
CeF_3	cerium(III) fluoride

CeF_4	cerium(IV) fluoride
CeI_2	cerium(II) iodide
CeI_3	cerium(III) iodide
CeN	cerium nitride
CeO_2	cerium(IV) oxide cerianite
CeS	cerium(II) sulfide
$Ce(SO_4)_2$	cerium(IV) sulfate
$CeSi_2$	cerium silicide
Ce_2C_3	cerium(III) carbide
Ce_2O_3	cerium(III) oxide
Ce_2S_3	cerium(III) sulfide
CF_3Cl	chlorotrifluoromethane
CF_4	tetrafluoromethane
ClF	chlorine fluoride
ClF_3	chlorine trifluoride
ClF_5	chlorine pentafluoride
$ClOClO_3$	chlorine perchlorate
ClO_2	chlorine dioxide
ClO_3F	chlorine trioxide fluoride
Cl_2	chlorine
Cl_2O_3	chlorine trioxide
Cl_2O_6	chlorine hexoxide
Cl_2O_7	chlorine heptoxide
Cl_2O_8	Chlorine octaoxide
$CoAl_2O_4$	cobalt(II) aluminate
CoAs	cobalt arsenide
$CoAs_2$	cobalt(II) arsenide
CoB	cobalt(II) boride
$CoBr_2$	cobalt(II) bromide
$Co(CN)_2$	cobalt(II) cyanide
$Co(C_2H_3O_2)_2$	cobalt(II) acetate
$Co(C_2H_3O_2)_3$	cobalt(III) acetate
CoC_2O_4	cobalt(II) oxalate
$Co(ClO_4)_2$	cobalt(II) perchlorate
$CoCl_2$	cobalt(II) chloride
$CoCrO_4$	cobalt(II) chromate
$CoCr_2O_4$	cobalt(II) chromite
CoF_2	cobalt(II) fluoride
CoF_3	cobalt(III) fluoride
$Co(IO_3)_2$	cobalt(II) iodate

CoI_2	cobalt(II) iodide
$CoMoO_4$	cobalt(II) molybdate
$Co(NO_3)_2$	cobalt(II) nitrate
$Co(NO_3)_3$	cobalt(III) nitrate
CoO	cobalt(II) oxide
$Co(OH)_2$	cobalt(II) hydroxide
$Co(OH)_3$	cobalt(III) hydroxide
CoS	cobalt(II) sulfide
CoS_2	cobalt disulfide
$CoSb$	cobalt antimonide
$CoSe$	cobalt(II) selenide
$CoSeO_3$	cobalt(II) selenite
$CoTe$	cobalt(II) telluride
$CoTiO_3$	cobalt(II) titanate
$CoWO_4$	cobalt(II) tungstate
Co_2B	cobalt boride
Co_2SO_4	cobalt(II) sulfate
Co_2S_3	cobalt(III) sulfide
Co_2SiO_4	cobalt(II) orthosilicate
Co_2SnO_4	cobalt(II) stannate
Co_2TiO_4	cobalt(II) titanite
$Co_3(AsO_4)_2$	cobalt arsenate
$Co_3(Fe(CN)_6)_2$	cobalt(II) ferricyanide
$CrBr_2$	chromium(II) bromide
$CrBr_3$	chromium(III) bromide
$CrCl_2$	chromium(II) chloride
$CrCl_3$	chromium(III) chloride
$CrCl_4$	chromium(IV) chloride
CrF_2	chromium(II) fluoride
CrF_3	chromium(III) fluoride
CrF_4	chromium(IV) fluoride
CrF_5	chromium(V) fluoride
CrF_6	chromium(VI) fluoride
CrI_2	chromium(II) iodide
CrI_3	chromium(III) iodide
$Cr(NO_3)_3$	chromium(III) nitrate
$Cr(NO_2)_3$	chromium(III) nitrite
$Cr(OH)_3$	chromium(III) hydroxide
CrO_2	chromium(IV) oxide
CrO_3	chromium(VI) oxide

CrO_4^{2-}	chromate ion
CrO_2Cl_2	chromium(VI) oxychloride
$CrPO_4$	chromium(III) phosphate
CrSb	chromium antimonide
CrSe	chromium(II) selenide
$CrSi_2$	chromium(II) silicide
$CrVO_4$	chromium(III) orthovanadate
Cr_2O_3	chromium(III) oxide eskolaite
$Cr_2(SO_4)_3$	chromium(III) sulfate
Cr_2S_3	chromium(III) sulfide
Cr_2Se_3	chromium(III) selenide
$Cr_2(TeO_4)_3$	chromium(III) tellurate
Cr_2Te_3	chromium(III) telluride
Cr_3As_2	chromium(II) arsenide
Cr_3C_2	chromium(II) carbide
Cr_3Sb_2	chromium(II) antimonide
$CsBO_2$	caesium borate
CsBr	caesium bromide
CsBrO	caesium hypobromite
$CsBrO_2$	caesium bromite
$CsBrO_3$	caesium bromate
$CsBrO_4$	caesium perbromate
$CsBr_3$	caesium tribromide
CsCN	caesium cyanide
CsCNO	caesium cyanate
CsCNO	caesium fulminate
$CsC_2H_3O_2$	caesium acetate
CsCl	caesium chloride
CsClO	caesium hypochlorite
$CsClO_2$	caesium chlorite
$CsClO_3$	caesium chlorate
$CsClO_4$	caesium perchlorate
CsF	caesium fluoride
CsH	caesium hydride
CsHS	caesium hydrosulfide
CsI	caesium iodide
CsIO	caesium hypoiodite
$CsIO_2$	caesium iodite
$CsIO_3$	caesium iodate
$CsIO_4$	caesium periodate

CsI_3	caesium triiodide
$CsNH_2$	caesium amide
$CsNO_2$	caesium nitrite
$CsNO_3$	caesium nitrate
CsN_3	caesium azide
$CsNbO_3$	caesium niobate
Cs_2NbO_3	caesium metaniobate
$CsOH$	caesium hydroxide
CsO_2	caesium superoxide
Cs_2O_2	caesium peroxide
Cs_2S	caesium sulfide
$CsSCN$	caesium thiocyanate
$CsSeO_4$	caesium selenate
$CsTaO_3$	caesium metatantalate
Cs_2CO_3	caesium carbonate
$CsHCO_3$	caesium bicarbonate
CsH_2PO_3	monocaesium phosphite
CsH_2PO_4	monocaesium phosphate
$CsHSO_3$	caesium bisulfite
$CsHSO_4$	caesium hydrogen sulfate
$Cs_2C_2O_4$	caesium oxalate
Cs_2CrO_4	caesium chromate
$Cs_2Cr_2O_7$	caesium dichromate
Cs_2HPO_4	caesium hydrogen orthophosphate
Cs_2MoO_4	caesium molybdate
Cs_2O	caesium oxide
Cs_2SO_3	caesium sulfite
Cs_2SO_4	caesium sulfate
Cs_2SiO_3	caesium metasilicate
Cs_2TeO_4	caesium tellurate
Cs_2TiO_3	caesium titanate caesium metatitanate
Cs_2WO_4	caesium orthotungstate
Cs_2HPO_3	dicaesium phosphite
Cs_2HPO_4	dicaesium phosphate
Cs_3PO_3	tricaesium phosphite
Cs_3PO_4	caesium orthophosphate
Cs_3VO_4	caesium orthovanadate
$CuBr$	copper(I) bromide
$Cu(BrO_3)_2 \cdot 6H_2O$	copper(II) bromate hexahydrate
$CuBr_2$	copper(II) bromide

CuC_2O_4	copper oxalate
Cu(CH3COO)	copper(I) acetate
$Cu(CH3COO)_2$	copper(II) acetate
CuCl	copper(I) chloride
$Cu(ClO_3)_2 \cdot 6H_2O$	copper(II) chlorate hexahydrate
$CuCl_2$	copper(II) chloride
CuF	copper(I) fluoride
CuF_2	copper(II) fluoride
$CuFeS_2$	copper iron sulfide chalcopyrite
$CuFe_2O_4$	copper(II) iron(II) oxide
$CuFe_2S_3$	copper iron sulfide cubanite
$[Cu(H_2O)_4]SO_4 \cdot H_2O$	blue vitriol
CuI	copper(I) iodide
$CuIO_3$	copper(I) iodate
$Cu(IO_3)_2$	copper(II) iodate
$CuMoO_4$	copper(II) orthomolybdate
$Cu(NO_3)_2$	copper(II) nitrate
$Cu(NO_3)_2 \cdot 3H_2O$	copper(II) nitrate trihydrate
$Cu(NO_3)_2 \cdot 6H_2O$	copper(II) nitrate hexahydrate
$Cu(NbO_3)_2$	copper(II) orthoniobate
CuO	copper(II) oxide
Cu_2O	copper(I) oxide
$Cu(OH)_2$	copper(II) hydroxide
$Cu_2(OH)_2CO_3$	basic copper carbonate
CuS	copper(II) sulfide covellite
CuSCN	copper(I) thiocyanate
$CuSO_4$	copper(II) sulfate
$CuSO_4 \cdot 5H_2O$	copper(II) sulfate pentahydrate
CuSe	copper(II) selenide
$CuSeO_3 \cdot 2H_2O$	copper(II) selenite dihydrate
$CuSeO_4 \cdot 5H_2O$	copper(II) selenate pentahydrate
$CuSiO_3$	copper(II) metasilicate
CuTe	copper(II) telluride
$CuTeO_3$	copper(II) tellurite
$CuTiO_3$	copper(II) metatitanate
$Cu(VO_3)_2$	copper(II) metavanadate
$CuWO_4$	copper(II) orthotungstate
$Cu_2CO_3(OH)_2$	malachite

Cu_2S	copper(I) sulfide chalcocite
Cu_2Se	copper(I) selenide
Cu_2Te	copper(I) telluride
Cu_3As	copper(I) arsenide
Cu_3P	copper(I) phosphide
$Cu_3(PO_4)_2$	copper(II) phosphate
Cu_3Sb	copper(III) antimonide
Cu_9S_5	copper sulfide digenite
DBr	deuterium bromide
DI	deuterium iodide
DLi	lithium deuteride
DNa	sodium deuteride
D_2O	deuterium oxide heavy water
D_3O^+	trideuterium oxide cation
$DyBr_3$	dysprosium(III) bromide
$DyCl_2$	dysprosium(II) chloride
$DyCl_3$	dysprosium(III) chloride
$DySi_2$	dysprosium(II) silicide
Dy_2O_3	dysprosium(III) oxide
Dy_2S_3	dysprosium(III) sulfide
$ErCl_3$	erbium(III) chloride
ErF	erbium monofluoride
ErF_2	erbium difluoride
ErF_3	erbium trifluoride
ErI_3	erbium triiodide
ErI_4Na	erbium sodium tetraiodide
ErO	erbium monoxide
$EuCl_2$	europium(II) chloride
$EuCl_3$	europium(III) chloride
EuF	europium monofluoride
EuF_3	europium trifluoride
EuI_2	europium diiodide
$EuNbO_2$	europium niobium dioxide
$EuNb_2O_6$	europium diniobium hexaoxide
EuO	europium monoxide
EuO_2V	monoeuropium monovandium dioxide
EuO_3Ti	europium titanium trioxide
EuO_3V	europium metavanadate

EuO_4W	europium tungsten tetraoxide
EuS	europium monosulfide
$EuSO_4$	europium(II) sulfate
EuS_2	europium disulfide
Eu_2O	dieuropium monoxide
Eu_2O_2	dieuropium dioxide
Eu_2O_3	europium(III) oxide
Eu_2S	dieuropium monosulfide
Eu_2S_2	dieuropium disulfide
$Eu_2(SO_4)_3$	europium(III) sulfate
FGa	gallium monofluoride
FGaO	gallium monofluoride monoxide
FGd	gadolinium monofluoride
FGe	germanium monofluoride
FHo	holmium monofluoride
FI	iodine monofluoride
FI_2	monofluorodiiodine
FIn	indium monofluoride
FLa	lanthanum monofluoride
FLi	lithium fluoride
FLiO	lithium hypofluorite
FLi_2	dilithium monofluoride
FMg	magnesium monofluoride
FMn	monomanganese monofluoride
$FMnO_3$	manganese fluoride trioxide
FMo	molybdenum monofluoride
FN	fluoroimidogen
FNO	nitrosyl fluoride
FNO_2	nitryl fluoride
FNO_3	fluorine nitrate
FNS	thiazyl fluoride
FNa	sodium fluoride
FNa_2	disodium monofluoride
FNd	neodymium monofluoride
FO	oxygen monofluoride
FOTh	thorium monofluoride monoxide
FOTi	titanium fluoride oxide
FO_2	dioxygen monofluoride
FO_3S	fluorosulfate radical
FP	phosphorus monofluoride

FPS	phosphenothious fluoride
FPS_2	phosphenodithioic fluoride
FPb	lead monofluoride
FPu	plutonium monofluoride
FRb	rubidium fluoride
FS	monosulfur monofluoride
FSc	scandium monofluoride
FSm	samarium monofluoride
FSn	tin monofluoride
FSr	strontium monofluoride
FTh	thorium monofluoride
FTi	titanium fluoride
FTl	thallium monofluoride
FW	tungsten monofluoride
FXe	xenon monofluoride
FY	yttrium monofluoride
FZr	zirconium fluoride
F_2	fluorine
F_2Fe	ferrous fluoride
F_2Ga	gallium difluoride
F_2Gd	gadolinium difluoride
F_2Ge	germanium difluoride
F_2GeO	difluorogermanone
F_2Hg	mercury fluoride
F_2Hg_2	mercury fluoride
F_2Ho	holmium difluoride
F_2IP	difluoroiodophosphine
F_2K_2	dipotassium difluoride
F_2Kr	krypton difluoride
F_2La	lanthanum difluoride
F_2Li_2	lithium fluoride
F_2Mg	magnesium fluoride
F_2Mn	manganese difluoride
F_2Mo	molybdenum difluoride
F_2MoO_2	molybdenum difluoride dioxide
F_2N	difluoroamino radical
F_2N_2O	nitrosodifluoroamine
F_2Na_2	disodium difluoride
F_2Nd	neodymium difluoride
F_2Ni	nickel difluoride

F_2O	oxygen difluoride
F_2OS	thionyl fluoride
F_2OSi	difluorooxosilane
F_2OTi	titanium fluoride oxide
F_2O_2	perfluoroperoxide
F_2O_2S	sulfuryl fluoride
F_2O_2W	tungsten difluoride dioxide
$F_2O_5S_3$	peroxydisulfuryl difluoride
F_2P	phosphorus difluoride
F_2Pb	lead difluoride
F_2Pt	platinum difluoride
F_2Pu	plutonium difluoride
F_2S	sulfur difluoride
F_2SW	tungsten difluoride monosulfide
F_2S_2	difluorodisulfane
F_2S_2	thiothionyl fluoride
F_2S_2	thiothionyl fluoride
F_2S_2W	tungsten difluoride disulfide
F_2Sc	scandium difluoride
F_2Se	selenium difluoride
F_2Si	difluorosilylene
F_2Sn	tin difluoride
F_2Sr	strontium fluoride
F_2Th	thorium difluoride
F_2Ti	titanium difluoride
F_2Tl_2	dithallium difluoride
F_2W	tungsten difluoride
F_2Xe	xenon difluoride
F_2Y	yttrium difluoride
F_2Zn	zinc difluoride
F_2Zr	zirconium fluoride
F_3Fe	iron trifluoride
F_3Ga	gallium trifluoride
F_3Gd	gadolinium trifluoride
F_3Ho	holmium trifluoride
F_3La	lanthanum trifluoride
F_3Li_3	trilithium trifluoride
F_3Lu	lutetium trifluoride
F_3Mn	manganese trifluoride
F_3Mo	molybdenum trifluoride

F_3MoO	molybdenum trifluoride oxide
F_3MoS	molybdenum trifluoride sulfide
F_3N	nitrogen trifluoride
F_3NO	nitrogen trifluoride oxide
F_3NO_2S	difluoroaminosulfonyl fluoride
F_3NO_3S	difluoraminooxysulfonyl fluoride
F_3NS	thiazyl trifluoride
F_3NaSn	sodium trifluorostannate
F_3Nd	neodymium trifluoride
F_3OP	phosphoryl fluoride
F_3OTa	tantalum monoxide trifluoride
F_3OV	vanadium trifluoride oxide
F_3P	phosphorus trifluoride
F_3PS	thiophosphoryl fluoride
F_3Pr	praseodymium trifluoride
F_3Pu	plutonium trifluoride
F_3Rh	rhodium fluoride
F_3S	sulfur trifluoride
F_3SW	tungsten trifluoride monosulfide
F_3Sb	antimony trifluoride
F_3Sc	scandium fluoride
F_3Si	trifluorosilyl radical
F_3Sm	samarium trifluoride
F_3Tb	terbium trifluoride
F_3Th	thorium trifluoride
F_3Ti	titanium trifluoride
F_3Tl	thallium trifluoride
F_3Tm	thulium trifluoride
F_3W	tungsten trifluoride
F_3Y	yttrium trifluoride
F_3Yb	ytterbium trifluoride
F_3Zr	zirconium trifluoride
F_4Ge	germanium tetrafluoride
F_4Ge_2	digermanium tetrafluoride
F_4Hf	hafnium fluoride
F_4Mg_2	dimagnesium tetrafluoride
F_4Mg_2	magnesium fluoride
F_4Mo	molybdenum tetrafluoride
F_4MoO	molybdenum tetrafluoride oxide
F_4MoS	molybdenum tetrafluoride monosulfide

F_4N_2	tetrafluorohydrazine
F_4Na_2Sn	disodium tetrafluorostannate
F_4OOs	osmium oxide tetrafluoride
F_4OP_2	diphosphorus tetrafluoride oxide
F_4ORe	rhenium tetrafluoride oxide
F_4OS	sulfur tetrafluoride oxide
F_4OW	tungsten tetrafluoride oxide
F_4OXe	xenon tetrafluoride oxide
F_4P_2	diphosphorus tetrafluoride
F_4Pb	lead tetrafluoride
F_4Pt	platinum tetrafluoride
F_4Pu	plutonium tetrafluoride
F_4S	sulfur tetrafluoride
F_4SW	tungsten tetrafluoride monosulfide
F_4Se	selenium tetrafluoride
F_4Si	silicon tetrafluoride
F_4Sn_2	ditin tetrafluoride
F_4Ti	titanium fluoride
F_4U	uranium tetrafluoride
F_4W	tungsten tetrafluoride
F_4Xe	xenon tetrafluoride
F_4Zr	zirconium tetrafluoride
F_5I	iodine pentafluoride
F_5Mo	molybdenum pentafluoride
F_5ORe	rhenium monoxide pentafluoride
F_5P	phosphorus pentafluoride
F_5Pu	plutonium pentafluoride
F_5S	disulfur decafluoride
F_5Sb	antimony pentafluoride
F_5Ta	tantalum pentafluoride
F_5U	uranium pentafluoride
F_5W	tungsten pentafluoride
F_6Fe_2	diiron hexafluoride
F_6La_2	lanthanum trifluoride dimer
F_6Mo	molybdenum hexafluoride
F_6NP_3	nitridotriphosphorous hexafluoride
F_6Os	osmium hexafluoride
F_6Pu	plutonium hexafluoride
F_6Re	rhenium hexafluoride
F_6S	sulfur hexafluoride

F_6Se	selenium hexafluoride
F_6Si_2	hexafluorodisilane
F_6Sn_3	tritin hexafluoride
F_6Te	tellurium hexafluoride
F_6U	uranium hexafluoride
F_6W	tungsten hexafluoride
F_6Xe	xenon hexafluoride
F_7I	iodine fluoride
F_7NS	pentafluorosulfanyldifluoroamine
F_7Re	rhenium heptafluoride
F_8Si_3	octafluorotrisilane
$F_{10}Mo_2$	molybdenum fluoride
$F_{10}S_2$	sulfur fluoride
$F_{15}Mo_3$	molybdenum fluoride
FeAsS	iron arsenic sulfide arsenopyrite
$FeBr_2$	iron(II) bromide
$FeBr_3$	iron(III) bromide
$FeBr_3 \cdot 6H_2O$	iron(III) bromide hexahydrate
$FeCO_3$	siderite
FeC_2O_4	iron oxalate
FeC_5O_5	iron pentacarbonyl pentacarbonyl iron
$FeC_{10}H_{10}$	ferrocene
$FeCl_2$	iron(II) chloride
$FeCl_3$	iron(III) chloride
$FeCr_2O_4$	chromite (ore)
FeF_2	iron fluoride
$FeF_2 \cdot 4H_2O$	iron(II) fluoride tetrahydrate
FeI	iron monoiodide
FeI_2	iron diiodide iron(II) iodide
$FeI_2 \cdot 4H_2O$	iron(II) iodide tetrahydrate
FeI_3	iron(III) iodide
$FeMoO_4$	iron(II) orthomolybdate
FeO	iron monoxide iron(II) oxide wüstite
FeO_2	iron dioxide
FeO_2H	goethite
$FeO_2H \cdot nH_2O$	limonite

$Fe(OH)_2$	iron(II) hydroxide
$Fe(OH)_3$	iron(III) hydroxide
$Fe(SCN)_3$	iron(III) Thiocyanate
FeO_4S	ferrous sulfate
FeO_4Se	iron(II) selenate ferrous selenate
$FeO_8H_4P_2$	iron(II) dihydrogen phosphate
FeP	iron(III) phosphide
$FePO_4$	iron(III) phosphate
FeS	iron sulfide iron(II) sulfide
FeS_2	pyrite fool's gold
	iron(IV) sulfide marcasite
FeSe	iron(II) selenide
FeTe	iron(II) telluride
$FeTiO_3$	iron(II) metatitanate
	ilmenite
$FeVO_4$	iron(III) orthovanadate
$FeWO_4$	iron(II) orthotungstate
$FeZrO_3$	iron(II) metazirconate
Fe_2I_2	diiron diiodide
Fe_2I_4	diiron tetraiodide
Fe_2O_3	iron oxide iron(III) oxide hematite
Fe_2O_3	venetian red
$Fe_2O_{12}S_3$	ferric sulfate iron(III) sulfate
$Fe_2O_{12}W_3$	iron(III) orthotungstate
Fe_2P	diiron phosphide
Fe_2SiO_4	fayalite
$Fe_3H_2Na_2O_{45}Si$	chrysotile white asbestos
Fe_3O_4	iron(II,III) oxide magnetite triiron(II, III) tetraoxide
Fe_3P	iron(tri) phosphide
$Fe_4(P_2O_7)_3$	iron(III) pyrophosphate
$Fe_7Si_8O_{24}H_2$	amosite

	brown asbestos grunerite
$GaAs$	gallium(III) arsenide
$GaAsO_4$	gallium(III) orthoarsenate
$GaBr_3$	gallium(III) bromide
$Ga(C_2H_3O_2)_3$	gallium(III) acetate
$GaCl_2$	gallium(II) chloride
$GaCl_3$</	gallium trichloride
$Ga(ClO_4)_3$	gallium(III) perchlorate
GaI_2	gallium(II) iodide
GaI_3	gallium(III) iodide
GaN	gallium(III) nitride
$Ga(OH)_3$	gallium(III) hydroxide
$GaPO_4$	gallium(III) orthophosphate
$GaSb$	gallium(III) antimonide
$GaTe$	gallium(II) telluride
Ga_2O_3	gallium(III) oxide
$Ga_2(SO_4)_3 \cdot 18H_2O$	gallium(III) sulfate octadecahydrate
Ga_2S_3	gallium(III) sulfide
Ga_2Te_3	gallium(III) telluride
$GeBr_4$	germanium(IV) bromide
GeH_3COOH	2-germaacetic acid
GeI_2	germanium(II) iodide
GeI_4	germanium(IV) iodide
GeO	germanium(II) oxide
$HArF$	argon fluorohydride
HAt	hydrogen astatide
HBr	hydrogen bromide hydrobromic acid
$HBrO$	hypobromous acid
$HBrO_2$	bromous acid
$HBrO_3$	bromic acid
$HBrO_4$	perbromic acid
$HCCH$	acetylene ethyne
HCN	hydrocyanic acid hydrogen cyanide
$HCNO$	fulminic acid
$HCONH_2$	formamide methanamide
$HCOO^-$	formate ion

HCOOH	formic acid methanoic acid
$HCOONH_4$	ammonium formate
HCO_3^-	hydrogen carbonate ion
$HC_3H_5O_3$	lactic acid
$HC_5H_5N^+$	pyridinium ion
$HC_6H_7O_6$	ascorbic acid
$HC_9H_7O_4$	acetylsalicylic acid
$HC_{12}H_{17}ON_4SCl_2$	thiamine hydrochloride vitamin B_1 hydrochloride
HCl	hydrochloric acid hydrogen chloride
HClO	hypochlorous acid
$HClO_2$	chlorous acid
$HClO_3$	chloric acid
$HClO_4$	perchloric acid
HDO	semiheavy water water-d1
HF	hydrofluoric acid
HI	hydroiodic acid
HIO	hypoiodous acid
HIO_2	iodous acid
HIO_3	iodic acid
HIO_4	periodic acid
HNCO	isocyanic acid
HNO	nitroxyl
HNO_2	nitrous acid
HNO_3	nitric acid hydrogen nitrate
HN_3	hydrazoic acid
HOBr	hypobromous acid
HOCl	hypochlorous acid
HOF	hypofluorous acid
HOOCCOOH	oxalic acid
HPO_4^{2-}	hydrogen phosphate ion
HSO_3^-	hydrogen sulfite ion
HSO_4^-	hydrogen sulfate
HTO	partially tritiated water water-t
H_2	hydrogen
$H_2C(CH)CN$	acrylonitrile

H_2CO	formaldehyde
H_2CO_3	carbonic acid
H_2CSO	sulfine
$H_2C_2O_4$	oxalic acid
$H_2C_4H_4O_6$	tartaric acid
$H_2C_8H_4O_4$	phthalic acid H_2Ph
H_2CrO_4	chromic acid
H_2NCH_2COOH	glycine
$H_2N_2O_2$	hyponitrous acid
H_2NNH_2	hydrazine
H_2O	water
H_2O_2	hydrogen peroxide
$H_2PO_4^-$	dihydrogen phosphate ion
H_2S	hydrogen sulfide hydrosulfuric acid
H_2SO_3	sulfurous acid
H_2SO_4	sulfuric acid hydrogen sulfate
$H_2S_2O_2$	thiosulfurous acid
$H_2S_2O_3$	thiosulfuric acid
$H_2S_2O_4$	dithionous acid
$H_2S_2O_5$	disulfurous acid
$H_2S_2O_6$	dithionic acid
$H_2S_2O_7$	disulfuric acid
$H_2S_2O_8$	peroxydisulfuric acid
H_2SeO_3	selenous acid
H_2SeO_4	selenic acid
H_2SiO_3	silicic acid
H_2TeO_3	tellurous acid
H_2TiO_3	titanic acid
H_3AsO_4	arsenic acid
$H_3CCH_2CH_3$	propane
$H_3N^+CH_2COO^-$	zwitterion
H_3O^+	hydronium ion
H_3PO_2	hypophosphorous acid
H_3PO_3	phosphorous acid
H_3PO_4	phosphoric acid
H_4XeO_6	perxenic acid
H_6TeO_6	telluric acid
$HfBr_4$	hafnium(IV) bromide

HfF_4	hafnium(IV) fluoride
$HfOCl_2 \cdot 8H_2O$	hafnium(IV) oxychloride octahydrate
$HfOH(C_2H_3O_2)_3$	hafnium(IV) acetate, basic
$Hf(SO_4)_2$	hafnium(IV) sulfate
$Hg(BrO_3)_2 \cdot 2H_2O$	mercury(II) bromate dihydrate
Hg_2Br_2	mercury(I) bromide
$HgBr_2$	mercury(II) bromide
$Hg(C_2H_3O_2)_2$	mercury(II) acetate
$Hg(C_7H_5O_2)_2 \cdot H_2O$	mercury(II) benzoate monohydrate
$HgClO_4 \cdot 4H_2O$	mercury(I) perchlorate tetrahydrate
$Hg(ClO_4)_2 \cdot 3H_2O$	mercury(II) perchlorate trihydrate
$HgCl_2$	mercury(II) chloride
$Hg(IO_3)_2$	mercury(II) iodate
HgI_2	mercury(II) iodide
$Hg(NO_3)_2 \cdot H_2O$	mercury(II) nitrate monohydrate
$Hg(CNO)_2$	mercury(II) fulminate
HgO	mercury(II) oxide
$Hg(OH)_2$	mercury(II) hydroxide
HgS	mercury(II) sulfide cinnabar
$Hg(SCN)_2$	mercury(II) thiocyanate
$HgSe$	mercury(II) selenide
$HgSeO_3$	mercury(II) selenite
$HgTe$	mercury(II) telluride
$HgTeO_3$	mercury(II) tellurite
$HgWO_4$	mercury(II) tungstate
Hg_2Br_2	mercury(I) bromide
Hg_2Cl_2	mercury(I) chloride
Hg_2I_2	mercury(I) iodide
$Hg_3(AsO_4)_2$	mercury(II) orthoarsenate
$Hg_3(PO_4)_2$	mercury(II) phosphate
IBr	iodine(I) bromide
IBr_3	iodine(III) bromide
ICl	Iodine monochloride
ICl_3	iodine(III) chloride
IO_3^-	iodate ion
I_2	iodine
I_2O_5	iodine pentoxide
I_3^-	triiodide ion
$InAs$	indium(III) arsenide
$InBr$	indium(I) bromide

$InBrI_2$	indium(III) bromodiiodide
$InBr_2I$	indium(III) dibromoiodide
$InBr_3$	indium(III) bromide
InCl	indium(I) chloride
$InCl_2$	indium(II) chloride
$InCl_3$	indium(III) chloride
$InCl_3 \cdot 4H_2O$	indium(III) chloride tetrahydrate
InI	indium(I) iodide
$In(IO_3)_3$	indium(III) iodate
InI_2	indium(II) iodide
InI_3	indium(III) iodide
$In(NO_3)_3 \cdot 4.5H_2O$	indium(III) nitrate tetrahemihydrate
$In(OH)_3$	indium(III) hydroxide
InP	indium(III) phosphide
$InPO_4$	indium(III) orthophosphate
InS	indium(II) sulfide
InSb	indium(III) antimonide
InTe	indium(II) telluride
In_2O_3	indium(III) oxide
$In_2(SO_4)_3 \cdot H_2O$	indium(III) sulfate monohydrate
In_2S_3	indium(III) sulfide
In_2Se_3	indium(III) selenide
In_2Te_3	indium(III) telluride
$IrBr_3$	iridium(III) bromide
$KAl(SO_4)_2$	potassium alum
$KAsO_2$	potassium arsenite
KH_2AsO_4	potassium dihydrogen arsenate
KBr	potassium bromide
KBrO	potassium hypobromite
$KBrO_2$	potassium bromite
$KBrO_3$	potassium bromate
$KBrO_4$	potassium perbromate
KCN	potassium cyanide
KCNO	potassium cyanate
KCNO	potassium fulminate
KCNS	potassium thiocyanate
KCl	potassium chloride
KClO	potassium hypochlorite
$KClO_2$	potassium chlorite
$KClO_3$	potassium chlorate

$KClO_4$	potassium perchlorate
K_2CrO_4	potassium chromate
$K_2Cr_2O_7$	potassium dichromate
K_2HAsO_4	dipotassium hydrogen arsenate
K_2HPO_3	dipotassium phosphite
K_2HPO_4	dipotassium phosphate
K_3AsO_4	potassium arsenate
$K_3C_6H_5O_7$	potassium citrate
K_3PO_3	tripotassium phosphite
K_3PO_4	tripotassium phosphate
KF	potassium fluoride
KOF	potassium hypofluorite
KH	potassium hydride
$KHCO_3$	potassium bicarbonate
KHS	potassium hydrosulfide
$KHSO_3$	potassium bisulfite
$KHSO_4$	potassium bisulfate
KH_2PO_3	monopotassium phosphite
KH_2PO_4	monopotassium phosphate
KI	potassium iodide
KIO	potassium hypoiodite
KIO_2	potassium iodite
KIO_3	potassium iodate
KIO_4	potassium periodate
$KMnO_4$	potassium permanganate
KNO_3	potassium nitrate
KNO_2	potassium nitrite
K_2CO_3	potassium carbonate
K_2MnO_4	potassium manganate
$K_2N_2O_2$	potassium hyponitrite
$KNbO_3$	potassium niobate
K_2O	potassium oxide
K_2O_2	potassium peroxide
K_2S	potassium sulfide
$K_2S_2O_3$	potassium thiosulfate
$K_2S_2O_5$	potassium metabisulfite
$K_2S_2O_8$	potassium persulfate
K_2SO_3	potassium sulfite
K_2SO_4	potassium sulfate
KOH	potassium hydroxide/custic potash

$LaBr_3$	lanthanum(III) bromide
$LaCl_3$	lanthanum(III) chloride
LaI_3	lanthanum(III) iodide
La_2O_3	lanthanum(III) oxide
$La(OH)_3$	lanthanum hydroxide
$LaPO_4$	lanthanum(III) phosphate
$LaPO_4 \cdot 0.5H_2O$	lanthanum(III) phosphate crystal hemihydrate
$LiAlH_4$	lithium aluminium hydride
$Li(AlSi_2O_6)$	keatite
$LiBH_4$	lithium borohydride
$LiBr$	lithium bromide
$LiBr \cdot 2H_2O$	lithium bromide dihydrate
$LiBrO$	lithium hypobromite
$LiBrO_2$	lithium bromite
$LiBrO_3$	lithium bromate
$LiBrO_4$	lithium perbromate
$LiCl$	lithium chloride
$LiClO$	lithium hypochlorite
$LiClO_2$	lithium chlorite
$LiClO_3$	lithium chlorate
$LiClO_4$	lithium perchlorate
$LiCN$	lithium cyanide
$LiCNO$	lithium cyanate
LiC_2H_5O	lithium ethoxide
LiF	lithium fluoride
LiH	lithium hydride
$LiHCO_3$	lithium bicarbonate
$LiHS$	lithium hydrosulfide
$LiHSO_3$	lithium bisulfite
$LiHSO_4$	lithium hydrogen sulfate
LiH_2AsO_4	lithium dihydrogen arsenate
LiH_2PO_3	monolithium phosphite
LiH_2PO_4	monolithium phosphate
LiI	lithium iodide
$LiIO$	lithium hypoiodite
$LiIO_2$	lithium iodite
$LiIO_3$	lithium iodate
$LiIO_4$	lithium periodate
$LiNa$	sodium lithium
$LiNbO_3$	lithium niobate

$LiNO_2$	lithium nitrite
$LiNO_3$	lithium nitrate
$LiNO_3 \cdot H_2O$	lithium nitrate monohydrate
$LiOH$	lithium hydroxide
$LiTaO_3$	lithium tantalate lithium metatantalate
$LiVO_3 \cdot 2H_2O$	lithium metavanadate dihydrate
Li_2HAsO_4	dilithium hydrogen arsenate
$Li_2B_4O_7 \cdot 5H_2O$	lithium tetraborate pentahydrate
Li_2CO_3	lithium carbonate
Li_2CrO_4	lithium chromate
$Li_2CrO_4 \cdot 2H_2O$	lithium chromate dihydrate
$Li_2Cr_2O_7$	lithium dichromate
Li_2HPO_3	dilithium phosphite
Li_2HPO_4	dilithium phosphate
Li_2MoO_4	lithium orthomolybdate
Li_2NbO_3	lithium metaniobate
$Li_2N_2O_2$	lithium hyponitrite
Li_2O	lithium oxide
Li_2O_2	lithium peroxide
Li_2S	lithium sulfide
Li_2SO_3	lithium sulfite
Li_2SO_4	lithium sulfate
Li_2SeO_3	lithium selenite
Li_2SeO_4	lithium selenate
Li_2SiO_3	lithium metasilicate
	lithium orthosilicate
Li_2TeO_3	lithium tellurite
Li_2TeO_4	lithium tellurate
Li_2TiO_3	lithium metatitanate
Li_2WO_4	lithium orthotungstate
Li_2ZrO_3	lithium metazirconate
Li_3AsO_4	trilithium arsenate
Li_3PO_3	trilithium phosphite
Li_3PO_4	trilithium phosphate
$MgBr_2$	magnesium bromide
$Mg(BrO)_2$	magnesium hypobromite
$Mg(BrO_2)_2$	magnesium bromite
$Mg(BrO_3)_2$	magnesium bromate
$Mg(BrO_4)_2$	magnesium perbromate
$Mg(AlO_2)_2$	magnesium aluminate

As_2Mg_3	magnesium arsenide
$MgCO_3$	magnesium carbonate magnesite
MgC_2O_4	magnesium oxalate
$Mg(ClO)_2$	magnesium hypochlorite
$Mg(ClO_2)_2$	magnesium chlorite
$Mg(ClO_3)_2$	magnesium chlorate
$Mg(ClO_3)_2 \cdot xH_2O$	magnesium chlorate hydrate
$Mg(ClO_4)_2$	magnesium perchlorate
$MgCl_2$	magnesium chloride
$MgCrO_4$	magnesium chromate
$MgCrO_4 \cdot 5H_2O$	magnesium chromate pentahydrate
MgF_2	magnesium fluoride
$MgHPO_4$	dimagnesium phosphate
MgI_2	magnesium iodide
$Mg(IO)_2$	magnesium hypoiodite
$Mg(IO_2)_2$	magnesium iodite
$Mg(IO_3)_2$	magnesium iodate
$Mg(IO_4)_2$	magnesium periodate
$MgMoO_4$	magnesium molybdate
$MgNH_4PO_4 \cdot 6H_2O$	magnesium ammonium phosphate hexahydrate
$Mg(NO_2)_2$	magnesium nitrite
$Mg(NO_3)_2$	magnesium nitrate
$Mg(NO_3)_2 \cdot 6H_2O$	magnesium nitrate hexahydrate
$MgNaAl_5(Si_4O_{10})_3(OH)_6$	montmorillonite (clay)
MgO	magnesium oxide magnesia periclase
$Mg(OH)_2$	magnesium hydroxide milk of magnesia
$MgPo$	magnesium polonide
MgS	magnesium sulfide
$MgSO_3$	magnesium sulfite
$MgSO_4$	magnesium sulfate
$MgSe$	magnesium selenide
$MgSeO_3$	magnesium selenite
$MgSeO_4$	magnesium selenate
$MgSiO_3$	magnesium metasilicate enstatite
$MgTiO_3$	magnesium metatitanate

$Mg(VO_3)_2$	magnesium metavanadate
$MgWO_4$	magnesium tungstate
$Mg_2Al(AlSiO_5)(OH)_4$	amesite
$Mg_2P_2O_7$	magnesium pyrophosphate
Mg_2SiO_4	forsterite
Mg_3As_2	magnesium arsenide
Mg_3Bi_2	magnesium bismuthide
Mg_3P_2	magnesium phosphide
$Mg_3(Si_2O_5)(OH)_4$	chrysotile
$Mg_3(Si_4O_{10})(OH)_2$	talc
$Mg_3(VO_4)_2$	magnesium orthovanadate
MnAs	manganese(III) arsenide
MnBi	manganese(III) bismuthide
$MnBr_2$	manganese(II) bromide
$MnBr_2 \cdot 4H_2O$	manganese(II) bromide tetrahydrate
$Mn(CHO_2)_2$	manganese(II) formate
$Mn(CHO_2)_2 \cdot 2H_2O$	manganese(II) formate dihydrate
$MnCO_3$	manganese(II) carbonate
$MnCl_2$	manganese(II) chloride
MnF_2	manganese(II) fluoride
MnI_2	manganese(II) iodide
$MnMoO_4$	manganese(II) orthomolybdate
$Mn(NO_3)_2$	manganese(II) nitrate
$Mn(NO_3)_2 \cdot 4H_2O$	manganese(II) nitrate tetrahydrate
MnO	manganese(II) oxide
$Mn(OH)_2$	manganese hydroxide
MnOOH	manganite
MnO_2	manganese dioxide pyrolusite
MnO_4^-	permanganate ion
$MnPb_8(Si_2O_7)_3$	barysilate
MnS	manganese sulfide
MnTe	manganese(II) telluride
$MnZrO_3$	manganese(II) metazirconate
Mn_2O_3	manganese(III) oxide
Mn_3As_2	manganese(II) arsenide
Mn_3O_4	manganese(II,III) oxide trimanganese tetroxide hausmannite
Mn_3P_2	manganese(II) phosphide
Mn_3Sb_2	manganese(II) antimonide

$MoBr_2$	molybdenum(II) bromide
$MoBr_3$	molybdenum(III) bromide
$MoCl_2$	molybdenum(II) chloride
$MoCl_3$	molybdenum(III) chloride
$MoCl_5$	molybdenum(V) chloride
MoO_2	molybdenum(IV) oxide
MoO_3	Molybdenum trioxide
MoO_4^{2-}	molybdate ion
$MoSe_2$	molybdenum(IV) selenide
MoS_2	molybdenum sulfide molybdenum disulfide molybdenite
NCl_3	nitrogen trichloride
$NHCl_2$	dichloramine
NH_2Cl	monochloramine
NH_2^-	amide ion
$NH_2CH_2CH_2NH_2$	ethylenediamine
NH_2CH_2CN	aminoacetonitrile
NH_2COOH	carbamic acid
NH_2CONH_2	urea
$NH_2C_6H_4SO_3H$	sulfanilic Acid
NH_2OH	hydroxylamine
$(NH_2)_2CO$	urea
NH_3	ammonia
NH_4^+	ammonium ion
$(NH_4)_3N$	ammonium nitride
NH_4Br	ammonium bromide
$NH_4CO_2NH_2$	ammonium carbamate
$(NH_4)_2CO_3$	ammonium carbonate
NH_4Cl	ammonium chloride
NH_4ClO_4	Ammonium perchlorate
NH_4HS	ammonium hydrosulfide
$(NH_4)H_2AsO_4$	ammonium dihydrogen arsenate
NH_4NO_3	ammonium nitrate
NH_4OCONH_2	ammonium carbamate
NH_4OH	ammonium hydroxide
$(NH_4)_2Ce(NO_3)_6$	ammonium cerium(IV) nitrate ceric ammonium nitrate CAN
$(NH_4)_3PO_4$	ammonium phosphate
$(NH_4)_2CrO_4$	ammonium chromate

$(NH_4)_2Hg(SCN)_4$	mercury(II) ammonium thiocyanate
$(NH_4)_2[PtCl_6]$	ammonium hexachloroplatinate(IV)
$(NH_4)_2[Pt(SCN)_6]$	ammonium hexathiocyanoplatinate(IV)
$(NH_4)_2SO_4$	ammonium sulfate
NI_3	nitrogen triiodide
NO	nitric oxide nitrogen oxide nitrogen(II) oxide
NOCl	nitrosyl chloride
NOBr	nitrosyl bromide
NOI	nitrosyl iodide
NO_2	nitrogen dioxide nitrogen(IV) oxide
NO_2^-	nitrite ion
NO_2Cl	nitryl chloride
NO_3^-	nitrate ion
N_2	nitrogen
N_2H_2	diazene
N_2H_4	hydrazine
N_2O	nitrous oxide dinitrogen oxide nitrogen(I) oxide
N_2O_3	dinitrogen trioxide nitrogen(III) oxide
N_2O_4	dinitrogen tetroxide nitrogen(IV) oxide
N_2O_5	dinitrogen pentaoxide nitrogen(V) oxide
N_4H_4	*trans*-tetrazene
$NaAlSi_3O_3$	albite
$NaAsO_2$	sodium metaarsenite
NaH_2AsO_4	sodium dihydrogen arsenate
$NaAu(CN)_2$	sodium dicyanoaurate(I)
$Na_2Cr_2O_7 \cdot 2H_2O$	Sodium dichromate dihydrate
$Na[B(NO_3)_4]$	sodium tetranitratoborate(III)
NaBr	sodium bromide
NaBrO	sodium hypobromite
$NaBrO_2$	sodium bromite
$NaBrO_3$	sodium bromate
$NaBrO_4$	sodium perbromate
NaCN	sodium cyanide

$NaCNO$	sodium cyanate
$NaCNO$	sodium fulminate
NaC_6F_5COO	pentafluorobenzoate
NaC_6H_5COO	sodium benzoate
$NaC_6H_7O_7$	monosodium citrate
$NaCa_2(Al_5Si_5O_{20}) \cdot 6H_2O$	thomsonite
$NaCl$	sodium chloride rock-salt halite
$NaClO_2$	sodium chlorite
$NaClO_3$	sodium chlorate
$NaClO_4$	sodium perchlorate
NaF	sodium fluoride
$NaOF$	sodium hypofluorite
NaH	sodium hydride
$NaHCOO$	sodium formate
$NaHCO_3$	sodium bicarbonate baking soda
$NaHS$	sodium hydrosulfide
$NaHSO_3$	sodium bisulfite
$NaHSO_4$	sodium bisulfate
NaH_2PO_3	monosodium phosphite
NaH_2PO_4	monosodium phosphate
NaI	sodium iodide
$NaIO$	sodium hypoiodite
$NaIO_2$	sodium iodite
$NaIO_3$	sodium iodate
$NaIO_4$	sodium periodate
$NaNH_2C_6H_4SO_3$	sodium sulfanilate
$NaNO_2$	sodium nitrite
$NaNO_3$	sodium nitrate
$NaNbO_3$	sodium metaniobate
$NaNbO_3 \cdot 7H_2O$	sodium metaniobate heptahydrate
$NaOCl$	sodium hypochlorite
$NaOH$	sodium hydroxide
$NaO_2As(CH_3)_2 \cdot 3H_2O$	sodium salt of cacodylic acid
$NaSeO_3$	sodium selenite
$NaTaO_3$	sodium metatantalate
$NaVO_3$	sodium metavanadate
Na_2CO_3	sodium carbonate soda ash

$Na_2C_2O_4$	sodium oxalate
$Na_2C_6H_6O_7$	disodium citrate
Na_2HAsO_4	disodium hydrogen arsenate
Na_2HPO_3	disodium phosphite
Na_2HPO_4	disodium phosphate
Na_2MoS_4	sodium thiomolybdate
$Na_2N_2O_2$	sodium hyponitrite
Na_2O_2	sodium peroxide
Na_2O	sodium oxide
Na_2S	sodium monosulfide
Na_2SO_3	sodium sulfite
Na_2SO_4	sodium sulfate salt cake
$Na_2S_2O_3$	sodium thiosulfate
$Na_2S_2O_5$	sodium disulfite
$Na_2S_2O_8$	sodium persulfate
Na_2S_4	sodium tetrasulfide
Na_2SeO_3	sodium selenite
Na_2SeO_4	sodium selenate
Na_2TeO_3	sodium tellurite
Na_2TeO_4	sodium tellurate
Na_2TiO_3	sodium metatitanate
$Na_2Zn(OH)_4$	sodium zincate
Na_2ZnO_2	sodium zincate
Na_2ZrO_3	sodium metazirconate
Na_3AlF_6	cryolite
Na_3AsO_4	sodium arsenate
$Na_3[Co(CO_3)_3]$	sodium tricarbonatocobaltate(III)
Na_3VO_4	sodium orthovanadate
$Na_3C_6H_5O_7$	trisodium citrate
Na_3PO_3	trisodium phosphite
Na_3PO_4	trisodium phosphate
$Na_4V_2O_7$	sodium pyrovanadate
$NbBr_5$	niobium(V) bromide
$NbCl_3$	niobium(III) chloride
$NbCl_5$	niobium(V) chloride
NbI_5	niobium(V) iodide
Nb_2O_3	niobium(III) oxide
$NdCl_2$	neodymium(II) chloride neodymium dichloride
NdI_2	neodymium(III) iodide

	neodymium diiodide
$Nd(OH)_3$	neodymium hydroxide
Nd_2O_3	neodymium(III) oxide dineodymium trioxide
NiAs	nickel(III) arsenide
NiAsS	nickel arsenic sulfide gersdorffite
$NiBr_2$	nickel(II) bromide
$NiBr_2 \cdot 3H_2O$	nickel(II) bromide trihydrate
$NiBr_2 \cdot 6H_2O$	nickel(II) bromide hexahydrate
$Ni(CO)_3$	nickel(II) carbonate
$Ni(CO)_4$	nickel tetracarbonyl
$NiC_2O_4 \cdot 2H_2O$	nickel(II) oxalate dihydrate
$NiCl_2$	nickel(II) chloride
$NiFe_2O_4$	nickel(II) iron(III) oxide
NiI_2	nickel(II) iodide
$Ni(H_2PO)_2 \cdot 6H_2O$	nickel(II) hypophosphite hexahydrate
$NiMoO_4$	nickel(II) orthomolybdate
$Ni(NO_3)_2 \cdot 6H_2O$	nickel(II) nitrate hexahydrate
NiOOH	nickel oxo-hydroxide
NiO	nickel(II) oxide
$Ni(OH)_2$	nickel(II) hydroxide
NiS	nickel(II) sulfide millerite
$NiSO_4$	nickel sulfate
NiS_2	nickel sulfide
NiSb	nickel antimonide
NiSe	nickel(II) selenide
$NiTiO_3$	nickel(II) metatitanate
$Ni(VO_3)_2$	nickel(II) metavanadate
$NiWO_4$	nickel(II) orthotungstate
Ni_2SiO_4	nickel(II) orthosilicate
$Ni_3(PO_4)_2$	nickel(II) orthophosphate
Ni_3Sb_2	nickel(II) antimonide
O	oxygen
O_2	dioxygen
O_2^-	superoxide ion
O_2^{2-}	peroxide ion
OF_2	oxygen difluoride
O_2F_2	dioxygen difluoride
OH^-	hydroxide ion

O_3	ozone
O_3^-	ozonide ion
PCl_3	phosphorus trichloride
PCl_5	phosphorus pentachloride
$POCl_3$	phosphoryl chloride
P_2I_4	diphosphorus tetraiodide
P_2O_5	phosphorus pentoxide
P_2S_3	diphosphorus trisulfide
P_2Se_3	diphosphorus triselenide
P_3N_5	triphosphorus pentanitride
PH_3	phosphine
$POCl_3$	phosphoryl chloride
$PbCl_2$	lead(II) chloride
$PbCl_4$	lead(IV) chloride
$PbHAsO_4$	lead hydrogen arsenate
PbI_2	lead(II) iodide
$Pb(IO_3)_2$	lead(II) iodate
$Pb(N_3)_2$	lead(II) nitride
$Pb(NO_3)_2$	lead(II) nitrate
$Pb(OH)_2$	lead(II) hydroxide
$Pb(OH)_4$	lead(IV) hydroxide
PbC_2O_4	lead oxalate
$PbCO_3$	lead carbonate
$PbCrO_4$	lead chromate
PbF_2	lead(II) fluoride
PbO	lead(II) oxide
PbO_2	lead dioxide
PbS	lead(II) sulfide
$PbSO_4$	lead(II) sulfate
$PoBr_2$	polonium dibromide
$PoCl_2$	polonium dichloride
$PoCl_4$	polonium tetrachloride
PoF_6	polonium hexafluoride
PoH_2	polonium hydride
PoO	polonium monoxide
PoO_2	polonium dioxide
PoO_3	polonium trioxide
$RaCl_2$	radium chloride
$RbBr$	rubidium bromide
$RbBrO$	rubidium hypobromite

$RbBrO_2$	rubidium bromite
$RbBrO_3$	rubidium bromate
$RbBrO_4$	rubidium perbromate
RbCl	rubidium chloride
RbClO	rubidium hypochlorite
$RbClO_2$	rubidium chlorite
$RbClO_3$	rubidium chlorate
$RbClO_4$	rubidium perchlorate
RbCN	rubidium cyanide
RbCNO	rubidium cyanate
RbCNO	rubidium fulminate
RbF	rubidium fluoride
RbH	rubidium hydride
RbH_2PO_3	monorubidium phosphite
RbH_2PO_4	monorubidium phosphate
RbHS	rubidium hydrosulfide
RbI	rubidium iodide
RbIO	rubidium hypoiodite
$RbIO_2$	rubidium iodite
$RbIO_3$	rubidium iodate
$RbIO_4$	rubidium periodate
RbOH	rubidium hydroxide
Rb_2O	rubidium oxide
Rb_2O_2	rubidium peroxide
Rb_2CO_3	rubidium carbonate
Rb_2S	rubidium sulfide
Rb_2SO_3	rubidium sulfite
Rb_2SO_4	rubidium sulfate
Rb_2HPO_3	dirubidium phosphite
Rb_2HPO_4	dirubidium phosphate
Rb_3PO_3	trirubidium phosphite
Rb_3PO_4	trirubidium phosphate
$RbHCO_3$	rubidium bicarbonate
$RbHSO_3$	rubidium bisulfite
$RbHSO_4$	rubidium bisulfate
$RbNbO_3$	rubidium niobate
$RbNO_2$	rubidium nitrite
$RbNO_3$	rubidium nitrate
RnF_2	radon difluoride
$RuCl_3$	ruthenium(III) chloride

RuF_6	ruthenium hexafluoride
RuO_4	ruthenium tetroxide
SCN^-	thiocyanate
SF_4	sulfur tetrafluoride
SF_6	sulfur hexafluoride
SOF_2	thionyl difluoride
SO_2	sulfur dioxide
SO_2Cl_2	sulfuryl chloride
SO_2F_2	sulfuryl difluoride
SO_2OOH^-	peroxymonosulfurous acid (aqueous)
SO_3	sulfur trioxide
SO_3^{2-}	sulfite ion
SO_4^{2-}	sulfate ion
S_2Br_2	sulfur(II) bromide
$S_2O_3^{2-}$	thiosulfate ion
$S_2O_7^{2-}$	disulfate ion
$SbBr_3$	antimony(III) bromide
$SbCl_3$	antimony(III) chloride
$SbCl_5$	antimony(V) chloride
SbI_3	antimony(III) iodide
$SbPO_4$	antimony(III) phosphate
Sb_2OS_2	antimony oxysulfide kermesite
Sb_2O_3	antimony(III) oxide
Sb_2O_5	antimony(V) oxide
Sb_2S_3	antimony(III) sulfide
Sb_2Se_3	antimony(III) selenide
Sb_2Se_5	antimony(V) selenide
Sb_2Te_3	antimony(III) telluride
Sc_2O_3	scandium oxide scandia
$SeBr_4$	selenium(IV) bromide
$SeCl$	selenium(I) chloride
$SeCl_4$	selenium(IV) chloride
$SeOCl_2$	selenium(IV) oxychloride
$SeOF_2$	selenyl difluoride
SeO_2	selenium(IV) oxide
SeO_4^{2-}	selenate ion
$SeTe$	selenium(IV) telluride
$SiBr_4$	silicon(IV) bromide
SiC	silicon carbide

$SiCl_4$	silicon(IV) chloride
SiH_4	silane
SiI_4	silicon(IV) iodide
SiO_2	silicon(IV) dioxide silica quartz
SiO_4^{4-}	silicate ion
$Si_2O_7^{6-}$	disilicate ion
Si_3N_4	silicon nitride
$Si_6O_{18}^{12-}$	cyclosilicate ion
$SnBrCl_3$	tin(IV) bromotrichloride
$SnBr_2$	tin(II) bromide
$SnBr_2Cl_2$	tin(IV) dibromodichloride
$SnBr_3Cl$	tin(IV) tribromochloride
$SnBr_4$	tin(IV) bromide
$Sn(CH_3COO)_2$	tin(II) acetate
$Sn(CH_3COO)_4$	tin(IV) acetate
$SnCl_2$	tin(II) chloride
$SnCl_2I_2$	tin(IV) dichlorodiiodide
$SnCl_4$	tin(IV) chloride
$Sn(CrO_4)_2$	tin(IV) chromate
SnI_4	tin(IV) iodide
$Sn(OH)_2$	tin(II) hydroxide
$Sn(OH)_4$	tin(IV) hydroxide
SnO	tin(II) oxide
SnO_2	tin(IV) oxide
SnO_3^{2-}	stannate ion
SnS	tin(II) sulfide
SnS_2	tin(IV) sulfide
$Sn(SO_4)_2 \cdot 2H_2O$	tin(IV) sulfate dihydrate
$SnSe$	tin(II) selenide
$SnSe_2$	tin(IV) selenide
$SnTe$	tin(II) telluride
$SnTe_4$	tin(IV) telluride
$Sn(VO_3)_2$	tin(II) metavanadate
Sn_3Sb_4	tin(IV) antimonide
$SrBr_2$	strontium bromide
$SrBr_2 \cdot 6H_2O$	strontium bromide hexahydrate
$SrCO_3$	strontium carbonate
$SrCl_2$	strontium chloride
$Sr(ClO)_2$	strontium hypochlorite

$Sr(ClO_2)_2$	strontium chlorite
$Sr(ClO_3)_2$	strontium chlorate
$Sr(ClO_4)_2$	strontium perchlorate
SrC_2O_4	strontium oxalate
SrF_2	strontium fluoride
$SrHfO_3$	strontium hafnate
$Sr(HS)_2$	strontium hydrosulfide
SrI_2	strontium iodide
$SrI_2 \cdot 6H_2O$	strontium iodide hexahydrate
$Sr(IO)_2$	strontium hypoiodite
$Sr(IO_2)_2$	strontium iodite
$Sr(IO_3)_2$	strontium iodate
$Sr(IO_4)_2$	strontium periodate
$Sr(MnO_4)_2$	strontium permanganate
$SrMoO_4$	strontium orthomolybdate
$Sr(NbO_3)_2$	strontium metaniobate
SrO	strontium oxide
$Sr(OH)_2$	strontium hydroxide
Sr_2RuO_4	strontium ruthenate
SrS	strontium sulfide
$SrSeO_3$	strontium selenite
$SrSeO_4$	strontium selenate
$SrTeO_3$	strontium tellurite
$SrTeO_4$	strontium tellurate
$SrTiO_3$	strontium metatitanate
T_2O	tritium oxide tritiated water
$TaBr_3$	tantalum(III) bromide
$TaBr_5$	tantalum(V) bromide
$TaCl_5$	tantalum(V) chloride
TaI_5	tantalum(V) iodide
TaO_3^-	tantalate ion
TcO_4^-	pertechnetate ion
$TeBr_2$	tellurium(II) bromide
$TeBr_4$	tellurium(IV) bromide
$TeCl_2$	tellurium(II) chloride
$TeCl_4$	tellurium(IV) chloride
TeI_2	tellurium(II) iodide
TeI_4	tellurium(IV) iodide
TeO_2	tellurium(IV) oxide
TeO_4^-	tellurate ion

TeY	yttrium telluride
$Th(CO_3)_2$	thorium carbonate
$Th(NO_3)_4$	thorium nitrate
ThO_2	thorium(IV) oxide
$Th(SO_4)_2$	thorium(IV) sulfate
$TiBr_4$	titanium(IV) bromide
$TiCl_2I_2$	titanium(IV) dichlorodiiodide
$TiCl_3I$	titanium(IV) trichloroiodide
$TiCl_4$	titanium tetrachloride
TiH_2	titanium hydride
TiO_2	titanium dioxide rutile
TiO_3^{2-}	titanate ion
TlBr	thallium(I) bromide
$TlBr_3$	thallium(III) bromide
$Tl(CHO_2)$	thallium(I) formate
$TlC_2H_3O_2$	thallium(I) acetate
$Tl(C_3H_3O_4)$	thalliium(I) malonate
TlCl	thallium(I) chloride
$TlCl_3$	thallium(III) chloride
TlF	thallium(I) fluoride
TlI	thallium(I) iodide
$TlIO_3$	thallium(I) iodate
TlI_3	thallium(III) iodide
TiI_4	titanium(IV) iodide
$TiO(NO_3)_2 \cdot xH_2O$	titanium(IV) oxynitrate hydrate
$TlNO_3$	thallium(I) nitrate
TlOH	thallium(I) hydroxide
$TlPF_6$	thallium(I) hexafluorophosphate
TlSCN	thallium thiocyanate
Tl_2MoO_4	thallium(I) orthomolybdate
Tl_2SeO_3	thallium(I) selenite
Tl_2TeO_3	thallium(I) tellurite
Tl_2WO_4	thallium(I) orthotungstate
Tl_3As	thallium(I) arsenide
$TmCl_3$	thulium(III) chloride
$Tm(NO_3)_3$	thulium(III) nitrate
$Tm_2(SO_4)_3$	thullium(III) sulfate
UBr_2	uranium dibromide
UBr_3	uranium tribromide
UBr_5	uranium pentabromide

UC_2	uranium carbide
UCl_3	uranium trichloride
UCl_4	uranium tetrachloride
UF_4	uranium(IV) fluoride
UF_6	uranium(VI) fluoride
UI_3	uranium(III) iodide
UN	uranium nitride
UO_2	uranium dioxide
$UO_2(CH_3COO)_2$	uranyl acetate
UO_2Cl_2	uranyl chloride
$UO_2(HCOO)_2$	uranyl formate
$UO_2(NO_3)_2$	uranyl nitrate
UO_2SO_4	uranyl sulfate
UO_3	uranium trioxide
U_3O_8	triuranium octoxide
USe_2	uranium diselenide
US_2	uranium sulfide
UTe_2	uranium ditelluride
VBr_2	vanadium(II) bromide
VBr_3	vanadium(III) bromide
VCl_2	vanadium(II) chloride
VCl_3	vanadium(III) chloride
VI_3	vanadium(III) iodide
VN	vanadium nitride
VOC_2O_4	vanadyl oxalate
$VOSO_4$	vanadium oxysulfate
V_2O_3	vanadium(III) oxide
V_2O_5	vanadium pentoxide
$V_2O_7^{4-}$	divanadate ion pyrovanadate ion
WBr_2	tungsten(II) bromide
WBr_3	tungsten(III) bromide
WBr_4	tungsten(IV) bromide
WBr_5	tungsten(V) bromide
WBr_6	tungsten(VI) bromide
$W(CO)_6$	tungsten(VI) carbonyl
WCl_2	tungsten(II) chloride
WCl_3	tungsten(III) chloride
WCl_4	tungsten(IV) chloride
WCl_5	tungsten(V) chloride
WCl_6	tungsten(VI) chloride

WF_4	tungsten(IV) fluoride
WF_5	tungsten(V) fluoride
WF_6	tungsten(VI) fluoride
WI_2	tungsten(II) iodide
WI_4	tungsten(IV) iodide
$WOBr_3$	tungsten(V) oxytribromide
$WOBr_4$	tungsten(VI) oxytetrabromide
$WOCl_3$	tungsten(V) oxytrichloride
$WOCl_4$	tungsten(VI) oxytetrachloride
WOF_4	tungsten(VI) oxytetrafluoride
WO_2	tungsten(IV) oxide
WO_2Br_2	tungsten(VI) dioxydibromide
WO_2Cl_2	tungsten(VI) dioxydichloride
WO_2I_2	tungsten(VI) dioxydiiodide
WO_3	tungsten(VI) oxide
WO_4^{2-}	tungstate ion
WS_2	tungsten(IV) sulfide
WS_3	tungsten(VI) sulfide
WSe_2	tungsten(IV) selenide
WTe_2	tungsten(IV) telluride
WC	tungsten carbide
YAs	yttrium arsenide
YB_6	yttrium boride
YBr_3	yttrium bromide
YC_2	yttrium carbide
YCl_3	yttrium chloride
YF_3	yttrium fluoride
YP	yttrium phosphide
YSb	yttrium antimonide
YVO_4	yttrium vanadate
Y_2O_3	yttria yttrium oxide
Y_2S_3	yttrium sulfide
$YbBr_2$	ytterbium(II) bromide
$YbBr_3$	ytterbium(III) bromide
$YbCl_2$	ytterbium(II)chloride
$YbCl_3$	ytterbium(III) chloride
$YbCl_3 \cdot 6H_2O$	ytterbium(III) chloride hexahydrate
$Yb(ClO_4)_3$	ytterbium(III) perchlorate
YbF_2	ytterbium(II) fluoride
YbF_3	ytterbium(III) fluoride

YbI_2	ytterbium(II) iodide
YbI_3	ytterbium(III) iodide
$YbPO_4$	ytterbium(III) phosphate
YbSe	ytterbium(II) selenide
$YbSi_2$	ytterbium(II) silicide
Yb_2O_3	ytterbium(III) oxide
Yb_2S_3	ytterbium(III) sulfide
Yb_2Se_3	ytterbium(III) selenide
YbTe	ytterbium(II) telluride
$Zn(AlO_2)_2$	zinc aluminate
$Zn(AsO_2)_2$	zinc arsenite
$ZnBr_2$	zinc bromide
$Zn(CN)_2$	zinc cyanide
$ZnCO_3$	zinc carbonate
$Zn(C_8H_{15}O_2)_2$	zinc caprylate
$Zn(ClO_3)_2$	zinc chlorate
$ZnCl_2$	zinc chloride
$ZnCr_2O_4$	zinc chromite
ZnF_2	zinc fluoride
$Zn(IO_3)_2$	zinc iodate
ZnI_2	zinc iodide
$ZnMoO_4$	zinc orthomolybdate
$Zn(NO_2)_2$	zinc nitrite
$Zn(NO_3)_2$	zinc nitrate
$Zn(NbO_3)_2$	zinc metaniobate
ZnO	zinc(II) oxide zinc oxide
ZnO_2	zinc peroxide
$Zn(OH)_2$	zinc hydroxide
$Zn(OH)_4^{2-}$	zincate ion
ZnS	zinc sulfide sphalerite
$Zn(SCN)_2$	zinc thiocyanate
$Zn(SeCN)_2$	zinc selenocyanate
$ZnSO_3$	zinc sulfite
ZnS_2O_3	zinc thiosulfate
$ZnSO_4$	zinc sulfate
ZnSb	zinc antimonide
ZnSe	zinc selenide
$ZnSeO_3$	zinc selenite
$ZnSeO_4$	zinc selenate

$ZnSnO_3$	zinc stannate
$Zn(TaO_3)_2$	zinc metatantalate
ZnTe	zinc telluride
$ZnTeO_3$	zinc tellurite
$ZnTeO_4$	zinc tellurate
$ZnTiO_3$	zinc metatitanate
$Zn(VO_3)_2$	zinc metavanadate
$ZnWO_4$	zinc orthotungstate
$ZnZrO_3$	zinc metazirconate
$Zn_2P_2O_7$	zinc pyrophosphate
Zn_2SiO_4	zinc orthosilicate
$Zn_3(AsO_4)_2$	zinc arsenate
Zn_3As_2	zinc arsenide
Zn_3N_2	zinc nitride
Zn_3P_2	zinc phosphide
$Zn_3(PO_4)_2$	zinc phosphate
Zn_3Sb_2	zinc antimonide
ZrB_2	zirconium boride
$ZrBr_4$	zirconium bromide
ZrC	zirconium carbide
$ZrCl_4$	zirconium tetrachloride
ZrF_4	zirconium fluoride
ZrI_4	zirconium iodide
ZrN	zirconium nitride
$Zr(NO_3)_4$	zirconium(IV) nitrate
$Zr(OH)_4$	zirconium hydroxide
ZrO_2	zirconium dioxide baddeleyite
ZrO_3^{2-}	zirconate ion
ZrP_2	zirconium phosphide
ZrS_2	zirconium sulfide
$ZrSi_2$	zirconium silicide
$ZrSiO_4$	zirconium(IV) silicate
$Zr(SO_4)_2$	zirconium(IV) sulfate
$Zr_3(PO_4)_4$	zirconium phosphate

Ten most common elements in the Milky Way Galaxy estimated spectroscopically

Atomic no	Element	Mass fraction (ppm)
1	Hydrogen	739,000
2	Helium	240,000
8	Oxygen	10,400
6	Carbon	4,600
10	Neon	1,340
26	Iron	1,090
7	Nitrogen	960
14	Silicon	650
12	Magnesium	580
16	Sulfur	440
	Total	999,500

Most abundant nuclides in the Solar System

Nuclide	Atomic mass	Mass fraction in parts per million	Atom fraction in parts per million

Sulfur-32	32	396	16
Sodium-23	23	33	2
Silicon-30	30	23	1
Silicon-29	29	34	2
Silicon-28	28	653	30
Oxygen-16	16	9,592	477
Nitrogen-14	14	1,105	102
Nickel-58	58	49	1
Neon-22	22	208	12
Neon-20	20	1,548	100
Magnesium-26	26	79	4
Magnesium-25	25	69	4
Magnesium-24	24	513	28
Iron-57	57	28	1
Iron-56	56	1,169	27
Iron-54	54	72	2

Hydrogen-2	2	23	15
Hydrogen-1	1	705,700	909,964
Helium-4	4	275,200	88,714
Helium-3	3	35	15
Carbon-13	13	37	4
Carbon-12	12	3,032	326
Calcium-40	40	60	2
Argon-36	36	77	3
Aluminium-27	27	58	3

Electron configurations of the elements

1 H hydrogen: $1s^1$

2 He helium: $1s^2$

3 Li lithium: [He] $2s^1$

4 Be beryllium: [He] $2s^2$

5 B boron: [He] $2s^2$ $2p^1$

6 C carbon: [He] $2s^2$ $2p^2$

7 N nitrogen: [He] $2s^2$ $2p^3$

8 O oxygen: [He] $2s^2$ $2p^4$

9 F fluorine: [He] $2s^2$ $2p^5$

10 Ne neon: [He] $2s^2$ $2p^6$

11 Na sodium: [Ne] $3s^1$

12 Mg magnesium: [Ne] $3s^2$

13 Al aluminium: [Ne] $3s^2$ $3p^1$

14 Si silicon: [Ne] $3s^2$ $3p^2$

15 P phosphorus: [Ne] $3s^2$ $3p^3$

16 S sulfur: [Ne] $3s^2$ $3p^4$

17 Cl chlorine: [Ne] $3s^2$ $3p^5$

18 Ar argon: [Ne] $3s^2$ $3p^6$

19 K potassium: [Ar] $4s^1$

20 Ca calcium: [Ar] $4s^2$

21 Sc scandium: [Ar] $3d^1$ $4s^2$

22 Ti titanium: [Ar] $3d^2$ $4s^2$

23 V vanadium: [Ar] $3d^3$ $4s^2$

24 Cr chromium: [Ar] $3d^5$ $4s^1$

25 Mn manganese: [Ar] $3d^5$ $4s^2$

26 Fe iron: [Ar] $3d^6$ $4s^2$

27 Co cobalt: [Ar] $3d^7$ $4s^2$

28 Ni nickel: [Ar] $3d^8$ $4s^2$ *or* [Ar] $3d^9$ $4s^1$

29 Cu copper: [Ar] $3d^{10}$ $4s^1$

30 Zn zinc: [Ar] $3d^{10}$ $4s^2$

31 Ga gallium: [Ar] $3d^{10}$ $4s^2$ $4p^1$

32 Ge germanium: [Ar] $3d^{10}$ $4s^2$ $4p^2$

33 As arsenic: [Ar] $3d^{10}$ $4s^2$ $4p^3$

34 Se selenium: [Ar] $3d^{10}$ $4s^2$ $4p^4$

35 Br bromine: [Ar] $3d^{10}$ $4s^2$ $4p^5$

36 Kr krypton: [Ar] $3d^{10}$ $4s^2$ $4p^6$

37 Rb rubidium: [Kr] $5s^1$

38 Sr strontium: [Kr] $5s^2$

39 Y yttrium: [Kr] $4d^1$ $5s^2$

40 Zr zirconium: [Kr] $4d^2$ $5s^2$

41 Nb niobium: [Kr] $4d^4$ $5s^1$

42 Mo molybdenum: [Kr] $4d^5$ $5s^1$

43 Tc technetium: [Kr] $4d^5$ $5s^2$

44 Ru ruthenium: [Kr] $4d^7$ $5s^1$

45 Rh rhodium: [Kr] $4d^8$ $5s^1$

46 Pd palladium: [Kr] $4d^{10}$

47 Ag silver: [Kr] $4d^{10}$ $5s^1$

48 Cd cadmium: [Kr] $4d^{10}$ $5s^2$

49 In indium: [Kr] $4d^{10}$ $5s^2$ $5p^1$

50 Sn tin: [Kr] $4d^{10}$ $5s^2$ $5p^2$

51 Sb antimony: [Kr] $4d^{10}$ $5s^2$ $5p^3$

52 Te tellurium: [Kr] $4d^{10}$ $5s^2$ $5p^4$

53 I iodine: [Kr] $4d^{10}$ $5s^2$ $5p^5$

54 Xe xenon: [Kr] $4d^{10}$ $5s^2$ $5p^6$

55 Cs caesium: [Xe] $6s^1$

56 Ba barium: [Xe] $6s^2$

57 La lanthanum: [Xe] $5d^1$ $6s^2$

58 Ce cerium: [Xe] $4f^1$ $5d^1$ $6s^2$

59 Pr praseodymium: [Xe] $4f^3$ $6s^2$

60 Nd neodymium: [Xe] $4f^4$ $6s^2$

61 Pm promethium: [Xe] $4f^5$ $6s^2$

62 Sm samarium: [Xe] $4f^6$ $6s^2$

63 Eu europium: [Xe] $4f^7$ $6s^2$

64 Gd gadolinium: [Xe] $4f^7$ $5d^1$ $6s^2$

65 Tb terbium: [Xe] $4f^9$ $6s^2$

66 Dy dysprosium: [Xe] $4f^{10}$ $6s^2$

67 Ho holmium: [Xe] $4f^{11}$ $6s^2$

68 Er erbium: [Xe] $4f^{12}$ $6s^2$

69 Tm thulium: [Xe] $4f^{13}$ $6s^2$

70 Yb ytterbium: [Xe] $4f^{14}$ $6s^2$

71 Lu lutetium: [Xe] $4f^{14}$ $5d^1$ $6s^2$

72 Hf hafnium: [Xe] $4f^{14}$ $5d^2$ $6s^2$

73 Ta tantalum: [Xe] $4f^{14}$ $5d^3$ $6s^2$

74 W tungsten: [Xe] $4f^{14}$ $5d^4$ $6s^2$

75 Re rhenium: [Xe] $4f^{14}$ $5d^5$ $6s^2$

76 Os osmium: [Xe] $4f^{14}$ $5d^6$ $6s^2$

77 Ir iridium: [Xe] $4f^{14}$ $5d^7$ $6s^2$

78 Pt platinum: [Xe] $4f^{14}$ $5d^9$ $6s^1$

79 Au gold: [Xe] $4f^{14}$ $5d^{10}$ $6s^1$

80 Hg mercury: [Xe] $4f^{14}$ $5d^{10}$ $6s^2$

81 Tl thallium: [Xe] $4f^{14}$ $5d^{10}$ $6s^{2}$ $6p^{1}$

82 Pb lead: [Xe] $4f^{14}$ $5d^{10}$ $6s^{2}$ $6p^{2}$

83 Bi bismuth: [Xe] $4f^{14}$ $5d^{10}$ $6s^{2}$ $6p^{3}$

84 Po polonium: [Xe] $4f^{14}$ $5d^{10}$ $6s^{2}$ $6p^{4}$

85 At astatine: [Xe] $4f^{14}$ $5d^{10}$ $6s^{2}$ $6p^{5}$

86 Rn radon: [Xe] $4f^{14}$ $5d^{10}$ $6s^{2}$ $6p^{6}$

87 Fr francium: [Rn] $7s^{1}$

88 Ra radium: [Rn] $7s^{2}$

89 Ac actinium: [Rn] $6d^{1}$ $7s^{2}$

90 Th thorium: [Rn] $6d^{2}$ $7s^{2}$

91 Pa protactinium: [Rn] $5f^{2}$ $6d^{1}$ $7s^{2}$

92 U uranium: [Rn] $5f^{3}$ $6d^{1}$ $7s^{2}$

93 Np neptunium: [Rn] $5f^{4}$ $6d^{1}$ $7s^{2}$

94 Pu plutonium: [Rn] $5f^{6}$ $7s^{2}$

95 Am americium: [Rn] $5f^{7}$ $7s^{2}$

96 Cm curium: [Rn] $5f^7$ $6d^1$ $7s^2$

97 Bk berkelium: [Rn] $5f^9$ $7s^2$

98 Cf californium: [Rn] $5f^{10}$ $7s^2$

99 Es einsteinium: [Rn] $5f^{11}$ $7s^2$

100 Fm fermium: [Rn] $5f^{12}$ $7s^2$

101 Md mendelevium: [Rn] $5f^{13}$ $7s^2$

102 No nobelium: [Rn] $5f^{14}$ $7s^2$

103 Lr lawrencium: [Rn] $5f^{14}$ $7s^2$ $7p^1$

104 Rf rutherfordium: [Rn] $5f^{14}$ $6d^2$ $7s^2$

105 Db dubnium: [Rn] $5f^{14}$ $6d^3$ $7s^2$

106 Sg seaborgium: [Rn] $5f^{14}$ $6d^4$ $7s^2$

107 Bh bohrium: [Rn] $5f^{14}$ $6d^5$ $7s^2$

108 Hs hassium: [Rn] $5f^{14}$ $6d^6$ $7s^2$

109 Mt meitnerium: [Rn] $5f^{14}$ $6d^7$ $7s^2$

110 Ds darmstadtium: [Rn] $5f^{14}$ $6d^8$ $7s^2$

111 Rg roentgenium: [Rn] $5f^{14}$ $6d^{9}$ $7s^{2}$

112 Cn copernicium: [Rn] $5f^{14}$ $6d^{10}$ $7s^{2}$

113 Nh nihonium: [Rn] $5f^{14}$ $6d^{10}$ $7s^{2}$ $7p^{1}$

114 Fl flerovium: [Rn] $5f^{14}$ $6d^{10}$ $7s^{2}$ $7p^{2}$

115 Mc moscovium: [Rn] $5f^{14}$ $6d^{10}$ $7s^{2}$ $7p^{3}$

116 Lv livermorium: [Rn] $5f^{14}$ $6d^{10}$ $7s^{2}$ $7p^{4}$

117 Ts tennessine: [Rn] $5f^{14}$ $6d^{10}$ $7s^{2}$ $7p^{5}$

118 Og oganesson: [Rn] $5f^{14}$ $6d^{10}$ $7s^{2}$ $7p^{6}$

119 Uue ununennium: [Og] $8s^{1}$

120 Ubn unbinilium: [Og] $8s^{2}$

121 Ubu unbiunium: [Og] $8s^{2}$ $8p^{1}$

122 Ubb unbibium: [Og] $7d^{1}$ $8s^{2}$ $8p^{1}$

123 Ubt unbitrium: [Og] $6f^{1}$ $7d^{1}$ $8s^{2}$ $8p^{1}$

124 Ubq unbiquadium: [Og] $6f^{3}$ $8s^{2}$ $8p^{1}$

125 Ubp unbipentium: [Og] $5g^{1}$ $6f^{3}$ $8s^{2}$ $8p^{1}$

126 Ubh unbihexium: [Og] $5g^2$ $6f^2$ $7d^1$ $8s^2$ $8p^1$

127 Ubs unbiseptium: [Og] $5g^3$ $6f^2$ $8s^2$ $8p^2$

128 Ubo unbioctium: [Og] $5g^4$ $6f^2$ $8s^2$ $8p^2$

129 Ube unbiennium: [Og] $5g^5$ $6f^2$ $8s^2$ $8p^2$

130 Utn untrinilium: [Og] $5g^6$ $6f^2$ $8s^2$ $8p^2$

131 Utu untriunium: [Og] $5g^7$ $6f^2$ $8s^2$ $8p^2$

132 Utb untribium: [Og] $5g^8$ $6f^2$ $8s^2$ $8p^2$

133 Utt untritrium: [Og] $5g^8$ $6f^3$ $8s^2$ $8p^2$

134 Utq untriquadium: [Og] $5g^8$ $6f^4$ $8s^2$ $8p^2$

135 Utp untripentium: [Og] $5g^9$ $6f^4$ $8s^2$ $8p^2$

136 Uth untrihexium: [Og] $5g^{10}$ $6f^4$ $8s^2$ $8p^2$

137 Uts untriseptium: [Og] $5g^{11}$ $6f^3$ $7d^1$ $8s^2$ $8p^2$

138 Uto untrioctium: [Og] $5g^{12}$ $6f^3$ $7d^1$ $8s^2$ $8p^2$

139 Ute untriennium: [Og] $5g^{13}$ $6f^2$ $7d^2$ $8s^2$ $8p^2$

140 Uqn unquadnilium: [Og] $5g^{14}$ $6f^3$ $7d^1$ $8s^2$ $8p^2$

141 Uqu unquadunium: [Og] $5g^{15}$ $6f^{2}$ $7d^{2}$ $8s^{2}$ $8p^{2}$

142 Uqb unquadbium: [Og] $5g^{16}$ $6f^{2}$ $7d^{2}$ $8s^{2}$ $8p^{2}$

143 Uqt unquadtrium: [Og] $5g^{17}$ $6f^{2}$ $7d^{2}$ $8s^{2}$ $8p^{2}$

144 Uqq unquadquadium: [Og] $5g^{18}$ $6f^{1}$ $7d^{3}$ $8s^{2}$ $8p^{2}$

145 Uqp unquadpentium: [Og] $5g^{18}$ $6f^{3}$ $7d^{2}$ $8s^{2}$ $8p^{2}$

146 Uqh unquadhexium: [Og] $5g^{18}$ $6f^{4}$ $7d^{2}$ $8s^{2}$ $8p^{2}$

147 Uqs unquadseptium: [Og] $5g^{18}$ $6f^{5}$ $7d^{2}$ $8s^{2}$ $8p^{2}$

148 Uqo unquadoctium: [Og] $5g^{18}$ $6f^{6}$ $7d^{2}$ $8s^{2}$ $8p^{2}$

149 Uqe unquadennium: [Og] $5g^{18}$ $6f^{6}$ $7d^{3}$ $8s^{2}$ $8p^{2}$

150 Upn unpentnilium: [Og] $5g^{18}$ $6f^{6}$ $7d^{4}$ $8s^{2}$ $8p^{2}$

151 Upu unpentunium: [Og] $5g^{18}$ $6f^{8}$ $7d^{3}$ $8s^{2}$ $8p^{2}$

152 Upb unpentbium: [Og] $5g^{18}$ $6f^{9}$ $7d^{3}$ $8s^{2}$ $8p^{2}$

153 Upt unpenttrium: [Og] $5g^{18}$ $6f^{11}$ $7d^{2}$ $8s^{2}$ $8p^{2}$

154 Upq unpentquadium: [Og] $5g^{18}$ $6f^{12}$ $7d^{2}$ $8s^{2}$ $8p^{2}$

155 Upp unpentpentium: [Og] $5g^{18}$ $6f^{13}$ $7d^{2}$ $8s^{2}$ $8p^{2}$

156 Uph unpenthexium: [Og] $5g^{18}$ $6f^{14}$ $7d^{2}$ $8s^{2}$ $8p^{2}$

157 Ups unpentseptium: [Og] $5g^{18}$ $6f^{14}$ $7d^{3}$ $8s^{2}$ $8p^{2}$

158 Upo unpentoctium: [Og] $5g^{18}$ $6f^{14}$ $7d^{4}$ $8s^{2}$ $8p^{2}$

159 Upe unpentennium: [Og] $5g^{18}$ $6f^{14}$ $7d^{4}$ $8s^{2}$ $8p^{2}$ $9s^{1}$

160 Uhn unhexnilium: [Og] $5g^{18}$ $6f^{14}$ $7d^{5}$ $8s^{2}$ $8p^{2}$ $9s^{1}$

161 Uhu unhexunium: [Og] $5g^{18}$ $6f^{14}$ $7d^{6}$ $8s^{2}$ $8p^{2}$ $9s^{1}$

162 Uhb unhexbium: [Og] $5g^{18}$ $6f^{14}$ $7d^{8}$ $8s^{2}$ $8p^{2}$

163 Uht unhextrium: [Og] $5g^{18}$ $6f^{14}$ $7d^{9}$ $8s^{2}$ $8p^{2}$

164 Uhq unhexquadium: [Og] $5g^{18}$ $6f^{14}$ $7d^{10}$ $8s^{2}$ $8p^{2}$

165 Uhp unhexpentium: [Og] $5g^{18}$ $6f^{14}$ $7d^{10}$ $8s^{2}$ $8p^{2}$ $9s^{1}$

166 Uhh unhexhexium: [Og] $5g^{18}$ $6f^{14}$ $7d^{10}$ $8s^{2}$ $8p^{2}$ $9s^{2}$

167 Uhs unhexseptium: [Og] $5g^{18}$ $6f^{14}$ $7d^{10}$ $8s^{2}$ $8p^{2}$ $9s^{2}$ $9p^{1}$

168 Uho unhexoctium: [Og] $5g^{18}$ $6f^{14}$ $7d^{10}$ $8s^{2}$ $8p^{2}$ $9s^{2}$ $9p^{2}$

169 Uhe unhexennium: [Og] $5g^{18}$ $6f^{14}$ $7d^{10}$ $8s^{2}$ $8p^{3}$ $9s^{2}$ $9p^{2}$

170 Usn unseptnilium: [Og] $5g^{18}$ $6f^{14}$ $7d^{10}$ $8s^{2}$ $8p^{4}$ $9s^{2}$ $9p^{2}$

171 Usu unseptunium: [Og] $5g^{18}$ $6f^{14}$ $7d^{10}$ $8s^{2}$ $8p^{5}$ $9s^{2}$ $9p^{2}$

172 Usb unseptbium: [Og] $5g^{18}$ $6f^{14}$ $7d^{10}$ $8s^{2}$ $8p^{6}$ $9s^{2}$ $9p^{2}$

173 Ust unsepttrium: [Usb] $6g^{1}$

Reactivity series

Metal	Ion	Reactivity	Extraction
Caesium Cs	Cs^{+}	reacts with cold water	electrolysis
Francium Fr	Fr^{+}		
Rubidium Rb	Rb^{+}		
Potassium K	K^{+}		
Sodium Na	Na^{+}		
Lithium Li	Li^{+}		
Barium Ba	Ba^{2+}		
Radium Ra	Ra^{2+}		
Strontium Sr	Sr^{2+}		
Calcium Ca	Ca^{2+}		
Magnesium Mg	Mg^{2+}	reacts very slowly with cold water, but rapidly	

		in boiling water, and very vigorously with acids	
Beryllium Be	Be^{2+}	reacts with acids and steam	
Aluminium Al	Al^{3+}		
Titanium Ti	Ti^{4+}	reacts with concentrated mineral acids	pyrometallurgical extraction using magnesium, or less commonly other alkali metals, hydrogen or calcium in the Kroll process
Manganese Mn	Mn^{2+}	reacts with acids; very poor reaction with steam	smelting with coke
Zinc Zn	Zn^{2+}		
Chromium Cr	Cr^{3+}		aluminothermic reaction
Iron Fe	Fe^{2+}		smelting with coke
Cadmium Cd	Cd^{2+}		
Cobalt Co	Co^{2+}		
Nickel Ni	Ni^{2+}		
Tin Sn	Sn^{2+}		
Lead Pb	Pb^{2+}		
Antimony Sb	Sb^{3+}	may react with some strong oxidizing acids	heat or physical extraction
Bismuth Bi	Bi^{3+}		
Copper Cu	Cu^{2+}	reacts slowly with air	

Tungsten W	W^{3+}	may react with some strong oxidizing acids	
Mercury Hg	Hg^{2+}		
Silver Ag	Ag^{+}		
Gold Au	Au^{3+}[5][6]		
Platinum Pt	Pt^{4+}		

The four fundamental interactions of nature

Property/ Interaction	**Gravitation**	**Electroweak**		**Strong**	
		Weak	**Electromagnetic**	**Fundamental**	**Residual**
Mediating particles	Not yet observed (Graviton hypothesized)	W^+, W^- and Z^0	γ (photon)	Gluons	π, ρ and ω mesons
Affected particles	All particles	Left- handed fermions	Electrically charged	Quarks, gluons	Hadrons
Acts on	Mass, energy	Flavor	Electric charge	Color charge	
Bound states formed	Planets, stars, galaxies, galaxy groups	n/a	Atoms, molecules	Hadrons	Atomic nuclei
Strength at the scale	10^{-41}	10^{-4}	1	60	Not

of quarks (relative to electromagnetism)	(predicted)				applicable to quarks
Strength at the scale of protons/neutrons (relative to electromagnetism)	10^{-36} (predicted)	10^{-7}	1	Not applicable to hadrons	20

Formulas in Chemistry

- **Ideal Gas Law**

The ideal gas law is given by:

$PV = nRT$

where:

P: the absolute pressure of the gas

V: volume of the gas

n: number of moles, which is the ratio of mass and molar mass

R: universal gas constant, which is $R = 8.3145\ J\ mol^{-1}\ K^{-1}$

T: the absolute temperature

- **Henry's Law**

Henry's law is given by:

$p = K \cdot x$

where:

p: partial pressure of the solute

K: Henry's constant

- **Raoult's Law**

Raoult's law is given by:

$$p_i = x_i \cdot p_i{}^*$$

where:

p_i: pressure of component i

x_i: mole fraction in the solution

$p_i{}^*$: vapor pressure of the pure substance i

In a solution with two liquids A and B, if no gas are present, the total vapor pressure is given by:

$$P_{tot} = P_A + P_B$$

where:

P_A: vapor pressure of liquid A

P_B: vapor pressure of liquid B

For an ideal solution of liquids A and B, which obeys Raoult's law over the full range of composition. The total pressure is given by:

$$p_{tot} = x_A\, p_A{}^* + x_B\, p_B{}^*$$

which is equal to:

$$p_{tot} = (1 - x_B)\, p_A{}^* + x_B\, p_B{}^*$$

or

$$p_{tot} = p_A{}^* + x_B\, (p_B{}^* - p_A{}^*)$$

- **Hess' Law**

Hess' Law can be expressed in 3 ways and they are:

For enthalpy we have:

$$\Delta H = \sum \Delta H_{products} - \sum \Delta H_{reactants}$$

For entropy we have:

$$\Delta S = \sum \Delta S_{products} - \sum \Delta S_{reactants}$$

For Gibbs' free energy we have:

$$\Delta G = \sum \Delta G^{O}_{products} - \sum \Delta G^{O}_{reactants}$$

- **Acid and Base**

For a chemical reaction:

$$A + H_2O \leftrightarrow H_3O^+ + B$$

where:

A: acid

B: base

To determine the strength of the acid, we use the acid dissociation constant, which is given by:

$$K_A = \frac{[H_3O^+][B]}{[A]}$$

For a chemical reaction:

$$B + H_2O \leftrightarrow A + HO^-$$

where:

A: acid

B: base

To determine the strength of the base, we use the base dissociation constant, which is given by:

$$K_B = \frac{[OH^-][A]}{[B]}$$

- **pH**

$$pH = -\log_{10}[H^+]$$

$$H_2O \leftrightarrow H^+ + OH^-$$

The dissociation constant:

$$K = \frac{[H^+][OH^-]}{[H_2O]}$$

Here $[H_2O]$ is constant, So, $K\,[H_2O] = [H^+]\,[OH^-] = K_w$

K_w is an ionic product of water and its value is $1{\times}10^{-14}$ at 25°C.

$$[H^+]\,[OH^-] = 1{\times}10^{-14}$$

Pure water dissociates completely and has equal concentration. Thus $[H^+] = [OH^-]$

$$[H^+]\,[H^+] = 1{\times}10^{-14}$$
$$[H^+] = 10^{-7}$$
$$pH = 7$$

Thus, pure water is a neutral solution having pH equal to 7.0.

Acidic soution pH < 7
Basic solution pH > 7

- **Types of Chemical Reaction**

Synthesis

In a synthesis reaction, two or more simple substances combine to form a more complex substance.

$$A+B \rightarrow AB$$

"Two or more reactants giving one product" is another way to identify a synthesis reaction. One example of a synthesis reaction is the combination of iron and sulfur to form iron (II) sulfide:

$$8Fe + S_8 \rightarrow 8FeS$$

Another example is simple hydrogen gas combined with simple oxygen gas to produce a more complex substance, such as water.

Decomposition

A decomposition reaction is when a more complex substance breaks down into its more simple parts. It is thus the opposite of a synthesis reaction, and can be written as:

$$AB \rightarrow A+B$$

One example of a decomposition reaction is the electrolysis of water to make oxygen and hydrogen gas:

$$2H_2O \rightarrow 2H_2 + O_2$$

Single replacement

In a single replacement reaction, a single uncombined element replaces another in a compound; in other words, one element trades places with another element in a compound. These reactions come in the general form of:

$$A+BC \rightarrow AC+B$$

One example of a single displacement reaction is when magnesium replaces hydrogen in water to make magnesium hydroxide and hydrogen gas:

$$Mg+2H_2O \rightarrow Mg(OH)_2 + H_2$$

Double replacement

In a double replacement reaction, the anions and cations of two compounds switch places and form two entirely different compounds. These reactions are in the general form:

$$AB + CD \rightarrow AD + CB$$

For example, when barium chloride ($BaCl_2$) and magnesium sulfate ($MgSO_4$) react, the SO_4^{2-} anion switches places with the $2Cl^-$ anion, giving the compounds $BaSO_4$ and $MgCl_2$. Another example of a double displacement reaction is the reaction of lead(II) nitrate with potassium iodide to form lead(II) iodide and potassium nitrate:

$$Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$$

- Percent difference from theoretical value = $\frac{\text{experimental value – theoretical value}}{\text{theoretical value}} \times 100\%$

- magnification = power of ocular lens × power of objective lens

- molar concentration = $\frac{\text{number of moles (mol)}}{\text{volume (L)}}$

- number of moles = $\frac{\text{mass (g)}}{\text{molar mass }(\frac{\text{g}}{\text{mol}})}$

- percent by volume concentration = $\frac{V_{solute}}{V_{solution}} \times 100\%$

- parts per million = $\frac{m_{solute}}{m_{solution}} \times 10^6$ ppm

$$1 \text{ amu} = 1.66054 \times 10^{-27} \text{ kg} = 931.494 \text{ MeV/c}^2$$

$$1 \text{ MeV} = 1.60 \times 10^{-13} \text{ J}$$

Particle	**Electric Charge (C)**	**Atomic Charge**	**Mass (g)**	**Atomic Mass (Au)**	**Spin**
Protons	$+1.6022 \times 10^{-19}$	+1	1.6726×10^{-24}	1.0073	1/2
Neutrons	0	0	1.6740×10^{-24}	1.0078	1/2
Electrons	-1.6022×10^{-19}	-1	9.1094×10^{-28}	0.00054858	1/2

- **Enthalpy Formula**

Enthalpy is a thermodynamic function that is equal to the total internal energy of the system plus the product of pressure and volume. The equation is as follows:

$$\mathbf{H = E + PV}$$

where H is the enthalpy, E is the energy and PV is the pressure multiplied by the volume.

- **Molality Formula**

$$\text{Molality (m)} = \frac{\text{moles of solute}}{\text{kilograms of solvent}}$$

- **Molar Mass Formula**

$$\text{Molar mass} = \frac{\text{mass (grams)}}{\text{moles}}$$

- **Molarity Formula**

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{Liters of solution}}$$

- **Structural Formula**

Substance	Chemical Formula	Structural Formula
Methane	CH_4	H | H − C – H | H
Carbon Dioxide	CO_2	O = C = O

- **Chemical Equilibrium Formula**

Equilibrium Constant (K):

$$K = \frac{\text{rate constant of forward reaction}}{\text{rate constant of backward reaction}} = \frac{k_1}{k_2}$$

Equilibrium constant in terms of concentration (K_C) is given by

$$K_C = \frac{k_1}{k_2} = \frac{[C]^c\ [D]^d}{[A]^a\ [B]^b}$$

Equilibrium constant in the terms of partial pressure (K_P) is given by

$$K_P = \frac{k_1}{k_2} = \frac{[P_C]^c\ [P_D]^d}{[P_A]^a\ [P_B]^b}$$

The equilibrium constant is in terms of mole fraction (K_x) is given by

$$K_x = \frac{k_1}{k_2} = \frac{[x_C]^c\ [x_D]^d}{[x_A]^a\ [x_B]^b}$$

The Relation between K_P and K_C is given by

$$K_P = K_C\ (RT)^{\Delta n}$$

where: $\Delta n = (c + d) - (a + b)$

Relation between equilibrium constant and standard free energy change

$$\Delta G° = -2.303\ RT \log K$$

where:

$\Delta G°$ = standard free energy change

T = Absolute temperature

R = universal gas constant.

- **Normality Formula**

$$\text{Normality (N)} = \frac{\text{gram equivalent weight}}{\text{liter of solution}}$$

Normality (N) = Molarity (M) × number of equivalents

- **Photosynthesis Formula**

$$6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2$$

- **Boyle's Law Formula**

$$\boldsymbol{P_1V_1 = P_2V_2}$$

where:

P_1 = Initial Pressure (*atm or mmHg*)

V_1 = Initial Volume (*L or mL*)

P_2 = Final Pressure (*atm or mmHg*)

V_2 = Final Volume (*L or mL*)

- **Titration Formula**

$$M_{acid} \times V_{acid} = M_{base} \times V_{base}$$

where:

M_{acid} = Molarity of the acid

V_{acid} = Volume of the acid

M_{base} = Molarity of the base

V_{base} = Volume of the base

- **Charles' Law Formula**

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

where:

T_1 = Initial Temperature (*Kelvin - K*)

V_1 = Initial Volume (*L or mL*)

T_2 = Final Temperature (*Kelvin - K*)

V_2 = Final Volume (*L or mL*)

- **Gay-Lussac's Law Formula**

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

where:

T_1 = Initial Temperature (*Kelvin - K*)

P_1 = Initial Pressure (*atm or mmHg*)

T_2 = Final Temperature (*Kelvin - K*)

P_2 = Final Pressure (*atm or mmHg*)

- **Dilution Formula**

$$M_1 \times V_1 = M_2 \times V_2$$

where:

M_1 = the molarity of the original solution

V_1 = the volume of the original solution

M_2 = the molarity of the diluted solution

V_2 = the volume of the diluted solution

- **Heat of Fusion Formula**

$$H_f = \frac{q}{m}$$

where:

H_f = heat of fusion

q = heat

m = mass

- **Heat of Vaporization Formula**

$$H_v = \frac{q}{m}$$

where:

H_v = heat of vaporization

q = heat

m = mass

- **Lattice Energy Formula**

$$LE = \frac{kQ_1Q_2}{r}$$

LE = lattice energy

$k = 2.31 \times 10^{-19}$ J · nm

Q_1 and Q_2 = numerical ion charges

r = the distance between the ion centers

- **Mass Percent Formula**

$$\text{Mass percent} = \frac{grams\ of\ solute}{grams\ of\ solution} \times 100$$

- **Mole Fraction Formula**

$$\text{Mole fraction } (x_a) = \frac{\text{moles of a}}{\text{total moles}}$$

a = the component that is being identified for mole fraction

- **Osmotic Pressure Formula**

$$\text{Osmotic pressure } (\pi) = \text{MRT}$$

M = the molar concentration of the solution

R = the gas laws constant ($0.0821 \frac{\text{L·atm}}{\text{K·mol}}$)

T = the Kelvin temperature

- **Electric Potential Energy Formula**

$$E_{el} = \frac{kQ_1Q_2}{d}$$

E_{el} = electrostatic potential energy

$k = 8.99 \times 10^9 \frac{\text{J−m}}{\text{C}^2}$

Q_1 and Q_2 = electrical charges on the two particles

d = the distance between the charges

- **Percent Composition Formula**

$$\%\text{ composition} = \frac{grams\ of\ element}{grams\ of\ compund} \times 100$$

- **Rate of Decay Formula**

$$N_t = N_0\, e^{-\lambda t}$$

N_t = the amount of radioactive particles at time (t)

N_0 = the amount of radioactive particles at time = 0

λ = rate of decay constant

t = time

- **Specific Heat Capacity Formula**

$$s = \frac{q}{m \times \Delta T}$$

s = specific heat capacity

q = heat

m = mass

Δ T = change in temperature

- **Vapor Pressure Formula**

$$P_{solution} = x_{solvent} \times P^{o}_{solvent}$$

$P_{solution}$ = the vapor pressure of the solution

$x_{solvent}$ = the mole fraction of the solvent in the solution

$P^{o}_{solvent}$ = the vapor pressure of the pure solvent at standard conditions

- **Degree of unsaturation Formula**

$$\text{Degrees of unsaturation} = \frac{(2 \times \#C) + 2 + \#N - \#H - \#X}{2}$$

where #C, #N, #H, #X mean the number of carbon, nitrogen, hydrogen and halogen atoms present in the molecular formula.

- **Arrhenius equation**

$$k = A\, e^{\frac{-E_a}{RT}}$$

where:

A is the pre-exponential factor for the reaction (that is nearly a constant that depends on the temperature), E_a is the activation energy, R is the gas constant, T is the temperature and k is the reaction rate constant.

- **Boiling point Formula**

$$\Delta H_{vap} = H_{vapor} - H_{liquid}$$

where:

ΔH_{vap} is the change of enthalpy of vaporization, H_{vapor} is the enthalpy or heat of the gas state of a compound and H_{liquid} is the enthalpy of the liquid state of a compound.

- **Avogadro's law Formula**

$$V = k \times n$$

where:

V is the gas volume, n is the number of moles of gas and k is a constant, which is defined as $\frac{RT}{P}$, where R is a constant called the constant of the gases (8.314 JK^{-1} mol^{-1}), T is the temperature in Kelvin and P is the pressure.

- **Dalton's law Formula**

For a mixture of *n* gases, the total pressure is:

$$P_{total} = P_1 + P_2 + P_3 + ... + P_n$$

where P_1, P_2, P_3 ... P_n represent the partial pressure of each gas in the mixture.

- **Ionic strength formula**

$$\text{Ionic strength (I)} = \frac{1}{2}\sum_{1}^{n} C_i\, z_i^2$$

where:

C_i – ionic concentration

Z_i – ion charges

Calculate the ionic strength of KCl if its concentration is 2 M.

Ions	**Z**	**C**	**Z^2**
K^+	1	2	1
Cl^-	1	2	1

The ionic strength is given by

$$I = \frac{1}{2}[(2 \times 1) + (2 \times 1)] = 2$$

- **Percent by volume Formula**

$$\%\ \text{volume} = \frac{volume_{solute}}{volume_{solution}} \times 100\%$$

- **pOH**

$$pOH = -\log[OH^-]$$

For any aqueous solution at 25ºC:

$$pH + pOH = 14$$

- **Complete List of Inorganic Acids**

Acid Name	**Formula**
Acetic Acid	CH_3COOH

Antimonic Acid	$HSbO_3$
Antimonous Acid	H_3SbO_3
Arsenic Acid	H_3AsO_4
Boric Acid	H_3BO_3
Bromic Acid	$HBrO_3$
Bromous Acid	$HBrO_2$
Carbonic Acid	H_2CO_3
Carbonous Acid	H_2CO_2
Chloric Acid	$HClO_3$
Chlorous Acid	$HClO_2$
Chromic Acid	H_2CrO_4
Chromous Acid	H_2CrO_3
Citric Acid	$C_6H_8O_7$
Cyanic Acid	HCNO
Dichromic Acid	$H_2Cr_2O_7$
Disulfurous Acid	$H_2S_2O_5$
Dithionous Acid	$H_2S_2O_4$
Diuranic Acid	$H_2U_2O_7$
Ferricyanic Acid	$H_3[F_3(CN)_6]$
Fluoric Acid	HFO_3
Fluorous Acid	HFO_2
Formic Acid	HCOOH
Hydroarsenic Acid	H_3As
Hydrobromic Acid	HBr
Hydrochloric Acid	HCl
Hydrocyanic Acid	HCN
Hydrofluoric Acid	HF
Hydroiodic Acid	HI
Hydronitric Acid	HN_3
Hydrophosphoric Acid	H_3P
Hydroselenic Acid	H_2Se
Hydrosulfuric Acid	H_2S
Hypobromous Acid	HBrO
Hypocarbonous Acid	H_2CO
Hypochlorous Acid	HClO
Hypochromous Acid	H_2CrO_2
Hypofluorous Acid	HFO

Hypoiodous Acid	HIO
Hyponitrous Acid	HNO
Hypooxalous Acid	$H_2C_2O_2$
Hypophosphoric Acid	$H_4P_2O_6$
Hypophosphous Acid	H_3PO_2
Hyposulfurous Acid	H_2SO_2
Iodic Acid	HIO_3
Iodous Acid	HIO_2
Manganic Acid	H_2MnO_4
Metastannic Acid	H_2SnO_3
Molybdic Acid	H_2MoO_4
Nitric Acid	HNO_3
Nitrous Acid	HNO_2
Oxalic Acid	$H_2C_2O_4$
Percarbonic Acid	H_2CO_4
Perchloric Acid	$HClO_4$
Perchromic Acid	H_2CrO_5
Perfluoric Acid	HFO_4
Periodic Acid	HIO_4
Permanganic Acid	$HMnO_4$
Pernitric Acid	HNO_4
Peroxydisulfuric Acid	$H_2S_2O_8$
Perphosphoric Acid	H_3PO_5
Persulfuric Acid	H_2SO_5
Pertechnetic Acid	$HTcO_4$
Perxenic Acid	H_4XeO_6
Phosphoric Acid	H_3PO_4
Phosphorous Acid	H_3PO_3
Pyroantimonic Acid	$H_4Sb_2O_7$
Pyrophosphoric Acid	$H_4P_2O_7$
Pyrosulfuric Acid	$H_2S_2O_7$
Selenic Acid	H_2SeO_4
Selenous Acid	H_2SeO_3
Silicic Acid	H_2SiO_3
Silicofluoric Acid	H_2SiF_6
Silicous Acid	H_2SiO_2
Sulfuric Acid	H_2SO_4

Sulfurous Acid	H_2SO_3
Telluric Acid	H_6TeO_6
Tellurous Acid	H_2TeO_3
Tetraboric Acid	$H_2B_4O_7$
Tetrathionic Acid	$H_2S_4O_6$
Thiocyanic Acid	HSCN
Thiosulfurous Acid	$H_2S_2O_2$
Titanic Acid	H_2TiO_3
Tungstic Acid	H_2WO_4
Uranic Acid	H_2UO_4
Xenic Acid	H_2XeO_4

- **Complete List of Organic Acids**

Acid Name	**Formula**
Acetylsalicylic Acid	$HC_9H_7O_4$
Ascorbic Acid	$HC_6H_7O_6$
Azelaic Acid	$H_2C_9H_{14}O_4$
Barbituric Acid	$HC_4H_3N_2O_3$
Benzilic Acid	$HC_{14}H_{11}O_3$
Cinnamic Acid	$C_9H_8O_2$
Citric Acid	$H_2C_6H_6O_7$
Folic Acid	$C_{19}H_{19}N_7O_6$
Fumaric Acid	$C_4H_4O_4$
Gallic Acid	$HC_7H_5O_5$
Gluconic Acid	$C_6H_{12}O_7$
Glutamic Acid	$HC_5H_8NO_4$
Glutaric Acid	$C_5H_8O_4$
Hexanoic Acid	$C_5H_{11}COOH$
Lactic Acid	$HC_3H_5O_3$
Malic Acid	$H_2C_4H_4O_5$
Malonic Acid	$CH_2(COOH)_2$
Oleic Acid	$HC_{18}H_{33}O_2$
Phthalic Acid	$H_2C_8H_4O_4$
Propiolic Acid	HC_2COOH

Propionic Acid	CH_3CH_2COOH
Rosolic Acid	$C_{19}H_{14}O_3$
Stearic Acid	$C_{17}H_{35}COOH$
Tannic Acid	$C_{76}H_{52}O_{46}$
Tartartic Acid	$H_2C_4H_4O_6$
Trifluoroacetic Acid	$C_2HF_3O_2$
Uric Acid	$H_2C_5H_2N_4O_3$

Physics Formulas

- **Acceleration Formula**

$$a = \frac{v_f - v_i}{t} = \frac{\Delta v}{t}$$

a = acceleration (m/s^2)

v_f = the final velocity (m/s)

v_i = the initial velocity (m/s)

t = the time in which the change occurs (s)

Δv = short form for "the change in" velocity (m/s)

- **Force Formula**

$$Force = mass \times acceleration$$

$$F = m \times a$$

- **Frequency Formula**

$$\text{Frequency, the cycles in a unit of time} = \frac{\mathbf{1}}{\text{period, the time required for one cycle}}$$

$$\text{Frequency} = \frac{\text{number of cycles}}{time}$$

- **Velocity Formula**

$$\text{Velocity} = \frac{final\ position - initial\ position}{time} = \frac{change\ in\ the\ position}{time}$$

- **Wavelength Formula**

$$\text{Wavelength} = \frac{\text{wave velocity}}{\text{frequency}}$$

- **Angular Velocity Formula**

$$\text{Angular velocity} = \frac{final\ angle - initial\ angle}{time} = \frac{change\ in\ position}{time}$$

- **Displacement Formula**

Displacement = (final position) − (initial position) = change in position

- **Density Formula**

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

- **Kinematic Equations Formula**

$$D = v_i t + \frac{1}{2} at^2$$

$$v_f^2 = v_i^2 + 2aD$$

$$v_f = v_i + at$$

D = displacement

a = acceleration

t = time

v_f = final velocity

v_i = initial velocity

The heaviest element is a hard, brittle, bluish-white transition metal in the platinum group (osmium)

Approximately 20% of our body is carbon.

Lightning can reach temperature greater than 30,000 degrees Celsius.

The hardest substance in the human body is enamel (made mostly of an extremely hard mineral called calcium phosphate)

Rotten eggs float in water

Glass is an amorphous solid that lacks an ordered internal structure

Water is blue because it absorbs colors in the red part of the light spectrum

Dry ice is the solid form of carbon dioxide (CO_2)

If we were to urinate in space, it would vaporize and turn into a gas immediately

- **Tangential Velocity Formula**

$$V_t = \omega\, r$$

V_t = tangential velocity

ω = angular velocity

r = radius of wheel

- **Kinetic Energy Formula**

$$E_k = \frac{1}{2}\, mv^2$$

E_k = Kinetic energy

m = mass

v = velocity

- **Buoyancy Formula**

$$F_b = \rho g V = \rho g h A$$

F_b = buoyant force of a liquid acting on an object (N)

ρ = density of the liquid (kg/m^3)

g = gravitational acceleration ($9.8\ m/s^2$)

V = volume of liquid displaced (m^3 or liters, where $1\ m^3 = 1000\ L$)

h = height of water displaced by a floating object (m)

A = surface area of a floating object (m^2)

- **Efficiency Formula**

$$\text{Efficiency} = \frac{energy\ output}{energy\ input} \times 100\%$$

- **Static Friction Formula**

$$F_s \leq \mu_s\, \eta$$

$$F_s^{max} = \mu_s\, \eta$$

F_s = force of static friction

μ_s = coefficient of static friction

η = normal force

F_s^{max} = maximum force of static friction

- **Potential Energy: Elastic Formula**

$$U = \frac{1}{2} kx^2$$

U = potential energy of a spring at a certain position

k = the spring constant, specific to the spring, with units N/m.

x = distance the spring is stretched or compressed away from equilibrium

- **Tangential Acceleration Formula**

Tangential acceleration = radius of the rotation × angular acceleration

- **Potential Energy: Earth's Gravity Formula**

Potential energy = mass of the object × acceleration due to gravity × height

- **Potential Energy: Electric Potential Formula**

Potential energy = charge of particle × electric potential

- **Potential Energy: Two-Body Gravitation Formula**

$$U = -\frac{Gm_1m_2}{r}$$

U = potential energy of gravity between two objects

G = the universal gravitational constant, G = 6.673×10^{-11} (Nm^2) / kg^2

m_1 = mass of one of the objects

m_2 = mass of the second object

r = the distance between the centers of mass of the two objects

- **Potential Energy: Electrostatic Point Particles Formula**

$$U = -k\frac{q_1 q_2}{r}$$

U = potential energy of electrostatic point particles

k = the Coulomb constant, $k = 8.99 \times 10^9$ Nm^2/C^2 = $\frac{1}{4\pi\varepsilon_0}$

ϵ_0 = the permittivity of free space, $\epsilon_0 = 8.854 \times 10^{-12}$ C^2/ (Nm^2)

q_1 = charge of one of the point particles

q_2 = charge of the other point particle

r = distance between the two point charges

- **Doppler Shift Formula**

$$f = \frac{f_S\,(v + v_L)}{(v - v_L)} \text{ for sound}$$

f = frequency heard by listener

f_S = frequency of the source

v = velocity of sound

v_S = velocity of the source (positive if moving towards listener, negative if moving away from listener)

v_L = velocity of listener (positive if moving toward the source, negative if moving away from the source)

- **Current Density Formula**

$$J = \frac{I}{A}$$

J = current density in amperes/m^2

I = current through a conductor (in amperes)

A = cross-sectional area of the conductor (m^2)

- **Heat Transfer Formula**

Heat transfer = mass × specific heat × temperature change

- **Centripetal Force Formula**

$$F_c = \frac{mv^2}{r}$$

F_c = centripetal force

m = mass

v = velocity

r = radius of circular path

- **Kelvin to Celsius Formula**

$$K = °C + 273.15$$

K = temperature, Kelvin

°C = temperature, degrees Celsius (Centigrade)

- **Acceleration Due to Gravity Formula**

$$g = \frac{Gm}{r^2}$$

g = acceleration due to gravity (units m/s^2)

G = the universal gravitational constant, $G = 6.673 \times 10^{-11}\ (Nm^2) / kg^2$

m = mass of a large body (for example, Earth)

r = the distance from the center of mass of the large body

- **Momentum Formula**

$$\text{Momentum} = \text{mass} \times \text{velocity}$$

- **Power Formula**

$$\text{Power} = \frac{work\ done}{time\ interval}$$

- **Specific Gravity Formula**

$$\text{Specific gravity} = \frac{\text{density of the substance}}{\text{density of water at } 4.0°\text{C}}$$

- **Torque Formula (Moment of Inertia and Angular Acceleration)**

$$\text{Torque} = \text{moment of inertia} \times \text{angular acceleration}$$

- **Spring Constant Formula**

$$F = -kx$$

F = restoring force of the spring (directed toward equilibrium)

k = spring constant (units N/m)

x = displacement of the spring from its equilibrium position

- **Amplitude Formula**

$$x = A\ sin\ (\omega t + \phi)$$

x = displacement (m)

A = amplitude (m)

ω = angular frequency (radians/s)

t = time (s)

ϕ = phase shift (radians)

- **Torque Formula (Force at a Distance)**

Torque = (distance between a center of rotation and a force) × force

- **Tension Formula**

$$T = mg + ma$$

T = tension, N, kg-m/s^2

m = mass, kg

g = gravitational force, 9.8 m/s^2

a = acceleration, m/s^2

- **Centripetal Acceleration Formula**

$$a_c = \frac{v^2}{r}$$

a_c = centripetal acceleration

v = velocity

r = radius of circular path

- **Impulse Formula**

Impulse = Force × time

- **Capacitance Formula**

$$C = \frac{Q}{V}$$

C = capacitance (Farads, *F*)

Q = the charge built up on the capacitor (Coulombs, *C*)

V = voltage difference between two sides of a capacitor (Volts, *V*)

- **Distance Speed Time Formula**

$$\text{Distance} = \text{speed} \times \text{time}$$

- **Orbital Velocity Formula**

$$v_{orbit} = \sqrt{\frac{GM}{R}}$$

G = gravitational constant,

M = mass of the body at centre,

R = radius of the orbit.

- **Resistance Formula**

$$R = \frac{V}{I}$$

R = resistance (Ohms, Ω)

V = voltage difference between the two ends of a resistor (Volts, *V*)

I = the current flowing through a resistor (Amperes, A)

- **Reynold's Number Formula**

$$\text{Reynold's Number} = \frac{\text{inertial force}}{\text{viscous force}}$$

$$\text{Reynold's Number} = \frac{\text{density} \times \text{velocity} \times \text{diameter}}{\text{viscosity}}$$

- **Angular Momentum Formula**

Angular momentum = (distance from the center of rotation) × linear momentum

- **Unit Vector Formula**

$$\text{Unit vector} = \frac{\text{vector}}{\text{magnitude of the vector}}$$

- **Work Formula**

$$W = Fd\cos\theta$$

W = work (units J)

F = force (units N)

d = distance (m)

θ = the angle between the force direction and movement direction

- **Air Resistance Formula**

$$F = kv^2 = \frac{\rho\, C_D\, A}{2} v^2$$

F = force due to air resistance, or drag (N)

k = a constant that collects the effects of density, drag, and area *(kg/m)*

v = the velocity of the moving object (m/s)

ρ = the density of the air the object moves through *(kg/m³)*

C_D = the drag coefficient, includes hard-to-measure effects (unitless)

A = the area of the object the air presses on (m^2)

- **Angular Momentum Formula (Moment of Inertia and Angular Velocity)**

$$\text{Angular Momentum} = \text{moment of inertia} \times \text{angular velocity}$$

- **Center of Mass Formula**

$$\text{Center of Mass} = \frac{\text{sum of all (position} \times \text{mass)}}{\text{sum of all masses}}$$

- **Flow Rate Formula**

$$Q = Av$$

Q = liquid flow rate (*m^3/s or L/s*)

A = area of the pipe or channel (*m^2*)

v = velocity of the liquid (*m/s*)

- **Stopping Distance Formula**

$$d = \frac{v^2}{2\mu g}$$

d = stopping distance (*m*)

v = velocity of the car (*m/s*)

μ = coefficient of friction (unitless)

g = acceleration due to gravity (9.8 m/s^2)

- **Escape Velocity Formula**

$$escape\ velocity = \sqrt{\frac{2GM}{R}}$$

G = universal gravitational constant

M = mass of the planet (kg)

R = radius of the planet (m)

- **Inelastic Collision Formula**

(mass of object 1) (initial velocity 1) + (mass of object 2) (initial velocity 2) = **(mass of object 1 + mass of object 2)** (final velocity of combined objects)

- **Newton's Law of Cooling Formula**

$$T(t) = T_s + (T_0 - T_s)\, e^{-kt}$$

$T(t)$ = temperature of an object at a certain time (Kelvin, K)

t = time (s)

T_s = temperature of the surroundings (Kelvin, K)

T_0 = starting temperature of the object (Kelvin, K)

k = a cooling constant, specific to the object ($1/s$)

- **Pressure Formula**

Pressure = $\frac{F}{A}$, where F is a force, and A is the area it acts on.

$$P = \rho g h$$

P = pressure (Pa)

ρ = density of a gas or fluid (kg/m^3)

g = acceleration due to gravity (9.8 m/s^2)

h = the height of a column of gas or fluid (m)

- **De Broglie Wavelength Formula**

$$\text{de Broglie wavelength} = \frac{\text{The Planck constant}}{\text{momentum}} = \frac{\text{The Planck constant}}{\text{mass} \times \text{velocity}}$$

- **Horizontal Range Formula**

$$R = \frac{v_0^2 \ \sin 2\theta}{g}$$

R = horizontal range (m)

v_0 = initial velocity (m/s)

g = acceleration due to gravity (9.8 m/s^2)

θ = angle of the initial velocity from the horizontal plane (radians or degrees)

- **Maximum Height Formula**

$$H = \frac{v_0^2 \ \sin^2\theta}{2g}$$

H = maximum height (m)

v_0 = initial velocity (m/s)

g = acceleration due to gravity (9.8 m/s^2)

θ = angle of the initial velocity from the horizontal plane (radians or degrees)

- **Rotational Kinetic Energy Formula**

$$\textit{rotational kinetic energy} = \frac{1}{2}\,(\text{moment of inertia}) \times (\text{angular velocity})^2$$

- **Strain Formula (general form)**

$$\text{strain} = \frac{change\ in\ dimension}{original\ value\ of\ dimension}$$

- **Time of Flight Formula**

$$t = \frac{2v_0 \sin\theta}{g}$$

t = time of flight (*s*)

v_0 = initial velocity (*m/s*)

g = acceleration due to gravity (9.8 m/s^2)

θ = angle of the initial velocity from the horizontal plane (radians or degrees)

- **Trajectory Formula**

$$y = x\tan\theta - \frac{gx^2}{2v_0^2\cos^2\theta}$$

y = vertical position (*m*)

x = horizontal position (*m*)

v_0 = initial velocity (combined components, *m/s*)

g = acceleration due to gravity (9.8 m/s^2)

θ = angle of the initial velocity from the horizontal plane (radians or degrees)

- **Capacitors in Parallel Formula**

$$C_{eq} = C_1 + C_2 + C_3 + \dots$$

C_{eq} = equivalent capacitance (F)

C_1 = capacitance of first capacitor (F)

C_2 = capacitance of second capacitor (F)

C_3 = capacitance of third capacitor (F)

- **Capacitors in Series Formula**

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots.$$

C_{eq} = equivalent capacitance (F)

C_1 = capacitance of first capacitor (F)

C_2 = capacitance of second capacitor (F)

C_3 = capacitance of third capacitor (F)

- **Electric Power Formula**

$$\text{electric power} = \text{voltage difference} \times \text{current}$$

- **Resistors in Parallel Formula**

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots.$$

R_{eq} = equivalent resistance (Ω)

R_1 = resistance of first resistor (Ω)

R_2 = resistance of second resistor (Ω)

R_3 = resistance of third resistor (Ω)

- **Resistors in Series Formula**

$$R_{eq} = R_1 + R_2 + R_3 + \ldots$$

R_{eq} = equivalent resistance (Ω)

R_1 = resistance of first resistor (Ω)

R_2 = resistance of second resistor (Ω)

R_3 = resistance of third resistor (Ω)

- **Length Contraction Formula**

$$\text{observed length} = \text{proper length}\sqrt{1-\frac{\text{velocity}^2}{\text{speed of light}^2}}$$

- **Snell's Law Formula**

$$\frac{\sin i}{\sin r} = \text{constant} = n$$

where:

i is the angle of incidence and r is the angle of refraction. This constant value is called the refractive index of the second medium with respect to the first.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

n_1 and n_2 are the two different mediums that will impact the refraction. θ_1 is the angle of incidence; θ_2 is the angle of refraction.

- **Time Dilation Formula**

$$\text{observer time} = \frac{\text{proper time}}{\sqrt{1-\frac{\text{velocity}^2}{\text{speed of light}^2}}}$$

- **Kirchhoff's Junction Rule Formula**

sum of the currents in and out of a circuit junction = 0

$$\sum I = 0$$

I = current, (Amperes, A)

- **Kirchhoff's Loop Rule Formula**

$$\text{sum of voltage differences around a circuit loop} = 0$$

$$\sum V = 0$$

V = voltage difference, (Volts, V)

- **Decibel Formula**

$$\beta = 10 \text{ decibels} \times \log \frac{I}{I_0}$$

β = sound intensity, in decibels (dB)

I = sound intensity (W/m^2)

I_0 = reference sound intensity (10^{-12} W/m^2)

- **Einstein's Mass-Energy Equivalence Formula**

$$\text{Energy} = \text{mass} \times (\text{speed of light})^2$$

- **Kinetic Energy of Gas Formula**

$$\langle KE \rangle = \frac{3}{2} k_B T$$

<KE> = average kinetic energy per molecule of gas (J)

k_B = Boltzmann's constant (1.38×10^{-23} J/K)

T = temperature (K)

- **Impulse-Momentum Theorem Formula**

$$\text{Impulse} = \text{final momentum} - \text{initial momentum}$$

- **Magnetic Field Formula**

$$B = \frac{\mu_0 I}{2\pi r}$$

B = magnetic field magnitude (Tesla, T)

μ_0 = permeability of free space ($4\pi \times 10^{-7}$ Tm/A)

I = magnitude of the electric current (Amperes, A)

r = distance (m)

- **Parallel Axis Theorem Formula**

$$I_P = I_{cm} + Md^2$$

I_P = moment of inertia for rotation around a parallel axis ($kg \cdot m^2$)

I_{cm} = moment of inertia for rotation around an axis through the center of mass ($kg \cdot m^2$)

M = total mass of the object (kg)

d = distance between the two rotation axes (m)

- **Bernoulli's Equation Formula**

$$P + \frac{1}{2} \rho v^2 + \rho g h = \text{constant}$$

P is the pressure exerted by the fluid

v is the velocity of the fluid

ρ is the density of the fluid

h is the height of the container

g is the acceleration due to gravity

- **Drag Formula**

$$F_D = \frac{1}{2} \rho v^2 C_D A$$

F_D: Drag force

ρ: fluid density

v: Relative velocity between the fluid and the object

C_D: Drag coefficient

A: Transversal area or cross sectional area

- **Dynamic Viscosity Formula**

$$\text{Dynamic viscosity} = \frac{\text{Shearing stress}}{\text{Shear rate}}$$

- **Kinematic Viscosity Formula**

$$\text{Kinematic viscosity} = \frac{\text{Dynamic viscosity}}{\text{Fluid mass density}}$$

- **Mass Flow Rate Formula**

$$m = \rho\ v\ A$$

ρ: Density of the fluid

v: Velocity of the fluid

A: Area of the cross section

- **Volume Flow Rate Formula**

$$\text{Volume Flow Rate} = \frac{\text{variation of volume}}{\text{variation of time}}$$

- **Pressure in a Fluid Formula**

$$P = \rho\ g\ h$$

ρ: Density of the fluid

g: Acceleration of gravity

h: Depth of the fluid

- **Bulk modulus Formula**

$$\text{Bulk modulus} = \frac{\text{change in pressure}}{\text{change in volume / original volume}}$$

- **Froude number Formula**

$$\text{Froude number} = \frac{\text{Velocity of the fluid}}{\sqrt{\text{gravitational acceleration} \times \text{depth of flow}}}$$

- **Latent Heat Formula**

$$Q = m\,L$$

Q: Latent heat

m: Mass of the body

L: Specific latent heat coefficient of the material

- **Liquid Expansion Formula**

$$\Delta L = L\,\alpha\,\Delta T$$

ΔL: Expansion of the liquid

L: Length of the liquid before the change of temperature

ΔT: Change of the temperature

α: Coefficient of expansion of the liquid

- **Shear modulus Formula**

$$\text{Shear modulus} = \frac{\text{shear stress}}{\text{strain}}$$

- **Entropy Formula**

$$S = k_B \ln \Omega$$

S: Entropy

k_B: Boltzmann constant. (1.38×10^{-23} J/ K)

Ω: number of microstates.

- **Surface tension Formula**

$$\gamma = \frac{F}{d}$$

γ: Surface tension

F: Force applied on the liquid

d: length along which the force acts

- **Heat Flow Rate Formula**

$$\text{Heat flow} = -\frac{\text{heat transfer coefficient} \times \text{area of the emitting body} \times \text{variation of the temperature}}{\text{length of the material}}$$

- **Maxwell-Boltzmann Distribution Formula**

$$f = \frac{1}{\exp(-E / k_B T)}$$

f: Energy distribution

E: energy of the system

k_B: Boltzmann constant

T: Absolute Temperature in Kelvin.

- **Molecular Speed Formula**

$$v = \sqrt{\frac{3RT}{m}}$$

v: molecular speed

R: Ideal gas constant

T: Absolute Temperature in Kelvin.

m: molar mass

- **Stephan-Boltzmann Law Formula**

$$P = \epsilon\ \sigma\ T^4\ A$$

P: total power radiated

σ: The Stefan-Boltzmann Constant

T: absolute temperature in Kelvin

ϵ: Emissivity of the material.

A: Area of the emitting body

- **Thermodynamic Work Formula**

Thermodynamic work = number of moles × ideal gas constant × change of temperature

- **Wien Displacement Law Formula**

$$\lambda_{max} = \frac{b}{T}$$

λ_{max}: The peak of the wavelength

b: Wien's displacement constant (2.9×10^{-3} m K)

T: Absolute Temperature in Kelvin

- **Capacitor potential energy Formula**

$$U = \frac{1}{2} C V^2$$

C: Capacitance

V: Voltage

U: Energy stored in the capacitor

- **Period of a Pendulum Formula**

$$T = 2\pi \sqrt{\frac{L}{g}}$$

where L represents the length of the pendulum and g is the value of the acceleration of gravity.

- **Work done by gravity Formula**

$$W = m \times g \times h$$

W = work done by gravity

m = mass

g = gravitational acceleration

h = height

- **Weight Formula**

$$\text{Weight} = \text{mass} \times \text{gravitational acceleration}$$

- **Inductance Formula**

$$L = \frac{\Phi N}{I}$$

L = Inductance

Φ = Magnetic flux

N = Number of coil turns

I = current intensity

- **Resonant Frequency Formula**

$$f_r = \frac{1}{2\pi\sqrt{\mathrm{LC}}}$$

f_r: resonant frequency

L: Inductance.

C: capacitance.

- **Intensity Formula**

$$\mathrm{I} = \frac{\mathrm{P}}{\mathrm{S}}$$

I = Intensity

P = power

S = surface perpendicular to the direction of propagation

- **Voltage divider Formula**

$$\mathrm{V_{out}} = \frac{Z_i}{\sum_{i=1}^{n} Z_i}\,\mathrm{V_{in}}$$

V_{out} = output voltage.

Z_i = generic impedance.

$\sum_{i=1}^{n} Z_i$ = the sum from the first to the nth impedance of the circuit.

V_{in} = input voltage.

- **Transformer Formula**

$$V_p \times I_p = V_s \times I_s$$

$$\frac{V_p}{V_s} = \frac{n_p}{n_s}$$

V_p = input voltage on the primary coil.

V_s = input voltage on the secondary coil.

I_p = input current on the primary coil.

I_s = input current on the secondary coil.

n_p = number of turns of wire on the primary coil.

n_s = number of turns of wire on the secondary coil.

- **Speed of sound Formula**

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

v = speed of sound.

γ = the coefficient of adiabatic expansion.

P = the pressure of the gas.

ρ = the density of the medium.

- **Sound intensity Formula**

$$\text{sound intensity} = \frac{\text{acoustic power}}{\text{normal area to the direction of propagation}}$$

- **Friction loss Formula**

$$FL = C \times \left[\frac{Q}{100}\right]^2 \times \frac{L}{100}$$

FL = friction loss.

C = friction loss coefficient.

Q = flow rate.

L = hose length.

- **Archimedes Principle Formula**

$$\text{push} = \text{density of fluid} \times \text{gravitational acceleration} \times \text{volume of object}$$

- **Uncertainty Principle Formula**

$$\Delta x \, \Delta \text{p} \geq \frac{\hbar}{2}$$

$$\Delta \text{E} \, \Delta \text{t} \geq \frac{\hbar}{2}$$

$\hbar$: reduced Planck's constant

Δx: Position uncertainty

Δp: Momentum uncertainty

ΔE: Energy uncertainty

Δt: Time uncertainty

- **Rydberg Formula**

$$\frac{1}{\lambda} = \text{R}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

R: Rydberg's constant (R=1.097 × 10^7 m^{-1})

λ: Wavelength of the emitted photon

n_1 and n_2 are integers and n_2 is always greater than n_1

- **Half-Life Formula**

$$t_{1/2} = \frac{\ln(2)}{\lambda}$$

λ: disintegration constant of the system

$t_{1/2}$: Half life time

- **Relativistic Momentum Formula**

$$\text{Relativistic momentum} = \frac{\text{rest mass} \times \text{velocity}}{\sqrt{1 - \frac{\text{velocity}^2}{\text{speed of light}^2}}}$$

- **Relativistic Mass Formula**

$$\text{Relativistic mass} = \frac{\text{rest mass}}{\sqrt{1 - \frac{\text{velocity}^2}{\text{speed of light}^2}}}$$

- **Relativistic Energy Formula**

$$\text{Relativistic energy} = \frac{\text{rest mass} \times \text{speed of light squared}}{\sqrt{1 - \frac{\text{velocity}^2}{\text{speed of light}^2}}}$$

- **Relativistic Doppler Effect Formula**

$$\text{frequency observed} = \text{frequency emitted} \times \sqrt{\frac{1 + \frac{v}{c}}{1 - \frac{v}{c}}}$$

c: speed of light

v: velocity of the observer respect to the source

- **Relative Velocity Formula**

$$v_{AB} = v_A - v_B$$

v_{AB}: relative velocity of the body A respect body B

v_A: velocity of the body A

v_B: velocity of the body B

- **Photon Energy Formula**

$$E = \frac{hc}{\lambda}$$

E: photon's energy

h: Plank's constant

λ: photon's wavelength

c: speed of light

- **Photoelectric Effect Formula**

photon energy = work function + electron kinetic energy

- **Energy momentum Formula**

$$E = \sqrt{p^2c^2 + (m_0c^2)^2}$$

E: Energy

p: momentum

c: speed of light

m_0: rest mass

- **Ampere's Law Formula**

$$\int B \cdot dl = \mu_0 I$$

B: magnetic field

dl: infinitesimal segment of the integration path

μ_0: vacuum permeability

I: enclosed electric current by the path

- **Motional Electromotive Force Formula**

$$\text{EMF} = v \times B \times L$$

EMF: Electromotive force

v: Velocity of the charge

B: Magnetic field

L: Length of the wire where the charge is moving

- **Magnetic Flux Formula**

Magnetic flux = Magnetic field × Area × (angle between the planar area and the magnetic flux)

- **Induced Electromotive Force Formula**

$$\text{EMF} = -\frac{\Delta\Phi}{\Delta t}$$

EMF: Electromotive force

$\Delta\Phi$: Change of the magnetic flux

Δt: change in time

- **Gauss's Law**

$$\Phi = \frac{Q}{\varepsilon_0}$$

Φ: Electric flux

Q: Enclosed charge by the surface

ϵ_0: absolute permittivity

- **Electric Flux Formula**

$$\Phi = E\ A\ \cos\theta$$

Φ: Electric Flux

A: Area

E: Electric field

θ: angle between a perpendicular vector to the area and the electric field

- **Spherical mirror Formula**

$$\frac{1}{\text{object distance}} + \frac{1}{\text{image distance}} = \frac{1}{\text{focal length}}$$

$$\text{Focal length} \approx \frac{\text{curvature radius}}{2}$$

- **Resistivity-Conductivity Formula**

$$\text{Resistivity} = \frac{1}{\text{conductivity}}$$

- **Image size Formula**

$$\frac{\text{image height}}{\text{object height}} = -\frac{\text{image distance}}{\text{object distance}}$$

- **Electric resistance Formula**

$$R = \rho \frac{L}{A}$$

R: Electric Resistance

ρ: Resistivity

L: Length of the material

A: cross sectional area of the material

- **Moment of Inertia Formula (common shapes)**

Object Type	Formula
Thin rod, axis through the center	$I = \frac{1}{12} ML^2$
Thin rod, axis through one end	$I = \frac{1}{3} ML^2$
Rectangular plate, axis through center	$I = \frac{1}{12} M (a^2 + b^2)$
Rectangular plate, axis along edge	$I = \frac{1}{3} Ma^2$
Hollow cylinder, with a wall thickness	$I = \frac{1}{2} M (R_1^2 + R_2^2)$
Solid cylinder	$I = \frac{1}{2} MR^2$

Thin-walled hollow cylinder	$I = MR^2$
Solid sphere	$I = \frac{2}{5} MR^2$
Thin-walled hollow sphere	$I = \frac{2}{3} MR^2$

I = moment of inertia ($kg \cdot m^2$)

M = total mass of the rotating object (kg)

L = the total length of the rod (m)

a = the length of two sides of the plate (m)

b = the length of the other two sides of the plate (m)

R_1 = the inner radius of the cylinder (m)

R_2 = the outer radius of the cylinder (m)

R = the radius of the cylinder or sphere (m)

- **Rotational Kinematics Formula**

$$\omega = \omega_0 + \alpha t$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$$

$$\omega^2 = \omega_0^2 + 2\alpha (\theta - \theta_0)$$

$$\theta - \theta_0 = \frac{1}{2} (\omega_0 + \omega)t$$

θ_0 is initial angle

θ is final angle

t is the time interval

ω_0 is initial angular velocity

ω is final angular velocity

α is angular acceleration

- **Electric Field**

$$E = \frac{F}{q}$$

E = Electric field (N/C)

F = Force (N)

q = charge (C)

- **Kepler's Third Law**

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

r = radius of motion (m)

T = period of motion (s)

G = universal gravitation constant (6.673×10^{-11} Nm^2 kg^{-2})

M = M_1+M_2 = total mass of system (kg)

- **Magnetic force on a current-carrying wire of length** L **in a magnetic field**

$$F = B \times I \times L$$

F = force (N)

B= Magnetic Field (T)

I = current (A)

L = length (m)

- **Force per unit length**

$$\frac{F}{l} = k\frac{I_1 I_2}{d}$$

F = force (N)

l = length (m) per unit

I_1, I_2 = two currents

d = separation of the two currents (m)

k = magnetic constant (2×10^{-7} $NC^{-1}m^{-1}$)

- **Torque on a coil immersed in a magnetic field**

$$\tau = n \times B \times I \times A \times \cos\theta$$

τ = torque (Nm)

n = number of turns of coil

B = magnetic field (T)

I = current (A)

A = area of coil immersed in magnetic field (m^2)

$\cos\theta$ = angle between the coil and the magnetic field

- **Magnetic force on a charge in a magnetic field**

$$F = q \times v \times \mathrm{B} \times \sin\theta$$

F = force (N)

q = charge (C)

v = velocity (m/s)

B = magnetic field (T)

$\sin\theta$ = angle between the velocity and the magnetic field

- **Acoustic Impedance**

$$Z = \rho \times v$$

Z = Acoustic impedance

ρ = acoustic density

v = speed of sound in medium

- **Astronomical Distance**

$$\mathrm{M} = \mathrm{m} - 5\log(\frac{\mathrm{d}}{10})$$

M = absolute magnitude

m = relative magnitude

d = distance in parsecs

- **Amplifier Gain**

$$\text{Amplifier Gain} = \frac{V_{out}}{V_{in}}$$

V_{out} = output voltage (V)

V_{in} = input voltage (V)

$$\text{Amplifier Gain} = \frac{\text{output voltage}}{\text{positive input voltage} - \text{negative input voltage}}$$

Water expands as it freezes due to the hydrogen bonding in the water.

The taste cells in our taste buds live for only about two weeks.

There are 10 times more bacterial cells in our body than human cells.

The human brain (made up of more than 100 billion nerves that communicate in trillions of connections) uses just as much power as a 10-watt light bulb.

An adult is made up of 7 octillion atoms.

We spend about five years of our lives eating.

Adult humans spend about 33% of their lives asleep. A python spends about 75% of their life, and a dog spends about 44%.

We will eat approximately 35 tons of food in our lifetime.

Emetophobia → The fear of vomiting

Bromidrophobia → The fear of body odors

On average, a person will blink approximately about 12,000 times a day.

- Percentage uncertainty (%) = $\frac{\text{absolute uncertainty}}{\text{measurement}} \times 100$

Heating processes	
Latent heat of fusion for water	$L_f = 3.34 \times 10^5$ J kg^{-1}
Latent heat of vaporization for water	$L_V = 2.26 \times 10^6$ J kg^{-1}
Specific heat capacity of ice	$c_i = 2.05 \times 10^3$ J kg^{-1} K^{-1}
Specific heat capacity of steam	$c_s = 2.00 \times 10^3$ J kg^{-1} K^{-1}
Specific heat capacity of water	$c_w = 4.18 \times 10^3$ J kg^{-1} K^{-1}

Electrical circuits	
Charge on an electron	$e = -1.60 \times 10^{-19}$ C

Waves	
Speed of sound in air at 25 °C	$w_s = 346$ m s^{-1}

- **List of Phytochemicals**

Phytochemicals	Plant Source	Uses
Carotenoids (beta-carotene, lycopene, lutein, zeaxanthin)	Red, orange and green fruits and vegetables including broccoli, carrots, cooked tomatoes, leafy greens, sweet potatoes, winter squash, apricots, cantaloupe, oranges and watermelon.	May inhibit cancer cell growth, work as antioxidants and improve immune response
Flavonoids (anthocyanins, quercetin)	Apples, citrus fruits, onions, soybeans and soy products (tofu, soy milk, edamame, etc.), coffee and tea	May inhibit inflammation and tumor growth; may aid immunity and boost production of detoxifying

		enzymes in the body
Indoles and Glucosinolates (sulforaphane)	Cruciferous vegetables (broccoli, cabbage, collard greens, kale, cauliflower and Brussels sprouts)	May induce detoxification of carcinogens, limit production of cancer-related hormones, block carcinogens and prevent tumor growth
Inositol (phytic acid)	Bran from corn, oats, rice rye and wheat, nuts, soybeans and soy products (tofu, soy milk, edamame, etc.)	May retard cell growth and work as antioxidant
Isoflavones (daidzein, genistein)	Soybeans and soy products (tofu, soy milk, edamame, etc.)	May inhibit tumor growth, limit production of cancer-related hormones and generally work as antioxidant
Isothiocyanates	Cruciferous vegetables (broccoli, cabbage, collard greens, kale, cauliflower and Brussels sprouts)	May induce detoxification of carcinogens, block tumor growth and work as antioxidants
Polyphenols (ellagic acid, resveratrol)	Green tea, grapes, wine, berries, citrus fruits, apples, whole grains and peanuts	May prevent cancer formation, prevent inflammation and work as antioxidants
Terpenes (perillyl alcohol, limonene, carnosol)	Cherries, citrus fruit peel, rosemary	May protect cells from becoming cancerous, slow cancer cell growth, strengthen immune function, limit production of cancer-related hormones, fight viruses, work as antioxidant

- **Refractive index =** $\dfrac{\text{real depth}}{\text{apparent depth}}$

Conics

	Ellipse	**Parabola**	**Hyperbola**	**Rectangular hyperbola**
Standard form	$\frac{x^2}{a^2}+\frac{y^2}{b^2}=1$	$y^2 = 4ax$	$\frac{x^2}{a^2}-\frac{y^2}{b^2}=1$	$xy = c^2$
Asymptotes	none	none	$\frac{x}{a} = \pm\frac{y}{b}$	$x = 0, y = 0$

- The perpendicular distance from (h, k) to $ax + by + c = 0$ is $\dfrac{|ah+bk+c|}{\sqrt{a^2+b^2}}$

- The acute angle between lines with gradients m_1 and m_2 is $\tan^{-1} \left| \dfrac{m_1-m_2}{1+ m_1m_2} \right|$

- The resolved part of a in the direction of b is $\dfrac{a \cdot b}{|b|}$

- The point dividing AB in the ratio $\lambda : \mu$ is $\dfrac{\mu a+\lambda b}{\lambda+ \mu}$

- 1 atm $=1.01\times10^5$ Nm^{-2} =101kPa = 760mmHg

- 1 radian (rad) = $\dfrac{180^o}{\pi}$

- 1 parsec (pc) = 3.26 light year

- If $y = a \pm b$ then $\Delta y = \Delta a + \Delta b$

- If $y = \dfrac{ab}{c}$ then $\dfrac{\Delta y}{y} = \dfrac{\Delta a}{a} + \dfrac{\Delta b}{b} + \dfrac{\Delta c}{c}$

- **Star Colors and Corresponding Approximate Temperatures**

Star Color	Approximate Temperature	Example
Blue	25,000 K	Spica
White	10,000 K	**Vega**
Yellow	6000 K	**Sun**
Orange	4000 K	Aldebaran
Red	3000 K	**Betelgeuse**

- Albedo = $\dfrac{\text{total scattered power}}{\text{total incident power}}$
- dose equivalent = absorbed dose × quality factor
- For small angle θ, measured in radians:

$$\sin\theta \approx \theta$$

$$\cos\theta \approx 1 - \frac{\theta^2}{2}$$

$$\tan\theta \approx \theta$$

- Constructive interference:

$$\text{path difference} = n\lambda$$

- Destructive interference:

$$\text{path difference} = \left(n + \frac{1}{2}\right)\lambda$$

- $T = 2\pi\sqrt{\frac{m}{k}}$

T is the time period of motion

k is the spring constant

m is the mass attached to the spring

Nitrogen Base	Classification	Abbreviation
Adenine	Purine	A
Guanine	Purine	G
Cytosine	Pyrimidine	C
Thymine	Pyrimidine	T
Uracil	Pyrimidine	U

Abbreviations for Some Hormones

Hormone	**Abbreviation**
Adrenocorticotropic hormone	ACTH
Antidiuretic hormone	ADH
Follicle-stimulating hormone	FSH
Gonadotropin-releasing hormone	GnRH
Human chorionic gonadotropin	hCG
Human growth hormone	hGH
Luteinizing hormone	LH
Parathyroid hormone	PTH
Prolactin	PRL
Thyroid-stimulating hormone	TSH

- **Statistical Analysis**

$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$

$s = \sqrt{\frac{\sum(x_i - \bar{x}^2)}{n-1}}$

Standard Error of the Mean = SE = $\frac{s}{\sqrt{n}}$

Chi-Square = $\chi^2 = \sum \frac{(o-e)^2}{e}$

$\bar{x}$ = sample mean

n = sample size

s = sample standard deviation

o = observed results

e = expected results

Σ = sum of all

Hardy-Weinberg Equations

$$p^2 + 2pq + q^2 = 1$$

$$p + q = 1$$

p = frequency of allele 1 in a population

q = frequency of allele 2 in a population

- Water Potential = pressure potential + solute potential
- The Solute Potential of a Solution = $-\, i\, CRT$

  i = ionization constant (1.0 for sucrose because sucrose does not ionize in water)

  C = molar concentration

  R = pressure constant (R = 0.0831 liter bars / mole K)

  T = temperature in Kelvin (ºC + 273)

Simpson's Diversity Index

$$\text{Diversity Index} = \text{I} - \sum \left(\frac{\text{total number of organisms of a particular species}}{\text{total number of organisms of all species}}\right)^2$$

- **Rate and Growth**

Rate

$$\text{Rate} = \frac{\mathrm{dY}}{\mathrm{dt}}$$

Population Growth

$$\frac{\mathrm{dN}}{\mathrm{dt}} = \text{B} - \text{D}$$

Exponential Growth

$$\frac{dN}{dt} = r_{max}\, N$$

Logistic Growth

$$\frac{dN}{dt} = r_{max}\, N \left(\frac{K - N}{N} \right)$$

dY = amount of change

dt = change in time

B =birthrate

D = death rate

N = population size

K = carrying capacity

r_{max} = maximum per capita growth rate of population

Shares and Dividends

- Money invested = number of shares × market value of one share.
- Annual income = number of shares × rate of dividend × face value of one share
- Rate of return = $\frac{\text{annual income}}{\text{investment}} \times 100\ \%$
- Number of shares purchased (or held) = $\frac{\text{investment}}{\text{market value of one share}}$

  $= \frac{\text{annual income}}{\text{income on one share}}$

- Investment = No. of shares × Market value per share
- Sales Proceeds = No. of shares × selling price of each share (Market Value of each share)

Matrices

- Size of Matrix = No. of rows × No. of columns.
- Identity matrix = $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$
- Null matrix = $\begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$
- Matrix $A_{m \times n}$ can only be multiplied with matrix $B_{p \times q}$ if n = p and the resultant matrix will have m rows and q columns i.e. $R_{m \times q}$
- Matrix multiplication is not commutative. (i.e. AB ≠ BA)
- Matrix multiplication is associative.

$$A (BC) = (AB) C$$

- A × I = I × A = A where I is a unit matrix of suitable order.
- A (B + C) = AB + AC (distributive property)
- If AB = AC then B ≠ C, A may or may not be zero.
- Height of water risen = $\frac{\text{Volume of solid immersed}}{\text{Area of base of container}}$
- Time taken to fill a tank = $\frac{\text{Volume of tank}}{\text{Volume of water given by pipe /sec}}$
- Volume of Big Sphere = No. of lead shots × Volume of each lead shot

- Volume = Area of cross section × length (height)

$$1m^3 = 1000 \text{ ltrs} = 10^6 \text{ cm}^3$$

- Probability of certain event = 1
- Probability of an impossible event = 0
- All possible outcomes added = 1
- Sample space denotes all possible outcomes.
- Complementary event

$$P(A) + P(A) = 1$$

$$P(A) = 1 - P(A)$$

- **BODMAS Rule:** This Rule depicts the correct sequence in which the operations are to be executed, so as to find out the value of a given expression.

B – Bracket

O – Of

D – Division

M – Multiplications

A – Addition

S – Subtractions

- Time taken to cross a stationary Engine = $\dfrac{(\text{Length of the train} + \text{Length of engine})}{\text{Speed of the train}}$
- Time taken to Cross a signal Post = $\dfrac{\text{Length of the train}}{\text{Speed of the Train}}$

- Acute angle = $0° – 90°$
- Right Angle = $90°$
- Obtuse angle = $90° – 180°$
- Straight Angle = $180°$
- Reflex Angle = $180° – 360°$
- Complete angle = $360°$
- Complementary Angle = sum of two angles = $90°$
- Supplementary angle = sum of two angles = $180°$
- Right Angle Triangle: One angle $90°$
- Obtuse Angle Triangle: One angle more than $90°$
- Acute Angle Triangle: All angles less than $90°$
- When $AC^2 < AB^2 + BC^2$ (Acute angle triangle)
- When $AC^2 > AB^2 + BC^2$ (Obtuse angle triangle)
- When $AC^2 = AB^2 + BC^2$ (Right angle triangle)
- A median divides triangle into 2 equal parts:

$$2 \times (\text{ median })^2 + 2 \times \left(\frac{1}{2} \text{ the third side }\right)^2 = \text{Sum of the square of other sides}$$

  - The diagonals of a parallelogram bisect each other.
  - Each diagonal of a parallelogram divides it into triangles of the same area.
  - The diagonals of a rectangle are equal and bisect each other.
  - The diagonals of a square are equal and bisect each other at right angles.
  - The diagonals of a rhombus are unequal and bisect each other at right angles.
  - Class Width = $\dfrac{\text{highest value} - \text{lowest value}}{\text{number classes}}$

- Class Midpoint = $\frac{\text{upper limit} + \text{lower limit}}{2}$

- Midrange = $\frac{\text{highest value} + \text{lowest value}}{2}$

- Range = Highest value − Lowest value

- Sample variance = (Sample standard deviation) ^{2}

- Coefficient of Determination = $\frac{\text{explained variation}}{\text{total variation}}$

List of mathematically significant natural numbers

- 1, the multiplicative identity. Also the only natural number (not including 0) that isn't prime or composite.
- 2, the base of the binary number system, used in almost all modern computers and information systems.
- 3, 2^2-1, the first Mersenne prime. It is the first odd prime, and it is also the 2 bit integer maximum value.
- 4, the first composite number
- 6, the first of the series of perfect numbers, whose proper factors sum to the number itself.
- 9, the first odd number that is composite
- 11, the fifth prime and first palindromic multi-digit number in base 10.
- 12, the first sublime number.
- 17, the sum of the first 4 prime numbers, and the only prime which is the sum of 4 consecutive primes.
- 24, all Dirichlet characters mod *n* are real if and only if *n* is a divisor of 24.
- 25, the first centered square number besides 1 that is also a square number
- 27, the cube of 3, the value of 3 $\uparrow\uparrow$ 2, where $\uparrow$ is Knuth's up-arrow notation.

- 28, the second perfect number.
- 30, the smallest sphenic number.
- 32, the smallest nontrivial fifth power.
- 36, the smallest number which is perfect power but not prime power.
- 72, the smallest Achilles number.
- 255, $2^8 - 1$, the smallest perfect totient number that is neither a power of three nor thrice a prime; it is also the largest number that can be represented using an 8-bit unsigned integer
- 341, the smallest base 2 Fermat pseudoprime.
- 496, the third perfect number.
- 1729, the Hardy–Ramanujan number, also known as the second taxicab number; that is, the smallest positive integer that can be written as the sum of two positive cubes in two different ways.
- 8128, the fourth perfect number.
- 142857, the smallest base 10 cyclic number.
- 9814072356, the largest perfect power that contains no repeated digits in base ten.

List of integers notable in computing

- 8, the number of bits in a byte
- 256, The number of possible combinations within 8 bits, or a byte.
- 1024, the number of bytes in a kibibyte. It's also the number of bits in a kibibit.
- 65535, $2^{16} - 1$, the maximum value of a 16-bit unsigned integer.
- 65536, 2^{16}, the number of possible 16-bit combinations.
- 65537, $2^{16} + 1$, the most popular RSA public key prime exponent in most SSL/TLS certificates on the Web/Internet.
- 16777216, 2^{24}, or 16^6; the hexadecimal "million" (0x1000000), and the total number of possible color combinations in 24/32-bit True Color computer graphics.

- 2147483647, $2^{31} - 1$, the maximum value of a 32-bit signed integer using two's complement representation.
- 9223372036854775807, $2^{63} - 1$, the maximum value of a 64-bit signed integer using two's complement representation.

Properties of Water

Heat energy gained during melting . . . . 334 J/g
Heat energy released during freezing . . . . 334 J/g
Heat energy gained during vaporization . . . . . 2260 J/g
Heat energy released during condensation . . . 2260 J/g
Density at 3.98°C . . . . 1.0 g/mL

- Eccentricity = $\frac{\text{distance between foci}}{\text{length of major axis}}$
- Gradient = $\frac{\text{change in field value}}{\text{distance}}$

Average Chemical Composition of Earth's Crust, Hydrosphere, and Troposphere

ELEMENT	CRUST		HYDROSPHERE	TROPOSPHERE
	Percent by mass	Percent by volume	Percent by volume	Percent by volume
Oxygen (O)	46.10	94.04	33.0	21.0
Silicon (Si)	28.20	0.88		
Aluminum (Al)	8.23	0.48		
Iron (Fe)	5.63	0.49		
Calcium (Ca)	4.15	1.18		
Sodium (Na)	2.36	1.11		
Magnesium (Mg)	2.33	0.33		
Potassium (K)	2.09	1.42		
Nitrogen (N)				78.0
Hydrogen (H)			66.0	
Other	0.91	0.07	1.0	1.0

Angle	**0°**	**30°**	**45°**	**60°**	**90°**
sinθ	0	$\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	1
cosθ	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	0
tanθ	0	$\frac{1}{\sqrt{3}}$	1	$\sqrt{3}$	Undefined
cotθ	Undefined	$\sqrt{3}$	1	$\frac{1}{\sqrt{3}}$	0
secθ	1	$\frac{2}{\sqrt{3}}$	$\sqrt{2}$	2	Undefined
cosecθ	Undefined	2	$\sqrt{2}$	$\frac{2}{\sqrt{3}}$	1

Mode is obtained using the modal class:

$$M_o = l + \left(\frac{f_1 - f_0}{2f_1 - f_0 - f_2} \right) h$$

where:

l = lower limit of the modal class,

h = size of the class interval (assuming all class sizes to be equal),

f_1 = frequency of the modal class,

f_0 = frequency of the class preceding the modal class,

f_2 = frequency of the class succeeding in the modal class

Approximate coefficients of friction

Material	Against Material	Static Friction		Kinetic Friction	
		Dry contact	Lubricated contact	Dry contact	Lubricated contact
Aluminium	**Steel**	0.61		0.47	
Aluminum	**Aluminum**	1.05-1.35	0.3	1.4-1.5	
Gold	**Gold**			2.5	
Platinum	**Platinum**	1.2	0.25	3.0	
Silver	**Silver**	1.4	0.55	1.5	
Alumina ceramic	**Silicon Nitride ceramic**				0.004 (wet)
BAM (Ceramic alloy $AlMgB_{14}$)	**Titanium boride (TiB_2)**	0.04-0.05	0.02		
Brass	**Steel**	0.35-0.51	0.19	0.44	
Cast iron	**Copper**	1.05		0.29	
Cast iron	**Zinc**	0.85		0.21	
Concrete	**Rubber**	1.0	0.30 (wet)	0.6-0.85	0.45-0.75 (wet)
Concrete	**Wood**	0.62			
Copper	**Glass**	0.68			
Copper	**Steel**	0.53		0.36	

Glass	**Glass**	0.9-1.0		0.4	
Human synovial fluid	**Cartilage**		0.01		0.003
Ice	**Ice**	0.02-0.09			
Polyethene	**Steel**	0.2	0.2		
PTFE (Teflon)	**PTFE (Teflon)**	0.04	0.04		0.04
Steel	**Ice**	0.03			
Steel	**PTFE (Teflon)**	0.04-0.2	0.04		0.04
Steel	**Steel**	0.74-0.80	0.16	0.42-0.62	
Wood	**Metal**	0.2-0.6	0.2 (wet)		
Wood	**Wood**	0.25-0.5	0.2 (wet)		

The Resistor Colour Code Table

Colour	**Digit**	**Multiplier**	**Tolerance**
Black	0	1	
Brown	1	10	± 1%
Red	2	100	± 2%
Orange	3	1,000	

Yellow	4	10,000	
Green	5	100,000	± 0.5%
Blue	6	1,000,000	± 0.25%
Violet	7	10,000,000	± 0.1%
Grey	8		± 0.05%
White	9		
Gold		0.1	± 5%
Silver		0.01	± 10%
None			± 20%

Resistivities at 20°C

Element	Resistivity at 20 °C (Ω m)
Aluminum	2.82×10^{-8}
Carbon (Graphite)	3.5×10^{-5}
Constantan	4.9×10^{-7}
Copper	1.7×10^{-8}
Germanium	4.6×10^{-1}
Glass	10^{10} to 10^{14}

Gold	2.44×10^{-8}
Iron	1.0×10^{-7}
Lead	2.2×10^{-7}
Manganin	4.82×10^{-7}
Mercury	9.8×10^{-7}
Platinum	1.1×10^{-7}
Quartz (fused)	7.5×10^{17}
Silicon	6.40×10^{2}
Silver	1.59×10^{-8}
Tungsten	5.6×10^{-8}

Properties of Minerals

Property	Description	Example of Mineral
Fluorescence	Mineral glows under ultraviolet light	Fluorite
Magnetism	Mineral is attracted to a magnet	Magnetite
Radioactivity	Mineral gives off radiation that can be measured with Geiger counter	Uraninite
Reactivity	Bubbles form when mineral is exposed to a weak acid	Calcite
Smell	Some minerals have a distinctive smell	Sulfur (smells like rotten eggs)
Taste	Some minerals taste salty	Halite

Etymology of period names

Period	Started	Root word	Meaning	Reason for name
Siderian	c.2500 Ma	Greek *sideros*	iron	the banded iron formations
Rhyacian	c.2300 Ma	Gk. *rhyax*	lava flow	much lava flowed
Orosirian	c.2050 Ma	Gk. *oroseira*	mountain range	much orogeny in this period's latter half
Statherian	c.1800 Ma	Gk. *statheros*	steady	continents became stable cratons
Calymmian	c.1600 Ma	Gk. *calymma*	cover	platform covers developed or expanded
Ectasian	c.1400 Ma	Gk. *ectasis*	stretch	platform covers expanded
Stenian	c.1200 Ma	Gk. *stenos*	narrow	much orogeny, which survives as **narrow** metamorphic belts
Tonian	c.1000 Ma	Gk. *tonos*	stretch	The continental crust stretched as Rodinia broke up
Cryogenian	c.720 Ma	Gk. *cryogenicos*	cold-making	In this period all the Earth froze over
Ediacaran	c.635 Ma	Ediacara Hills	stony ground	place in Australia where the Ediacaran biota fossils were found
Cambrian	c.541 Ma	Latin *Cambria*	Wales	the place in Great

				Britain where Cambrian rocks are best exposed
Ordovician	c.485.4 Ma	Celtic *Ordovices*		Tribe in north Wales, where the rocks were first identified
Silurian	c.443.8 Ma	Ctc. *Silures*		Tribe in south Wales, where the rocks were first identified
Devonian	c.419.2 Ma	Devon		County in England in which rocks from this period were first identified
Carboniferous	c.358.9 Ma	Lt. *carbo*	coal	Global coal beds were laid in this period
Permian	c.298.9 Ma	Perm Krai		Region in Russia where rocks from this period were first identified
Triassic	c.251.902 Ma	Lt. *trias*	triad	In Germany this period forms three distinct layers
Jurassic	c.201.3 Ma	Jura Mountains		Mountain range in the Alps in which rocks from this period were first identified
Cretaceous	c.145 Ma	Lt. *creta*	chalk	More chalk formed in this period than any other
Paleogene	c.66 Ma	Gk. *palaiogenos*	"ancient born"	

Neogene	c.23.03 Ma	Gk. *neogenos*	"new born"	
Quaternary	c.2.58 Ma	Lt. *quaternarius*	"fourth"	This was initially deemed the "fourth" period after the now-obsolete "primary", "secondary" and "tertiary" periods.

Abbreviations yr and ya

Non-SI abbreviation	Short for...	SI-prefixed equivalent	Comments and examples
kyr	kilo years	ka	• Thousand years
myr *Myr*	million years Mega years	Ma	• Million years
byr	billion years	Ga	• Billion years (thousand million years)
kya	kilo years ago	ka ago	• Appearance of *Homo sapiens*, *circa* 200 kya • Out-of-Africa migration, *circa* 60 kya • Last Glacial Maximum, *circa* 20 kya • Neolithic Revolution, *circa* 10 kya
mya *Mya*	million years ago Mega years ago	Ma ago	• Pliocene, 5.3 to 2.6 mya

			◦ The last geomagnetic reversal was 0.78 mya ◦ The (Eemian Stage) Ice Age started 0.13 mya • The Holocene started 0.01 mya
bya *Gya*	billion years ago giga years ago	Ga ago	• oldest Eukaryotes, 2 bya • formation of the Earth, 4.5 bya • Big Bang, 13.8 bya

Ionization Energies (1st, 2nd, 3rd and 4th) of Gaseous Atoms (kJ/mol)

Atomic number		First	Second	Third	Fourth
1	H	1,312			
2	He	2,372	5,251		
3	Li	520.3	7,298	11,815	
4	Be	899.5	1,757	14,849	21,007
5	B	800.7	2,427	3,660	25,026
6	C	1,086	2,353	4,621	6,223
7	N	1,402	2,856	7,475	9,445
8	O	1,314	3,388	5,301	7,469
9	F	1,681	3,374	6,051	8,408
10	Ne	2,081	3,952	6,122	9,370
11	Na	495.9	4,563	6,913	9,544
12	Mg	737.8	1,451	7,733	10,541
13	Al	577.6	1,817	2,745	11,578
14	Si	786.5	1,577	3,232	4,356
15	P	1,012	1,903	2,912	4,957
16	S	999.6	2,251	3,361	4,564
17	Cl	1,251	2,297	3,822	5,158
18	Ar	1,521	2,666	3,931	5,771
19	K	418.9	3,051	4,412	5,877
20	Ca	589.8	1,145	4,912	6,474

21	Sc	631	1,235	2,389	7,089
22	Ti	658	1,310	2,653	4,175
23	V	650	1,414	2,828	4,507
24	Cr	652.9	1,592	2,987	4,740
25	Mn	717.4	1,509	3,249	4,940
26	Fe	759.4	1,561	2,958	5,290
27	Co	758	1,646	3,232	4,950
28	Ni	736.7	1,753	3,394	5,300
29	Cu	745.5	1,958	3,554	5,330
30	Zn	906.4	1,733	3,833	5,730
31	Ga	578.8	1,979	2,963	6,200
32	Ge	762.2	1,537	3,302	4,411
33	As	947	1,798	2,736	4,837
34	Se	941	2,045	2,974	4,144
35	Br	1,140	2,100	3,500	4,560
36	Kr	1,351	2,368	3,565	5,070
37	Rb	403	2,632	3,900	5,080
38	Sr	549.5	1,064	4,210	5,500
39	Y	616	1,181	1,980	5,960
40	Zr	660	1,267	2,218	3,313
41	Nb	664	1,382	2,416	3,700
42	Mo	685	1,558	2,621	4,480
43	Tc	702	1,472	2,850	
44	Ru	711	1,617	2,747	
45	Rh	720	1,745	2,997	
46	Pd	805	1,875	3,177	
47	Ag	731	2,074	3,361	
48	Cd	867.7	1,631	3,616	
49	In	558.3	1,821	2,705	5,200
50	Sn	708.6	1,412	2,943	3,930
51	Sb	833.8	1,595	2,440	4,260
52	Te	869.3	1,790	2,698	3,610
53	I	1,008	1,846	3,200	
54	Xe	1,170	2,047	3,100	
55	Cs	375.7	2,420		
56	Ba	502.9	965.3		
57	La	538.1	1,067	1,850	4,820

58	Ce	527.4	1,047	1,949	3,547
59	Pr	523.2	1,018	2,086	3,761
60	Nd	529.6	1,035	2,130	3,899
61	Pm	535.9	1,052	2,150	3,970
62	Sm	543.3	1,068	2,260	3,990
63	Eu	546.7	1,085	2,405	4,110
64	Gd	592.6	1,167	1,991	4,250
65	Tb	564.7	1,112	2,114	3,839
66	Dy	571.9	1,126	2,200	4,001
67	Ho	580.7	1,139	2,204	4,100
68	Er	588.7	1,151	2,194	4,115
69	Tm	596.7	1,163	2,544	4,119
70	Yb	603.4	1,176	2,415	4,220
71	Lu	523.6	1,340	2,022	4,360
72	Hf	680	1,440	2,250	3,215
73	Ta	761			
74	W	770			
75	Re	760			
76	Os	840			
77	Ir	880			
78	Pt	870	1,791		
79	Au	890.1	1,980		
80	Hg	1,007	1,810	3,300	
81	Tl	589.4	1,971	2,878	
82	Pb	715.6	1,450	3,082	4,083
83	Bi	703.3	1,610	2,466	4,370
84	Po	812			
85	At	890			
86	Rn	1,037			
87	Fr	384			
88	Ra	509.4	971.9		
89	Ac	499			
90	Th	587			
91	Pa	568			
92	U	584			
93	Np	597			
94	Pu	585			

95	Am	578			
96	Cm	581			
97	Bk	601			
98	Cf	608			
99	Es	619			
100	Fm	627			
101	Md	635			
102	No	642			

Ionic radii

Ionic Radius		Name	Symbol	Atomic number
0.012 Å	1.2 pm	Hydrogen	H	1
0.13 Å	13 pm	Nitrogen	N	7
0.23 Å	23 pm	Boron	B	5
0.35 Å	35 pm	Beryllium	Be	4
0.38 Å	38 pm	Phosphorus	P	15
0.4 Å	40 pm	Silicon	Si	14
0.46 Å	46 pm	Manganese	Mn	25
0.5 Å	50 pm	Selenium	Se	34
0.52 Å	52 pm	Uranium	U	92
0.52 Å	52 pm	Chromium	Cr	24
0.53 Å	53 pm	Germanium	Ge	32
0.535 Å	53.5 pm	Aluminum	Al	13
0.56 Å	56 pm	Rhenium	Re	75
0.56 Å	56 pm	Technetium	Tc	43
0.58 Å	58 pm	Arsenic	As	33
0.59 Å	59 pm	Vanadium	V	23
0.605 Å	60.5 pm	Titanium	Ti	22
0.62 Å	62 pm	Tungsten	W	74
0.62 Å	62 pm	Gallium	Ga	31
0.625 Å	62.5 pm	Platinum	Pt	78
0.625 Å	62.5 pm	Iridium	Ir	77
0.63 Å	73 pm	Osmium	Os	76
0.64 Å	64 pm	Tantalum	Ta	73

0.645 Å	64.5 pm	Iron	Fe	26
0.65 Å	65 pm	Molybdenum	Mo	42
0.68 Å	68 pm	Rhodium	Rh	45
0.68 Å	68 pm	Ruthenium	Ru	44
0.69 Å	69 pm	Nickel	Ni	28
0.69 Å	69 pm	Niobium	Nb	41
0.69 Å	69 pm	Tin	Sn	50
0.71 Å	71 pm	Hafnium	Hf	72
0.72 Å	72 pm	Zirconium	Zr	40
0.72 Å	72 pm	Magnesium	Mg	12
0.73 Å	73 pm	Copper	Cu	29
0.74 Å	74 pm	Zinc	Zn	30
0.745 Å	74.5 pm	Cobalt	Co	27
0.745 Å	74.5 pm	Scandium	Sc	21
0.75 Å	75 pm	Neptunium	Np	93
0.76 Å	76 pm	Lithium	Li	3
0.76 Å	76 pm	Antimony	Sb	51
0.78 Å	78 pm	Protactinium	Pa	91
0.8 Å	80 pm	Indium	In	49
0.848 Å	84.8 pm	Lutetium	Lu	71
0.85 Å	85 pm	Gold	Au	79
0.858 Å	85.8 pm	Ytterbium	Yb	70
0.86 Å	86 pm	Palladium	Pd	46
0.869 Å	86.9 pm	Thulium	Tm	69
0.881 Å	88.1 pm	Erbium	Er	68
0.887 Å	88.7 pm	Plutonium	Pu	94
0.9 Å	90 pm	Yttrium	Y	39
0.901 Å	90.1 pm	Holmium	Ho	67
0.912 Å	91.2 pm	Dysprosium	Dy	66
0.923 Å	92.3 pm	Terbium	Tb	65
0.925 Å	92.5 pm	Einsteinium	Es	99
0.934 Å	93.4 pm	Californium	Cf	98
0.938 Å	93.8 pm	Gadolinium	Gd	64
0.947 Å	94.7 pm	Europium	Eu	63
0.949 Å	94.9 pm	Berkelium	Bk	97
0.964 Å	96.4 pm	Samarium	Sm	62

0.97 Å	97 pm	Curium	Cm	96
0.97 Å	97 pm	Tellurium	Te	52
0.97 Å	97 pm	Cadmium	Cd	48
0.972 Å	97.2 pm	Thorium	Th	90
0.979 Å	97.9 pm	Promethium	Pm	61
0.982 Å	98.2 pm	Americium	Am	95
0.99 Å	99 pm	Calcium	Ca	20
0.995 Å	99.5 pm	Neodymium	Nd	60
1.013 Å	101.3 pm	Praseodymium	Pr	59
1.02 Å	102 pm	Mercury	Hg	80
1.02 Å	102 pm	Sodium	Na	11
1.03 Å	103 pm	Bismuth	Bi	83
1.034 Å	103.4 pm	Cerium	Ce	58
1.061 Å	106.1 pm	Lanthanum	La	57
1.1 Å	110 pm	Nobelium	No	102
1.119 Å	111.9 pm	Actinium	Ac	89
1.12 Å	112 pm	Strontium	Sr	38
1.19 Å	119 pm	Lead	Pb	82
1.26 Å	126 pm	Silver	Ag	47
1.33 Å	133 pm	Fluorine	F	9
1.35 Å	135 pm	Barium	Ba	56
1.38 Å	138 pm	Potassium	K	19
1.4 Å	140 pm	Oxygen	O	8
1.43 Å	143 pm	Radium	Ra	88
1.5 Å	150 pm	Thallium	Tl	81
1.52 Å	152 pm	Rubidium	Rb	37
1.67 Å	167 pm	Cesium	Cs	55
1.8 Å	180 pm	Francium	Fr	87
1.81 Å	181 pm	Chlorine	Cl	17
1.84 Å	184 pm	Sulfur	S	16
1.96 Å	196 pm	Bromine	Br	35
2.2 Å	220 pm	Iodine	I	53
2.3 Å	230 pm	Polonium	Po	84

States of Matter and Appearance of Halogens at Room Temperature

States of Matter (at Room Temperature)	Halogen	Appearance
Solid	Iodine	Violet
Solid	Astatine	Black/Metallic [Assumed]
Liquid	Bromine	Reddish-Brown
Gas	Fluorine	Pale Yellow-Brown
Gas	Chlorine	Pale Green

The gyromagnetic ratios for several common nuclei

Nuclei	Spin	Gyromagetic Ratio (MHz/T)	Natural Abundance (%)
^{1}H	$\frac{1}{2}$	42.576	99.9985
^{13}C	$\frac{1}{2}$	10.705	1.07
^{31}P	$\frac{1}{2}$	17.235	100
^{27}Al	$\frac{5}{2}$	11.103	100
^{23}Na	$\frac{3}{2}$	11.262	100
^{7}Li	$\frac{3}{2}$	16.546	92.41
^{29}Si	$\frac{1}{2}$	-8.465	4.68
^{17}O	$\frac{5}{2}$	5.772	0.038

^{15}N	$\frac{1}{2}$	-4.361	0.368

COMMON ISOTOPE PAIRS CHART

Isotope		Half-life of Parent (years)	Effective Dating Range (years)
Parent	**Daughter**		
Uranium-238	Lead-206	4.5 billion	1 million to 4.5 billion
Potassium-40	Argon-40	1.3 billion	10 000 to 3 billion
Carbon-14	Nitrogen-14	5730	up to 50 000

Measurement

- Absolute error = indicated value – true value
- Absolute correction = true value – indicated value
- Relative error = $\frac{\text{absolute error}}{\text{true value}}$
- Relative correction = $\frac{\text{absolute correction}}{\text{true value}}$

Mechanical equations

- axial stress $= \frac{\text{axial force}}{\text{cross sectional area}}$
- axial strain $= \frac{\text{change in length}}{\text{original length}}$

- shear stress = $\frac{\text{shear force}}{\text{shear area}}$

- Working or allowable stress = $\frac{\text{ultimate stress}}{\text{Factor of Safety (FOS)}}$

- Mechanical advantage (MA) = $\frac{\text{output force (or torque)}}{\text{input force (or torque)}}$

- Velocity ratio (VR) = $\frac{\text{velocity of output from a mechanism}}{\text{velocity of input to a mechanism}}$

- Velocity ratio = $\frac{\text{speed of input}}{\text{speed of output}}$

- Input speed × input size = output speed × output size

- **Gear systems**

$$\text{MA} = \frac{\text{Number of teeth on output gear}}{\text{Number of teeth on input gear}}$$

$$\text{VR} = \frac{\text{Number of teeth on input gear}}{\text{Number of teeth on output gear}}$$

- **Belt and pulley systems**

$$\text{MA} = \frac{\text{Diameter of output pulley}}{\text{Diameter of input pulley}}$$

$$\text{VR} = \frac{\text{Diameter of input pulley}}{\text{Diameter of output pulley}}$$

Fluid mechanics

- **Pressure due to a column of liquid** = height of column × gravitational acceleration × density of liquid
- **Up-thrust force on a submerged body =** volume of submerged body × gravitational acceleration × density of liquid

Energy equations

- **Non-flow energy equation**

$$U_1 + Q = U_2 + W$$

where:

Q = energy entering the system

W = energy leaving the system

U_1 = initial energy in the system

U_2 = final energy in the system

- **Steady flow energy equation**

$$Q = (W_2 - W_1) + W$$

where:

Q = heat energy supplied to the system

W_1 = energy entering the system

W_2 = energy leaving the system

W = work done by the system.

Principle of moments

$$\Sigma \text{ clockwise moments} = \Sigma \text{ anti-clockwise moments}$$

HYDRAULICS

- **Pressure loss due to Friction**

$$P_f = \frac{9000 f l \mathrm{L}^2}{\mathrm{d}^5}$$

where:

P_f = Pressure loss due to friction in bar

f = Friction factor for the hose

l = Length of the hose in meters

L = Flow rate in liters per minute

d = Diameter of the hose in millimeters

- **Flow through a Nozzle**

$$\mathrm{L} = \frac{2}{3}\mathrm{d}^2\sqrt{\mathrm{P}}$$

where:
L = Flow rate in liters per minute
d = Diameter of the nozzle in millimeters
P = Pressure in bar

- **Water power and Efficiency**

$$\mathrm{WP} = \frac{100\mathrm{LP}}{60}$$

where:

WP = Water Power in Watts

L = Flow rate in liters per minute

P = Pressure in bar

$$E = \frac{WP}{BP} \times 100$$

where:

E = Efficiency of a pump (%)

WP = Water Power in Watts

BP = Brake Power of engine in Watts

- **Jet Reaction**

$$R = 0.157Pd^2$$

where:

R = Jet reaction in newtons

P = Pressure in bar

d = Diameter of the hose in millimeters

- **Effective Height of a Jet**

$$H_e = \frac{2}{3}\left(H - 0.113\frac{H^2}{d}\right)$$

where:

H_e = Effective height of jet in meters

H = Theoretical height to which water will rise when projected vertically from nozzle in meters

d = Diameter of nozzle in millimeters

$$\boxed{E^{\circ}_{net} = E^{\circ}_{red} + E^{\circ}_{ox}}$$

E°_{net} = net voltage of a cell (V)

E°_{red} = voltage of the reduction half reaction (V)

E°_{ox} = voltage of the oxidation half reaction (V)

NEWTON'S LAWS OF MOTION

- **Newton's First Law:** An object continues in its state of rest or of uniform motion in a straight line unless acted upon by an external force.
- **Newton's Second Law:** A change in motion (acceleration) is proportional to the force acting and takes place in the direction of the straight line along which the force acts.

$$\boxed{\text{Acting force} = \text{mass} \times \text{acceleration caused}}$$

- **Newton's Third Law:** To every action there is an equal and opposite reaction (or, if object A exerts a force on object B, then object B exerts an equal, but oppositely-directed, force on A).

The most abundant element in the universe is hydrogen.

The most abundant element on the Earth is Oxygen.

The idea of Friedrich August Kekule von Stradonitz's dream helped form the benzene structure.

The density of ice is 10% lower than that of water.

Hydrofluoric acid (a solution of hydrogen fluoride in water) is so corrosive that it can dissolve glass.

Helium (a colorless, odorless, tasteless, non-toxic, inert, monatomic gas) can be frozen only through pressure; not by cooling.

Graphene (an allotrope of carbon) is the best conductor of electricity and heat.

Chalk is made of trillions of fossils of planktonic microscopic skeleton.

Systematic Procedure for Inorganic Qualitative Analysis

Systematic Analysis of Anion

S.No	Experiment	Observation	Inference
1	Preliminary Reactions	Colourless	Absence of Fe^{2+}, Fe^{3+}, Ni^{2+}, Co^{2+}.
	Appearance	Green Blue Brown Pink	May be Fe^{2+}, Ni^{2+}, Cu^{2+} Cu^{2+} May be Fe^{2+} May be Co^{2+}, Mn^{2+}
2	Action of heat Take a small amount of the given salt taken in a dry test tube, heat it gently; then strongly.	A colourless gas with a characteristic pungent odour turning moist red litmus paper blue.	May be NH_4^+ salt
		Reddish brown vapours turning acidified ferrous sulphate paper brown, are obtained.	May be NO_3^-
		Substance is white when cold and yellow when hot.	May be $(Zn)^{2+}$
3	Flame Test To a small amount of the given salt taken in a watch glass, add a drop of Con. HCl and make it into a paste. Introduce the paste with the help of a glass rod to the base of the non-luminous bunsen burner.	(i) Bluish green flame (ii) Apple green (iii) Brick red (iv) Crimson red	May be Cu^{2+} May be Ba^{2+} May be Ca^{2+} May be Sr^{2+}
Identification of Anions from Volatile Products:			
4	Action of dilute H_2SO_4: To a small portion of the given salt taken in a test tube add 1 or 2ccs of H_2SO_4 and gently warm it.	Brisk effervescence of colourless, odourless gas turning lime water, milky is obtained.	Anion is CO_3^{2-}
		Colourless gas with a smell of rotten eggs, turning lead acetate paper black is obtained.	Anion is sulphide.
		Colourless gas with smell of burning sulphur turning acidified dichromatic green is obtained.	Anion is SO_3^{2-}
		Reddish brown gas with fishy odour turning acidified ferrous sulphate brown is obtained.	Anion is NO_3^-
		Colourless gas with smell of vinegar is obtained.	Anion may be acetate.
		No characteristic observation.	Absence of CO_3^{2-}, NO_3^- , S^{2-}, SO_3^{2-}, CH_3COO^-

5	Action of Con.H_2SO_4 To a small amount of given salt taken in a test tube, add 2-3 ccs of Con.H_2SO_4 and gently heat it.	Reddish brown vapours turning moist fluorescent paper red.	Anion may be bromide.
		Colourless gas with pungent smell giving dense white fumes with a glass rod dipped in NH_4OH solution.	Anion may be chloride.
		Violet coloured vapours turning starch paper blue or violet.	Anion may be Iodide.
		Reddish brown vapours turning acidified ferrous sulphate paper brown.	Anion may be nitrate.
		No characteristic observation.	Absence of Cl^-, Br^-, I^- & NO_3^-
6	Action of Con.H_2SO_4 with Cu turnings: Mix a small amount of the given salt taken in a test tube with a few Cu bits, add 2 – 3 ccs of H_2SO_4 and heat it.	Copius evolution of reddish brown gas turning acidified ferrous sulphate paper brown is observed. No reddish brown vapours.	Anion is nitrate. Absence of NO_3^-
7	Action of Con.H_2SO_4 with MnO_2 To a small amount of the given salt taken in a test tube, add an equal amount of MnO_2 and add a few ccs of Con.H_2SO_4 and gently heat.	A greenish yellow gas turning starch iodide paper violet (or) blue is obtained.	Anion may be chloride.
		Reddish brown vapours turning moist fluorescent paper red is obtained.	Anion may be bromide.
		Violet vapours turning starch paper blue (or) violet is obtained.	Anion may be iodide
		No characteristic coloured vapours are obtained.	Absence of Cl^-, Br^-, I^-
8	Action of NaOH To a pinch of the given salt taken in a test tube, add few ccs of 10% NaOH solution and gently warm it.	A colourless gas with a pungent smell giving dense white fumes with glass rod dipped in HCl is obtained. No characteristic gas is Ammonium liberated.	Cation is ammonium. Ammonium is absent.

Sodium Carbonate Extract

Identification of Anions in solution

Preparation of Extract:

Take about $\frac{1}{4}$ or $\frac{1}{5}$ of the given salt in a 50cc beaker. Mix it well with about thrice its amount of solid sodium carbonate. Add about 15 – 20ml of distilled water. Mix well with neat glass rod. Boil contents of the beaker over Bunsen flame. Cool and filter through filter assembly. Collect the clean filtrate in another beaker. The Filtrate is called soda extract.

S.No	Experiment	Observation	Inference
9	Silver Nitrate Test: To a portion of extract add dilute HNO_3 until effervescence ceases. Add few drops in excess, 2 – 3nos of $AgNO^3$ solution.	Curdy white precipitate soluble in NH_4OH. Pale yellow precipitate sparingly soluble in NH_4OH. Yellow precipitate insoluble in NH_4OH. No precipitate is obtained.	Anion is Cl^- Anion is Br^- Anion is I^- Absence of Br^-, Cl^-, I^-
10	Barium Chloride Test: To about one or two ccs of the extract, (after neutralizing with acetic acid and boiling of CO_2) add $BaCl_2$ solution. To a portion of the above ppt add dil. HCl.	A white precipitate insoluble in HCl. A white precipitate soluble in HCl. No precipitate is obtained.	Anion is SO_4^{2-} Anion is SO_3^{2-} Absence of SO_4^{2-}, SO_3^{2-}
11	Lead Acetate Test: To about one or two ccs of the extract (after acidifying with acetic acid, boiling off CO_2 and cooling) add lead acetate solution.	White ppt, soluble in excess of ammonium acetate solution.	SO_4^{2-} confirmed.
12	Ferrous Sulphate Test: (Brown Ring Test) To about 1 or 2cc of extract add dilute H2SO4 in drops until the effervescence ceases. And few drops in excess add 2- 3 drops of freshly prepared $FeSO_4$ solution. Keeping the test tube in a slanting position, add Con. H_2SO_4 without disturbing the solution.	A brown ring is obtained at the junction of the liquid. No brown ring is observed.	Anion is NO_3^- Anion NO_3^- is absent.
13	Ferric Chloride Test: Take about 1 or 2ccs of the extract in a test tube and add neutral $FeCl_3$ solution. Filter, if required, and divide the solution or the filtrate in two parts: (i) To one part add dil.HCl (ii) To the second part add water and boil	Deep red colouration produced Red colouration disappears Reddish brown ppt.	CH_3COO^- confirmed. CH_3COO^- confirmed. CH_3COO^- confirmed.

14	Calcium Chloride Test: To a portion of the sodium carbonate extract, taken in a test tube add dil. Acetic acid and boil off CO_2.Then add a few drops of calcium chloride solution. Add dil. HNO_3 to the white ppt and warm.	A white precipitate of calcium oxalate is obtained The precipitate dissolves.	Confirms Oxalate.
15	Ethyl Acetate Test: To a pinch of given salt taken in a test tube, add a few drops of ethanol followed by 1 or 2ccs of H_2SO_4. Gently heat and cool it. Pour into Na_2CO_3.	A pleasant fruity odor is obtained.	The presence of anion acetate is confirmed.

Diamond and graphite both are forms of pure carbon.

The chemical name for water (H_2O) is dihydrogen monoxide.

The only 2 non-silvery metals are gold and copper.

Our body contains enough carbon to provide graphite for 9,000 pencils.

If we mix half a liter of alcohol and half a liter of water, the total volume of the resultant liquid will be less than one liter.

Systematic Analysis of Cations

Preparation of Original solution:

Check solubility of the given salt in:

- Cold water (or) hot water (or) Dil HCl (or) Conc. HCl. Label this solution as original solution.

Procedure for Separation of Basic Radicals into Groups

To the original solution, add Dil. HCl.

↓

White ppt. Group I present (Pb^{2+} and Hg_2^{2+})					
	If no ppt. pass H_2S through the given solution. If a coloured ppt. is formed, group 2 cations are present (Cu^{2+}), Pb^{2+}.				
		If no ppt is obtained from the above, boil off H_2s gas and add a few drops of conc. HNO_3 to the remaining solution. Cool, add 2-3g of solid NH_4Cl. Boil again and add NH_4OH solution till it becomes alkaline.			
		If a ppt is formed, Group III cations are present. Reddish brown ppt. Fe^{3+} Gelatinous white ppt. Al^{3+}			
			If no ppt., pass H_2S to the given solution.		
			If a ppt is formed Group IV cations are present. Black ppt. (Co^{2+}, Ni^{2+}) Flesh coloured ppt. Mn^{2+} white ppt. Zn^{2+}.		
				If no ppt is formed, boil off H_2S gas add $(NH_4)_2CO_3$ solution.	
				If a white ppt is formed Group V cations are present (Ba^{2+}, Sr^{2+}, Ca^{2+})	
					If no ppt. Group VI cation is present (Mg^{2+})

If none of the cations are present, check for Group 0 (NH_4^+)

Cation Analysis

Group O (NH_4^+):

To a pinch of given salt add some water and warm. Then allow it to cool. Add Nessler's reagent and excess of NaOH solution.	Yellowish brown precipitate is obtained. No precipitate is obtained.	Cation is ammonium. Cation is not ammonium.

Group I (lead):

Group I precipitate is dissolved by heating the precipitate with dil.HNO_3 or distilled water. Divide the solution into 3 portions and carry out the following reactions.

Experiment	Observation	Inference
To one portion of the above solution add dilute H_2SO_4.	A white precipitate of $PbSO_4$ is obtained.	Pb^{2+} is present.
To another portion, add potassium chromate solution.	A yellow precipitate of $PbCrO_4$ is obtained.	Presence of Pb^{2+} is confirmed.
Golden Spangles Test: To the 3rd portion, add KI solution To above yellow precipitate, add some H_2O, boil and then cool.	A yellow precipitate is obtained. Precipitate dissolves and reappears in the form of golden spangles.	The presence of Pb^{2+} is confirmed.

Group II (Cu^{2+}):

The group 2 precipitate is dissolved by heating with dilute HCl. Precipitate dissolves.

Experiment	Observation	Inference
Test for Cu^{2+} : To one portion of the above solution add drops of NH_4OH, until it is in excess. To another portion, add dilute acetic acid and potassium ferrocyanide [$K_4(Fe(CN_6))$]	A pale blue precipitate which dissolves in excess NH_4OH to give any inky blue solution is obtained. A chocolate brown ppt.	The presence of Cu^{2+} is confirmed. Confirms copper.

Group III:

Group III precipitate is heated with Con. HCl and water, cooled and filtered.

Reddish brown precipitate indicates Fe^{2+} (or) Fe^{3+}

Gelatinous white indicates Al^{3+}

Experiment		Observation	Inference
1.	To 1 cm^3 OS, add a few drops of dilute HCl and then add	Formation of a deep blue colour or ppt.	Fe^{2+} confirmed.

	0.5 cm^3 of potassium ferricyanide solution.		
2.	White gelatinous precipitate dissolves in minimum quantity of dil. HCl. To this, add a few drops of blue litmus solution. Add NH_4OH solution in excess.	Formation of a blue floating ppt. in colourless solution. (This is known as Lake test) A blue ppt., suspended in a colourless medium (called a lake)	Al^{3+} confirmed.
2B	To one part of the above solution add NaOH solution	White Precipitate soluble in excess of NaOH solution	Al^{3+} confirmed
3. (i) (ii)	Reddish brown ppt. (Shows the presence of Fe^{3+}) Treat it with minimum quantity of dil. HCl solution to dissolve the ppt. and then heat. Divide the solution into two parts. To one part, add few drops of potassium ferrocyanide solution. To another portion add few drops of potassium sulphocyanide solution.	A yellow solution is produced. A deep blue colour or ppt. is obtained. A deep red colour is obtained.	Fe^{3+} may be present. Fe^{3+} confirmed. Fe^{3+} confirmed.

Group IV :

Group IV precipitate is warmed with dilute HCl centrifugate

Black precipitate Ni^{2+}

Ni is not soluble in dilute HCl. To residue add Con.HCl, boil, cool. Divide the solution into two parts and boil of H_2S. To one part add dimethyl glyoxime reagent. Con.NH_4OH, till the solution becomes alikaline.	A Red rosy precipitate confirms the presence of Ni^{2+}

Sodium Hydroxide and Br_2 – water test. To the second part of the above solution, add NaOH and Br_2 water and then boil	A black precipitate confirms the presence of Ni^{2+}.
Confirmation of Zn^{2+}: Dissolve a part of white ppt in dil. HCl. Boil off H_2S and divide the solution in two parts. (i) To one part of solution add Pot. ferrocyanide solution (ii) To second part of solution add NaOH.	Bluish White ppt confirms Zinc. White ppt soluble in excess of NaOH is obtained.
Flesh (buff) colour precipitate indicates Mn^{2+}. Dissolve the precipitate in Dil. HCl and boil off H_2S then add NaOH solution.	A white precipitate is formed. Add Br water to the white ppt it turns black or brown. Mn^{2+} confirmed.
Lead peroxide test To the second part of the flesh coloured ppt, add a little of PbO_2 powder and conc. HNO_3. Boil, cool and allow to stand.	A pink colouration is produced. Mn^{2+} is confirmed.

Group V :

Take a small portion of Group V precipitate, carry out flame test. Take group V precipitate, add dilute CH_3COOH, warm. Boil of CO_2 and divide the solution into three parts.

Barium, Ba^{2+}	Stronium Sr^{2+}	Calcium Ca^{2+}
1. Potassium chromate test. To one part of the above solution, add a few drops of K_2CrO_4 solution – Yellow ppt. Ba^{2+} confirmed.	1. Ammonium sulphate test. To the second part of the above solution add a few drops of ammonium sulphate solution – white ppt. Sr^{2+} confirmed.	1. Ammonium oxalate test. To the third portion of the above solution, add ammonium oxalate solution and then NH_4OH solution to make it alkaline and scratch the sides of the test tube – white ppt. Ca^{2+} confirmed.
2. Dil. H_2SO_4 Test To another portion of the above solution, add a few drops of dil. H_2SO_4 – white ppt. insoluble in HCl. Ba^{2+} confirmed.	Flame test	Flame test

Test for Mg^{2+}:

1. Ammonium phosphate test. To the original salt solution, add solid NH_4Cl, warm to dissolve, cool and add NH_4OH solution in slight excess. Then add ammonium phosphate solution, shake well and allow to stand	White crystalline ppt.
2. To the original sat solution, add disodium hydrogen phosphate.	White crystalline ppt confirms Mg^{2+}

Additional Test:

Ash test for Al^{3+}, Zn^{2+}, Mg^{2+}

To a pinch of given salt taken in a test tube, add a few drops of Con.H_2SO_4, $Co(No_3)_2$. Mix it well. Dip one filter paper bit in a Bunsen flame. After it burns remove it from flame. After cooking observe the odor of the ash formed.	Blue tinted ash is obtained. Green tinted ash is obtained. Pink tinted ash is obtained.	The presence of Al^{3+} is confirmed. The presence of Zn^{2+} is confirmed. The presence of Mg^{2+} is confirmed.

Sound travels 4.3 times faster in water than in air

Urine glows under ultraviolet light

Apples produce a gas called ethylene on ripening.

We have lost about 1% of our body's water by the time we feel thirsty.

Warm water freezes more quickly than cold water.

Known ice ages

Name of ice age	Years BP (Ma)	Geological period	Era
Pongola	2900–2780		Mesoarchean
Huron	2400–2100	Siderian Rhyacian	Paleoproterozoic
Sturt Marino Gaskiers Baykonur	715–680 650–635 580 547	Cryogenian Ediacaran	Neoproterozoic
Andean-Saharan (incl. Hirnantian and Late Ordovician glaciation)	450–420	Late Ordovician Silurian	Paleozoic
Karoo	360–260	Carboniferous Permian	Paleozoic
Late Cenozoic Ice Age (incl. Quaternary glaciation)	34–present	Late Paleogene Neogene Quaternary	Cenozoic

$$\text{Binding Energy per nucleon} = \frac{\text{Binding Energy}}{\text{Nucleon Number}}$$

Element	Mass of nucleons (u)	Nuclear mass (u)	Binding energy (MeV)	Binding energy per nucleon (MeV)
Deuterium	2.01594	2.01355	2.23	1.12

Helium 4	4.03188	4.00151	28.29	7.07
Lithium 7	7.05649	7.01336	40.15	5.74
Beryllium 9	9.07243	9.00999	58.13	6.46
Iron 56	56.44913	55.92069	492.24	8.79
Silver 107	107.86187	106.87934	915.23	8.55
Iodine 127	128.02684	126.87544	1072.53	8.45
Lead 206	207.67109	205.92952	1622.27	7.88
Polonium 210	211.70297	209.93683	1645.16	7.83
Uranium 235	236.90849	234.99351	1783.80	7.59
Uranium 238	239.93448	238.00037	1801.63	7.57

Viscosity of Water

Temperature °C	Dynamic Viscosity (centiPoise)	Kinematic Viscosity (centiPoise)	Density gm/cm^3
2	1.6735	1.6736	0.9999
3	1.619	1.6191	1
4	1.5673	1.5674	1
5	1.5182	1.5182	1
6	1.4715	1.4716	0.9999
7	1.4271	1.4272	0.9999
8	1.3847	1.3849	0.9999
9	1.3444	1.3447	0.9998
10	1.3059	1.3063	0.9997
11	1.2692	1.2696	0.9996
12	1.234	1.2347	0.9995
13	1.2005	1.2012	0.9994
14	1.1683	1.1692	0.9992

15	1.1375	1.1386	0.9991
16	1.1081	1.1092	0.9989
17	1.0798	1.0811	0.9988
18	1.0526	1.0541	0.9986
19	1.0266	1.0282	0.9984
20	1.0016	1.0034	0.9982
21	0.9775	0.9795	0.998
22	0.9544	0.9565	0.9978
23	0.9321	0.9344	0.9975
24	0.9107	0.9131	0.9973
25	0.89	0.8926	0.997
26	0.8701	0.8729	0.9968
27	0.8509	0.8539	0.9965
28	0.8324	0.8355	0.9962
29	0.8145	0.8178	0.9959
30	0.7972	0.8007	0.9956
31	0.7805	0.7842	0.9953
32	0.7644	0.7682	0.995
33	0.7488	0.7528	0.9947
34	0.7337	0.7379	0.9944
35	0.7191	0.7234	0.994
36	0.705	0.7095	0.9937
37	0.6913	0.6959	0.9933
38	0.678	0.6828	0.993
39	0.6652	0.6702	0.9926
40	0.6527	0.6579	0.9922
45	0.5958	0.6017	0.9902

50	0.5465	0.5531	0.988
55	0.5036	0.5109	0.9857
60	0.466	0.474	0.9832
65	0.4329	0.4415	0.9806
70	0.4035	0.4127	0.9778
75	0.3774	0.3872	0.9748
80	0.354	0.3643	0.9718

- **Beer–Lambert law**

The absorbance of a material that has only one attenuating species also depends on the pathlength and the concentration of the species, according to the Beer–Lambert law:

$$A = \varepsilon \times C \times L$$

where:

ε is the molar attenuation coefficient of that material

C is the molar concentration of those species

L is the pathlength

- **Profitability ratios (SL/HL)**

$$\text{Gross profit margin} = \frac{\text{gross profit}}{\text{sales revenue}} \times 100$$

$$\text{Net profit margin} = \frac{\text{net profit before interest and tax}}{\text{sales revenue}} \times 100$$

- **Liquidity ratios (SL/HL)**

Current ratio = $\frac{\text{current assets}}{\text{current liabilities}} \times 100$

Acid test (quick) ratio = $\frac{\text{current assets} - \text{stock}}{\text{current liabilities}} \times 100$

- **Efficiency ratios (SL/HL)**

Return on capital employed (ROCE) = $\frac{\text{net profit before interest and tax}}{\text{capital employed}} \times 100$

where:

capital employed = loan capital (or long-term liabilities) + share capital + retained profit

- **Efficiency ratios (HL only)**

Stock turnover (number of times) = $\frac{\text{cost of goods sold}}{\text{average stock}}$

Stock turnover (number of days) = $\frac{\text{average stock}}{\text{cost of goods sold}} \times 365$

where:

cost of goods sold is an approximation of total credit purchases and

average stock = $\frac{\text{opening stock} + \text{closing stock}}{2}$

Debtor days ratio (number of days) = $\frac{\text{debtors}}{\text{total sales revenue}} \times 365$

where total sales revenue is an approximation of total credit sales

$$\text{Creditor days ratio (number of days)} = \frac{\text{creditors}}{\text{cost of goods sold}} \times 365$$

where cost of goods sold is an approximation of total credit purchases

$$\text{Gearing ratio} = \frac{\text{loan capital}}{\text{capital employed}} \times 100$$

where capital employed = loan capital (or long-term liabilities) + share capital + retained profit

- **Investment appraisal (SL/HL)**

$$\text{Average rate of return (ARR)} = \frac{(\text{total returns} - \text{capital cost}) / \text{years of use}}{\text{capital cost}} \times 100$$

- **Investment appraisal (HL only)**

$$\text{Net present value (NPV)} = \Sigma \text{ present values of return} - \text{original cost}$$

- **Capacity utilization and productivity (HL only)**

$$\text{Capacity utilization rate} = \frac{\text{actual output}}{\text{productive capacity}} \times 100$$

$$\text{Productivity rate} = \frac{\text{total output}}{\text{total input}} \times 100$$

The Periodic Table of the Elements

1 **H** Hydrogen 1.00794																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012182											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955910	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938049	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933200	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				

58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93032	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Sources of antioxidants

- **allium sulphur compounds** – leeks, onions and garlic
- **anthocyanins** – eggplant, grapes and berries
- **beta-carotene** – pumpkin, mangoes, apricots, carrots, spinach and parsley
- **catechins** – red wine and tea
- **copper** – seafood, lean meat, milk and nuts
- **cryptoxanthins** – red capsicum, pumpkin and mangoes
- **flavonoids** – tea, green tea, citrus fruits, red wine, onion and apples
- **indoles** – cruciferous vegetables such as broccoli, cabbage and cauliflower
- **isoflavonoids** – soybeans, tofu, lentils, peas and milk
- **lignans** – sesame seeds, bran, whole grains and vegetables
- **lutein** – green, leafy vegetables like spinach, and corn
- **lycopene** – tomatoes, pink grapefruit and watermelon
- **manganese** – seafood, lean meat, milk and nuts
- **polyphenols** – thyme and oregano
- **selenium** – seafood, offal, lean meat and whole grains
- **vitamin A** – liver, sweet potatoes, carrots, milk, and egg yolks
- **vitamin C** – oranges, blackcurrants, kiwifruit, mangoes, broccoli, spinach, capsicum and strawberries
- **vitamin E** – vegetable oils (such as wheatgerm oil), avocados, nuts, seeds and whole grains
- **zinc** – seafood, lean meat, milk and nuts
- **zoochemicals** – red meat, offal and fish.

Oxidation states of the elements

Element			**Negative states**						**Positive states**									**Group**
			−5	**−4**	**−3**	**−2**	**−1**	**0**	**+1**	**+2**	**+3**	**+4**	**+5**	**+6**	**+7**	**+8**	**+9**	
Z																		
1	hydrogen	H					**−1**		**+1**									1
2	helium	He																18
3	lithium	Li							**+1**									1
4	beryllium	Be						0	+1	**+2**								2
5	boron	B	−5				−1	0	+1	+2	**+3**							13
6	carbon	C		**−4**	**−3**	**−2**	**−1**	0	**+1**	**+2**	**+3**	**+4**						14
7	nitrogen	N			**−3**	−2	−1		+1	+2	**+3**	+4	**+5**					15
8	oxygen	O				**−2**	−1	0	+1	+2								16
9	fluorine	F					**−1**											17
10	neon	Ne																18
11	sodium	Na					−1		**+1**									1
12	magnesium	Mg							+1	**+2**								2
13	aluminium	Al				−2	−1		+1	+2	**+3**							13
14	silicon	Si		**−4**	−3	−2	−1	0	+1	+2	+3	**+4**						14
15	phosphorus	P			**−3**	−2	−1	0	+1	+2	**+3**	+4	**+5**					15

16	sulfur	S				**−2**	−1	0	+1	**+2**	+3	**+4**	+5	**+6**				16
17	chlorine	Cl					**−1**		**+1**	+2	**+3**	+4	**+5**	+6	**+7**			17
18	argon	Ar						0										18
19	potassium	K					−1		**+1**									1
20	calcium	Ca							+1	**+2**								2
21	scandium	Sc						0	+1	+2	**+3**							3
22	titanium	Ti				−2	−1	0	+1	+2	+3	**+4**						4
23	vanadium	V			−3		−1	0	+1	+2	+3	+4	**+5**					5
24	chromium	Cr		−4		−2	−1	0	+1	+2	**+3**	+4	+5	**+6**				6
25	manganese	Mn			−3	−2	−1	0	+1	**+2**	+3	**+4**	+5	+6	**+7**			7
26	iron	Fe		−4		−2	−1	0	+1	**+2**	**+3**	+4	+5	**+6**	+7			8
27	cobalt	Co			−3		−1	0	+1	**+2**	**+3**	+4	+5					9
28	nickel	Ni				−2	−1	0	+1	**+2**	+3	+4						10
29	copper	Cu				−2		0	+1	**+2**	+3	+4						11
30	zinc	Zn				−2			+1	**+2**								12
31	gallium	Ga	−5	−4	−3	−2	−1		+1	+2	**+3**							13
32	germanium	Ge		**−4**	−3	−2	−1	0	+1	**+2**	+3	**+4**						14
33	arsenic	As			**−3**	−2	−1	0	+1	+2	**+3**	+4	**+5**					15
34	selenium	Se				**−2**	−1		+1	**+2**	+3	**+4**	+5	**+6**				16

35	bromine	Br					**−1**		**+1**		**+3**	+4	**+5**		+7			17
36	krypton	Kr						**0**	+1	+2								18
37	rubidium	Rb					−1		**+1**									1
38	strontium	Sr							+1	**+2**								2
39	yttrium	Y						0	+1	+2	**+3**							3
40	zirconium	Zr				−2			+1	+2	+3	**+4**						4
41	niobium	Nb			−3		−1		+1	+2	+3	+4	**+5**					5
42	molybdenum	Mo		−4		−2	−1	0	+1	+2	+3	**+4**	+5	**+6**				6
43	technetium	Tc			−3		−1	0	+1	+2	+3	**+4**	+5	+6	**+7**			7
44	ruthenium	Ru		−4		−2		0	+1	+2	**+3**	**+4**	+5	+6	+7	+8		8
45	rhodium	Rh			−3		−1	0	+1	+2	**+3**	+4	+5	+6				9
46	palladium	Pd						**0**	+1	**+2**	+3	**+4**						10
47	silver	Ag				−2	−1		**+1**	+2	+3							11
48	cadmium	Cd				−2			+1	**+2**								12
49	indium	In	−5			−2	−1		+1	+2	**+3**							13
50	tin	Sn		**−4**	−3	−2	−1	0	+1	**+2**	+3	**+4**						14
51	antimony	Sb			**−3**	−2	−1	0	+1	+2	**+3**	+4	**+5**					15
52	tellurium	Te				**−2**	−1		+1	**+2**	+3	**+4**	+5	**+6**				16
53	iodine	I					**−1**		**+1**		**+3**	+4	**+5**	+6	**+7**			17

54	xenon	Xe						**0**	+1	+2		+4		+6		+8		18
55	caesium	Cs					−1		**+1**									1
56	barium	Ba							+1	**+2**								2
57	lanthanum	La						0	+1	+2	**+3**							3
58	cerium	Ce								+2	**+3**	**+4**						n/a
59	praseodymium	Pr						0	+1	+2	**+3**	+4	+5					n/a
60	neodymium	Nd						0		+2	**+3**	+4						n/a
61	promethium	Pm								+2	**+3**							n/a
62	samarium	Sm						0		+2	**+3**							n/a
63	europium	Eu								**+2**	**+3**							n/a
64	gadolinium	Gd						0	+1	+2	**+3**							n/a
65	terbium	Tb						0	+1	+2	**+3**	+4						n/a
66	dysprosium	Dy						0		+2	**+3**	+4						n/a
67	holmium	Ho						0		+2	**+3**							n/a
68	erbium	Er						0		+2	**+3**							n/a
69	thulium	Tm								+2	**+3**							n/a
70	ytterbium	Yb								+2	**+3**							n/a
71	lutetium	Lu						0		+2	**+3**							n/a
72	hafnium	Hf				−2			+1	+2	+3	**+4**							4

73	tantalum	Ta			−3		−1		+1	+2	+3	+4	**+5**					5
74	tungsten	W		−4		−2	−1	0	+1	+2	+3	**+4**	+5	**+6**				6
75	rhenium	Re			−3		−1	0	+1	+2	+3	**+4**	+5	+6	+7			7
76	osmium	Os		−4		−2	−1	0	+1	+2	+3	**+4**	+5	+6	+7	+8		8
77	iridium	Ir			−3		−1	0	+1	+2	**+3**	**+4**	+5	+6	+7	+8	+9	9
78	platinum	Pt			−3	−2	−1	0	+1	**+2**	+3	**+4**	+5	+6				10
79	gold	Au			−3	−2	−1	0	+1	+2	**+3**		+5					11
80	mercury	Hg				−2			**+1**	**+2**								12
81	thallium	Tl	−5			−2	−1		**+1**	+2	**+3**							13
82	lead	Pb		−4		−2	−1		+1	**+2**	+3	**+4**						14
83	bismuth	Bi			−3	−2	−1		+1	+2	**+3**	+4	+5					15
84	polonium	Po				**−2**				**+2**		**+4**	+5	+6				16
85	astatine	At					**−1**		**+1**		+3		+5		+7			17
86	radon	Rn								**+2**				+6				18
87	francium	Fr							**+1**									1
88	radium	Ra								**+2**								2
89	actinium	Ac									**+3**							3
90	thorium	Th							+1	+2	+3	**+4**						n/a
91	protactinium	Pa									+3	+4	**+5**					n/a

92	uranium	U							+1	+2	+3	+4	+5	**+6**				n/a
93	neptunium	Np								+2	+3	+4	**+5**	+6	+7			n/a
94	plutonium	Pu								+2	+3	**+4**	+5	+6	+7			n/a
95	americium	Am								+2	**+3**	+4	+5	+6	+7			n/a
96	curium	Cm									**+3**	+4	+5	+6				n/a
97	berkelium	Bk								+2	**+3**	+4	+5					n/a
98	californium	Cf								+2	**+3**	+4	+5					n/a
99	einsteinium	Es								+2	**+3**	+4						n/a
100	fermium	Fm								+2	**+3**							n/a
101	mendelevium	Md								+2	**+3**							n/a
102	nobelium	No								**+2**	+3							n/a
103	lawrencium	Lr									**+3**							n/a
104	rutherfordium	Rf										**+4**						4
105	dubnium	Db											**+5**					5
106	seaborgium	Sg						0						**+6**				6
107	bohrium	Bh													**+7**			7
108	hassium	Hs														**+8**		8
109	meitnerium	Mt																9
110	darmstadtium	Ds																10

111	roentgenium	Rg																11
112	copernicium	Cn								**+2**								12
113	nihonium	Nh																13
114	flerovium	Fl																14
115	moscovium	Mc																15
116	livermorium	Lv																16
117	tennessine	Ts																17
118	oganesson	Og																18

Factorial table

Number **n**	**Factorial** **n!**
0	1
1	1
2	2
3	6
4	24
5	120
6	720
7	5040

8	40320
9	362880
10	3628800
11	3.991680×10^{7}
12	4.790016×10^{8}
13	6.227021×10^{9}
14	8.717829×10^{10}
15	1.307674×10^{12}
16	2.092279×10^{13}
17	3.556874×10^{14}
18	6.402374×10^{15}
19	1.216451×10^{17}
20	2.432902×10^{18}

Rocket Equations:

$$\text{Thrust} = \frac{dM}{dt}u$$

- $M \rightarrow$ mass of the rocket
- $u \rightarrow$ exhaust velocity in the rocket frame
- $(v - u) \rightarrow$ exhaust velocity in the observer frame
- $v \rightarrow$ velocity of the rocket

Under the influence of the rocket thrust in a gravity-free environment, the resulting velocity can be calculated from:

$$v = v_0 + u \ln\frac{m_0}{m}$$

$$\text{velocity} = \text{initial velocity} + \text{exhaust velocity} \times \ln\frac{\text{original mass}}{\text{mass}}$$

Under the influence of the rocket thrust in a gravity environment, the resulting velocity can be calculated from:

$$v = v_0 + u \ln\frac{m_0}{m} - gt$$

g→ gravitational acceleration

t→ time

Power Table from 1 to 10

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
$\mathbf{1^n}$	1	1	1	1	1	1	1	1	1	1
$\mathbf{2^n}$	2	4	8	16	32	64	128	256	512	1024
$\mathbf{3^n}$	3	9	27	81	243	729	2187	6561	19683	59049
$\mathbf{4^n}$	4	16	64	256	1024	4096	16384	65536	262144	1048576
$\mathbf{5^n}$	5	25	125	625	3125	15625	78125	390625	1953125	9765625

6^n	6	36	216	1296	7776	46656	279936	1679616	10077696	60466176
7^n	7	49	343	2401	16807	117649	823543	5764801	40353607	282475249
8^n	8	64	512	4096	32768	262144	2097152	16777216	134217728	1073741824
9^n	9	81	729	6561	59049	531441	4782969	43046721	387420489	3486784401
10^n	10	100	1000	10000	100000	1000000	10000000	100000000	1000000000	10000000000

Formulas of some saturated fatty acids

Common name	**Chemical structure**
Caprylic acid	$CH_3(CH_2)_6COOH$
Capric acid	$CH_3(CH_2)_8COOH$
Lauric acid	$CH_3(CH_2)_{10}COOH$
Myristic acid	$CH_3(CH_2)_{12}COOH$
Palmitic acid	$CH_3(CH_2)_{14}COOH$
Stearic acid	$CH_3(CH_2)_{16}COOH$
Arachidic acid	$CH_3(CH_2)_{18}COOH$
Behenic acid	$CH_3(CH_2)_{20}COOH$
Lignoceric acid	$CH_3(CH_2)_{22}COOH$

Cerotic acid	$CH_3(CH_2)_{24}COOH$

Formulas of some Unsaturated Fatty Acids

Common name	**Chemical structure**
Myristoleic acid	$CH_3(CH_2)_3\mathbf{CH{=}CH}(CH_2)_7COOH$
Palmitoleic acid	$CH_3(CH_2)_5\mathbf{CH{=}CH}(CH_2)_7COOH$
Sapienic acid	$CH_3(CH_2)_8\mathbf{CH{=}CH}(CH_2)_4COOH$
Oleic acid	$CH_3(CH_2)_7\mathbf{CH{=}CH}(CH_2)_7COOH$
Elaidic acid	$CH_3(CH_2)_7\mathbf{CH{=}CH}(CH_2)_7COOH$
Vaccenic acid	$CH_3(CH_2)_5\mathbf{CH{=}CH}(CH_2)_9COOH$
Linoleic acid	$CH_3(CH_2)_4\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}(CH_2)_7COOH$
Linoelaidic acid	$CH_3(CH_2)_4\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}(CH_2)_7COOH$
α-Linolenic acid	$CH_3CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}(CH_2)_7COOH$
Arachidonic acid	$CH_3(CH_2)_4\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}(CH_2)_3COOH$
Eicosapentaenoic acid	$CH_3CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}(CH_2)_3COOH$
Erucic acid	$CH_3(CH_2)_7\mathbf{CH{=}CH}(CH_2)_{11}COOH$
Docosahexaenoic acid	$CH_3CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}CH_2\mathbf{CH{=}CH}(CH_2)_2COOH$

Qualitative Analysis of the Phytochemicals

- **Test for Carbohydrates:** The presence of carbohydrates is confirmed when 2 ml of extract is treated with 1 ml of Molisch's reagent and few drops of concentrated sulphuric acid which results in the formation of purple or reddish color.
- **Test for Tannins:** To 1 ml of extract, 2 ml of 5% ferric chloride is added. Formation of dark blue or greenish black indicates the presence of tannins.
- **Test for Saponins:** 2 ml of extract, 2 ml of distilled water are added and shaken in a graduated cylinder for 15 min lengthwise. It results in the formation of 1 cm layer of foam that indicates the presence of saponins.
- **Test for Alkaloids:** To 2 ml of extract, 2 ml of concentrated hydrochloric acid is added. Then few drops of Mayer's reagent are added. Presence of green color or white precipitate indicates the presence of alkaloids.
- **Test for Flavonoids:** To 2 ml of extract, 1 ml of 2N sodium hydroxide is added. Presence of yellow color indicates the presence of flavonoids.
- **Test for Glycosides:** To 2 ml of extract, 3ml of chloroform and 10% ammonia solution is added. Formation of pink color indicates presence of glycosides.
- **Test for Quinones:** To 1 ml of extract, 1 ml of concentrated sulphuric acid is added. Formation of red color indicates presence of quinones.
- **Test for Phenols:** 2 ml of distilled water followed by few drops of 10% ferric chloride is added to 1ml of the extract. Formation of blue or green color indicates presence of phenols.

- **Test for Terpenoids:** 0.5 ml of the extract is treated with 2 ml of chloroform and conc. sulphuric acid. Formation of red brown colour at the interface indicates the presence of terpenoids.
- **Test for Cardiac Glycosides:** To 0.5 ml of the extract, 2 ml of glacial acetic acid and few drops of ferric chloride are added. This is under layered with 1 ml of conc. sulphuric acid. Formation of brown ring at the interface indicates the presence of cardiac glycosides.
- **Ninhydrin Test:** To 2 ml of the extract few drops of 0.2% ninhydrin reagent is added and heated for 5 min. Formation of blue colour indicates the presence of amino acids.
- **Test for Coumarins:** 1 ml of 10% sodium hydroxide is added to 1ml of the extract. Formation of yellow colour indicates the presence of coumarins.
- **Anthraquinones:** To 1 ml of extract few drops of 10% ammonia solution is added, appearance of pink color precipitate indicates the presence of anthraquinones
- **Steroids:** To 1 ml of extract equal volume of chloroform is added and a few drops of concentrated sulphuric acid added appearance of brown ring indicates the presence of steroids and appearance of bluish brown ring indicates the presence of phytosteroids.
- **Test for Phlobatannins:** Few drops of 2% hydrochloric acid are added to 1ml of the extract. Appearance of red colour precipitate indicates the presence of phlobatannins.
- **Anthracyanine:** To 1 ml of the extract is added 1 mL 2N sodium hydroxide and heated for 5 min at 100 °C. Formation of bluish green color indicates the presence of anthocyanin.

Common names and IUPAC names of some carboxylic acids

Carbon atoms	Common name	IUPAC name	Chemical formula
1	Formic acid	Methanoic acid	$HCOOH$
2	Acetic acid	Ethanoic acid	CH_3COOH
3	Propionic acid	Propanoic acid	CH_3CH_2COOH
4	Butyric acid	Butanoic acid	$CH_3(CH_2)_2COOH$
5	Valeric acid	Pentanoic acid	$CH_3(CH_2)_3COOH$
6	Caproic acid	Hexanoic acid	$CH_3(CH_2)_4COOH$
7	Enanthic acid	Heptanoic acid	$CH_3(CH_2)_5COOH$
8	Caprylic acid	Octanoic acid	$CH_3(CH_2)_6COOH$
9	Pelargonic acid	Nonanoic acid	$CH_3(CH_2)_7COOH$
10	Capric acid	Decanoic acid	$CH_3(CH_2)_8COOH$
11	Undecylic acid	Undecanoic acid	$CH_3(CH_2)_9COOH$
12	Lauric acid	Dodecanoic acid	$CH_3(CH_2)_{10}COOH$
13	Tridecylic acid	Tridecanoic acid	$CH_3(CH_2)_{11}COOH$
14	Myristic acid	Tetradecanoic acid	$CH_3(CH_2)_{12}COOH$
15	Pentadecylic acid	Pentadecanoic acid	$CH_3(CH_2)_{13}COOH$

16	Palmitic acid	Hexadecanoic acid	$CH_3(CH_2)_{14}COOH$
17	Margaric acid	Heptadecanoic acid	$CH_3(CH_2)_{15}COOH$
18	Stearic acid	Octadecanoic acid	$CH_3(CH_2)_{16}COOH$
19	Nonadecylic acid	Nonadecanoic acid	$CH_3(CH_2)_{17}COOH$
20	Arachidic acid	Icosanoic acid	$CH_3(CH_2)_{18}COOH$

Magnetic properties of common nuclei

Isotope	**Occurrence in nature (%)**	**Spin number I**	**Magnetic moment μ (μ_N)**	**Electric quadrupole moment ($e \times 10^{-24}$ cm^2)**	**Operating frequency at 7 T (MHz)**	**Relative sensitivity**
^{1}H	99.984	$\frac{1}{2}$	2.79628	0	300.13	1
^{2}H	0.016	1	0.85739	0.0028	46.07	0.0964
^{10}B	18.8	3	1.8005	0.074	32.25	0.0199
^{11}B	81.2	$\frac{3}{2}$	2.6880	0.026	96.29	0.165
^{12}C	98.9	0	0	0	0	0
^{13}C	1.1	$\frac{1}{2}$	0.70220	0	75.47	0.0159
^{14}N	99.64	1	0.40358	0.071	21.68	0.00101
^{15}N	0.37	$\frac{1}{2}$	−0.28304	0	30.41	0.00104
^{16}O	99.76	0	0	0	0	0
^{17}O	0.0317	$\frac{5}{2}$	−1.8930	−0.0040	40.69	0.0291
^{19}F	100	$\frac{1}{2}$	2.6273	0	282.40	0.834
^{28}Si	92.28	0	0	0	0	0

^{29}Si	4.70	$\frac{1}{2}$	−0.5548	0	59.63	0.0785
^{31}P	100	$\frac{1}{2}$	1.1205	0	121.49	0.0664
^{35}Cl	75.4	$\frac{3}{2}$	0.92091	−0.079	29.41	0.0047
^{37}Cl	24.6	$\frac{3}{2}$	0.68330	−0.062	24.48	0.0027

List of plant hormones and their functions

Hormone	Function
Ethylene	Fruit ripening and abscission
Gibberellins	Break the dormancy of seeds and buds; promote growth
Cytokinins	Promote cell division; prevent senescence
Abscisic Acid	Close the stomata; maintain dormancy
Auxins	Involved in tropisms and apical dominance

List of the Constellations

Constellation	Mythological Association	First Appeared	Genitive Form	Brightest Star
Andromeda	The Princess Andromeda; in Greek mythology, the daughter of Cepheus and Cassiopeia and wife of Perseus.	Ancient	Andromedae	Alpheratz
Antlia	The air pump; a southern	1756	Antliae	α-Ant

	constellation introduced by Lacaille in 1756, originally the 'pneumatic machine'.	(Lacaille)		
Apus	The bird of paradise; a southern constellation introduced by Keyser & de Houtman in 1598.	1598 (Keyser & de Houtman)	Apodis	α-Aps
Aquarius	The water bearer; in Greek mythology, Ganymede, wine-waiter to the Gods and lover of Zeus.	Ancient	Aquarii	Sadalsuud
Aquila	The eagle; in Greek mythology, the bird of Zeus and the retriever of his thunderbolts.	Ancient	Aquilae	Altair
Ara	The altar; in Greek mythology, used by the Gods to vow allegiance before their battle with the Titans.	Ancient	Arae	α-Ara
Aries	The ram; in Greek mythology, the animal whose golden fleece was recovered by Jason and the Argonauts.	Ancient	Arietis	Hamal
Auriga	The charioteer; in Greek mythology, Erichthonius, son of Vulcan, the first person to attach four horses to a chariot.	Ancient	Aurigae	Capella
Bootes	The herdsman; in Greek mythology, Arcas, son of Zeus by Callisto.	Ancient	Bootis	Arcturus
Caelum	The chisel; a southern constellation introduced by Lacaille in 1756.	1756 (Lacaille)	Caeli	α-Cae

Camelopardalis	The giraffe; a large but faint northern constellation introduced by Plancius in 1612.	1612 (Plancius)	Camelopardalis	β-Cam
Cancer	The crab; in Greek mythology, a crab which bit Hercules's foot.	Ancient	Cancri	β-Cnc
Canes Venatici	The hunting dogs; introduced by Johannes Hevelius in 1687, and said to be held by the herdsman Bootes.	1687 (Hevelius)	Canum Venaticorum	Cor-Caroli
Canis Major	The greater dog; in Greek mythology, a hunting dog belonging to Orion, depicted pursuing the hare Lepus.	Ancient	Canis Majoris	Sirius
Canis Minor	The lesser dog; in Greek mythology, a hunting dog belonging to Orion, depicted pursuing the hare Lepus.	Ancient	Canis Minoris	Procyon
Capricornus	The sea goat; associated with Pan in Greek mythology, god of the countryside.	Ancient	Capricorni	δ-Cap
Carina	The keel; a sub-division of the ancient constellation Argo – in Greek mythology, the ship of the Argonauts.	1756 (Lacaille)	Carinae	Canopus
Cassiopeia	Queen Cassiopeia; in Greek mythology, wife of Cepheus and mother of Andromeda.	Ancient	Cassiopeiae	γ-Cas
Centaurus	The Centaur: half man and half horse; in Greek mythology, the wise centaur Chiron.	Ancient	Centauri	Rigil-Kentaurus

Cepheus	King Cepheus of Ethiopeia; in Greek mythology, the king of Ethiopia, descended from Zeus and Io.	Ancient	Cephei	Alderamin
Cetus	The sea monster, which in Greek mythology attacked Cepheus's territory and Andromeda, but which was slain by Perseus.	Ancient	Ceti	Diphda
Chamaeleon	The chameleon; introduced by Keyser & de Houtman in 1598.	1598 (Keyser & de Houtman)	Chamaeleontis	α-Cha
Circinus	The pair of dividing compasses; a modern constellation introduced by Lacaille in 1756.	1756 (Lacaille)	Circini	α-Cir
Columba	The dove; introduced by Plancius in 1592. In Biblical history, said to be the dove of Noah.	1592 (Plancius)	Columbae	Phact
Coma Berenices	The hair of Queen Berenice of Egypt; introduced as a constellation by Vopel in 1536.	1536 (Vopel)	Comae Berenices	β-Com
Corona Australis	The southern crown, lying at the feet of Sagittarius, and known to the Greeks as a wreath.	Ancient	Coronae Australis	α-CrA
Corona Borealis	The northern crown; in Greek mythology, worn by the Princess Ariadne on her wedding day.	Ancient	Coronae Borealis	Alphecca
Corvus	The crow; in Greek mythology, sent by Apollo in search of water.	Ancient	Corvi	Gienah
Crater	The cup; in Greek mythology, clutched by the crow Crater in	Ancient	Crateris	δ-Crt

	its search for water.			
Crux	The southern cross; introduced as a constellation by Plancius in 1598.	1598 (Plancius)	Crucis	Acrux
Cygnus	The swan; in Greek mythology, Zeus in disguise.	Ancient	Cygni	Deneb
Delphinus	The dolphin; in Greek mythology, the messenger of Poseidon.	Ancient	Delphini	Rotanev
Dorado	The goldfish; a constellation introduced by Keyser & de Houtman in 1598.	1598 (Keyser & de Houtman)	Doradus	α-Dor
Draco	The dragon; in Greek mythology, Ladon, guard of the tree on which golden apples grew, slain by Hercules.	Ancient	Draconis	Eltanin
Equuleus	The little horse; a tiny yet ancient constellation with no mythological association.	Ancient (Ptolemy)	Equulei	Kitalpha
Eridanus	The mythical river Eridanus; associated variously with the Nile or Po.	Ancient	Eridani	Achernar
Fornax	The furnace; originally a chemist's distillation furnace, introduced by Lacaille in 1756.	1756 (Lacaille)	Fornacis	α-For
Gemini	The mythical twins Castor and Pollux.	Ancient	Geminorum	Pollux
Grus	The crane; a constellation introduced by Keyser & de Houtman in 1598.	1598 (Keyser & de Houtman)	Gruis	Alnair
Hercules	Hercules; a large yet dark	Ancient	Herculis	Kornephoros

	constellation representing the greatest hero of Greek mythology.			
Horologium	The pendulum clock; a modern constellation introduced by Lacaille in 1756.	1756 (Lacaille)	Horologii	α-Hor
Hydra	The multi-headed water snake, slain by Hercules in Greek mythology.	Ancient	Hydrae	Alphard
Hydrus	The lesser water snake; introduced as a constellation by Keyser & de Houtman in 1598.	1598 (Keyser & de Houtman)	Hydri	β-Hyi
Indus	The Indian; introduced as a constellation by Keyser & de Houtman in 1598.	1598 (Keyser & de Houtman)	Indi	α-Ind
Lacerta	The lizard; introduced as a constellation by Johannes Hevelius in 1690.	1690 (Hevelius)	Lacertae	α-Lac
Leo	The lion of Nemea; in Greek mythology, a monster slain by Hercules.	Ancient	Leonis	Regulus
Leo Minor	The lion cub; introduced as a constellation by Johannes Hevelius in 1687.	1687 (Hevelius)	Leonis Minoris	46-LMi
Lepus	The hare; often depicted being chased by Orion and his two dogs.	Ancient	Leporis	Arneb
Libra	The balance; a zodiacal constellation introduced by the Romans.	Ancient (Roman)	Librae	Zubeneschamali

Lupus	The wolf; an ancient constellation, but without mythological association.	Ancient	Lupi	α-Lup
Lynx	The lynx; a faint constellation introduced by Johannes Hevelius in 1687.	1687 (Hevelius)	Lyncis	α-Lyn
Lyra	The lyre; often said to be played by Orpheus, the greatest musician of his age.	Ancient	Lyrae	Vega
Mensa	Table Mountain, South Africa; a modern constellation introduced by Lacaille in 1756, celebrating his southern-hemisphere observing site.	1756 (Lacaille)	Mensae	α-Men
Microscopium	The microscope; a modern constellation introduced by Lacaille in 1756.	1756 (Lacaille)	Microscopii	γ-Mic
Monoceros	The unicorn; a constellation introduced by Plancius in 1612.	1612 (Plancius)	Monocerotis	α-Mon
Musca	The fly; a constellation introduced by Keyser & de Houtman in 1598.	1598 (Keyser & de Houtman)	Muscae	α-Mus
Norma	The set square; a modern constellation introduced by Lacaille in 1756.	1756 (Lacaille)	Normae	γ^2-Nor
Octans	The octant, a navigational instrument invented in the 1730s. A modern constellation introduced by Lacaille in 1756.	1756 (Lacaille)	Octantis	ν-Oct
Ophiuchus	The serpent bearer; in Greek	Ancient	Ophiuchi	Rasalhague

	mythology, Asclepius, the god of medicine, depicted in the sky holding the snake Serpens.			
Orion	The hunter; associated in Greek mythology with a son of Poseidon, but associated by the Sumerians with their great hero Gilgamesh.	Ancient	Orionis	Rigel
Pavo	The peacock; a constellation introduced by Keyser & de Houtman in 1598.	1598 (Keyser & de Houtman)	Pavonis	Peacock
Pegasus	The winged horse; in Greek mythology, used by Zeus to carry thunder and lightning.	Ancient	Pegasi	Enif
Perseus	Perseus; in Greek mythology, the husband of Andromeda, also known for slaying Medusa the Gorgon.	Ancient	Persei	Mirfak
Phoenix	The phoenix; a constellation introduced by Keyser & de Houtman in 1598.	1598 (Keyser & de Houtman)	Phoenicis	Ankaa
Pictor	The painter's easel; a modern constellation introduced by Lacaille in 1756.	1756 (Lacaille)	Pictoris	α-Pic
Pisces	Two fishes, swimming in opposite directions with their tails connected by a cord.	Ancient	Piscium	η-Psc
Piscis Austrinus	The southern fish; the parent of the two fish depicted by Pisces.	Ancient	Piscis Austrini	Fomalhaut
Puppis	The poop deck of the Argo Navis; a sub-division of the ancient	1756 (Lacaille)	Puppis	Naos

	constellation Argo – in Greek mythology, the ship of the Argonauts.			
Pyxis	The compass; a southern constellation introduced by Lacaille in 1756.	1756 (Lacaille)	Pyxidis	α-Pyx
Reticulum	The net; a southern constellation introduced by Lacaille in 1756, commemorating the cross-hair in his telescope.	1756 (Lacaille)	Reticuli	α-Ret
Sagitta	The arrow; in Greek mythology, perhaps the arrow that Apollo used to kill the Cyclopes.	Ancient	Sagittae	γ-Sge
Sagittarius	The archer; usually drawn as a centaur – half man, half horse	Ancient	Sagittarii	Kaus-Australis
Scorpius	The scorpion; said to have stung the hunter Orion to death in Greek mythology.	Ancient	Scorpii	Antares
Sculptor	The sculptor – originally, the sculptor's studio; a modern constellation introduced by Lacaille in 1756.	1756 (Lacaille)	Sculptoris	α-Scl
Scutum	The shield; a constellation honouring King John III Sobieski of Poland – the only politically inspired constellation still in use.	1684 (Hevelius)	Scuti	α-Sct
Serpens Caput	The serpent's head; held by Ophiuchus and part of the same constellation as Serpens Cauda.	Ancient	Serpentis Caput	Unukalhai

Serpens Cauda	The serpent's tail; held by Ophiuchus and part of the same constellation as Serpens Caput.	Ancient	Serpentis Cauda	η-Ser
Sextans	The sextant; a constellation introduced by Johannes Hevelius in 1687, celebrating an instrument used to measure star positions.	1687 (Hevelius)	Sextantis	α-Sex
Taurus	The bull; said by the Sumerians to be charging at Orion the hunter, but in Greek mythology said to be Zeus in disguise.	Ancient	Tauri	Aldebaran
Telescopium	The telescope; a modern constellation introduced by Lacaille in 1756.	1756 (Lacaille)	Telescopii	α-Tel
Triangulum	The triangle; appearing similar to a capital delta in the Greek alphabet.	Ancient	Trianguli	β-Tri
Triangulum Australe	The southern triangle; a constellation introduced by Keyser & de Houtman in 1598.	1598 (Keyser & de Houtman)	Trianguli Australe	Atria
Tucana	The toucan; a constellation introduced by Keyser & de Houtman in 1598.	1598 (Keyser & de Houtman)	Tucanae	α-Tuc
Ursa Major	The great bear, also known as the Big Dipper or the Plough. In Greek mythology, Callisto, lover of Zeus.	Ancient	Ursae Majoris	Alioth
Ursa Minor	The lesser bear; in Greek mythology, one of the nymphs	Ancient	Ursae Minoris	Polaris

	that nursed Zeus as an infant.			
Vela	The sail; a sub-division of the ancient constellation Argo – in Greek mythology, the ship of the Argonauts.	1756 (Lacaille)	Velorum	γ²-Vel
Virgo	The virgin; in Greek mythology, the goddess of justice.	Ancient	Virginis	Spica
Volans	The flying fish; a constellation introduced by Keyser & de Houtman in 1598, celebrating the family Exocoetidae.	1598 (Keyser & de Houtman)	Volantis	γ²-Vol
Vulpecula	The fox; a constellation introduced by Johannes Hevelius in 1687.	1687 (Hevelius)	Vulpeculae	α-Vul

List of superconductors

Substance	Class	Transition temperature (K)	Critical magnetic field (T)	Type
Al	Element	1.20	0.01	I
Bi	Element	5.3×10^{-4}	5.2×10^{-6}	I
Cd	Element	0.52	0.0028	I
Diamond:B	Element	11.4	4	II
Ga	Element	1.083	0.0058	I
Hf	Element	0.165		I
α-Hg	Element	4.15	0.04	I

β-Hg	Element	3.95	0.04	I
In	Element	3.4	0.03	I
Ir	Element	0.14	0.0016	I
α-La	Element	4.9		I
β-La	Element	6.3		I
Li	Element	4×10^{-4}		I
Mo	Element	0.92	0.0096	I
Nb	Element	9.26	0.82	II
Os	Element	0.65	0.007	I
Pa	Element	1.4		I
Pb	Element	7.19	0.08	I
Re	Element	2.4	0.03	I
Rh	Element	3.25×10^{-4}	4.9×10^{-6}	I
Ru	Element	0.49	0.005	I
Si:B	Element	0.4	0.4	II
Sn	Element	3.72	0.03	I
Ta	Element	4.48	0.09	I
Tc	Element	7.46–11.2	0.04	II
α-Th	Element	1.37	0.013	I
Ti	Element	0.39	0.01	I
Tl	Element	2.39	0.02	I
α-U	Element	0.68		I
β-U	Element	1.8		I
V	Element	5.03	1	II
α-W	Element	0.015	0.00012	I
β-W	Element	1–4		
Zn	Element	0.855	0.005	I
Zr	Element	0.55	0.014	I
Ba_8Si_{46}	Compound	8.07	0.008	II
C_6Ca	Compound	11.5	0.95	II
$C_6Li_3Ca_2$	Compound	11.15		II
C_8K	Compound	0.14		II
C_8KHg	Compound	1.4		II

C_6K	Compound	1.5		II
C_3K	Compound	3.0		II
C_3Li	Compound	<0.35		II
C_2Li	Compound	1.9		II
C_3Na	Compound	2.3–3.8		II
C_2Na	Compound	5.0		II
C_8Rb	Compound	0.025		II
C_6Sr	Compound	1.65		II
C_6Yb	Compound	6.5		II
$C_{60}Cs_2Rb$	Compound	33		II
$C_{60}K_3$	Compound	19.8	0.013	II
$C_{60}Rb_X$	Compound	28		II
FeB_4	Compound	2.9		II
InN	Compound	3		II
In_2O_3	Compound	3.3	~3	II
LaB_6	Compound	0.45		
MgB_2	Compound	39	74	II
Nb_3Al	Compound	18		II
$NbC_{1-x}N_x$	Compound	17.8	12	II
Nb_3Ge	Compound	23.2	37	II
NbO	Compound	1.38		II
NbN	Compound	16		II
Nb_3Sn	Compound	18.3	30	II
NbTi	Compound	10	15	II
SiC:B	Compound	1.4	0.008	I
SiC:Al	Compound	1.5	0.04	II
TiN	Compound	5.6	5	I
V_3Si	Compound	17		
YB_6	Compound	8.4		II
ZrN	Compound	10		
ZrB_{12}	Compound	6.0		II
YBCO	Cuprate	95	120–250	II
GdBCO	Cuprate	91		II

BSCCO	Cuprate	104		
HBCCO	Cuprate	135		
SmFeAs(O,F)	Iron-based	55		
CeFeAs(O,F)	Iron-based	41		
LaFeAs(O,F))	Iron-based	26		
LaFePO	Iron-based	4		
FeSe	Iron-based	65		
(Ba,K)Fe2As2	Iron-based	38		
NaFeAs	Iron-based	20		

List of vitamins and their functions

Water-soluble vitamins		
Vitamin	**Function**	**Sources**
Thiamine (vitamin B1)	Part of an enzyme needed for energy metabolism; important to nerve function	Found in all nutritious foods in moderate amounts: pork, whole-grain or enriched breads and cereals, legumes, nuts and seeds
Riboflavin (vitamin B2)	Part of an enzyme needed for energy metabolism; important for normal vision and skin health	Milk and milk products; leafy green vegetables; whole-grain, enriched breads and cereals
Niacin (vitamin B3)	Part of an enzyme needed for energy metabolism; important for nervous	Meat, poultry, fish, whole-grain or enriched breads and cereals, vegetables (especially mushrooms, asparagus, and leafy green

	system, digestive system, and skin health	vegetables), peanut butter
Pantothenic acid	Part of an enzyme needed for energy metabolism	Widespread in foods
Biotin	Part of an enzyme needed for energy metabolism	Widespread in foods; also produced in intestinal tract by bacteria
Pyridoxine (vitamin B6)	Part of an enzyme needed for protein metabolism; helps make red blood cells	Meat, fish, poultry, vegetables, fruits
Folic acid	Part of an enzyme needed for making DNA and new cells, especially red blood cells	Leafy green vegetables and legumes, seeds, orange juice, and liver; now added to most refined grains
Cobalamin (vitamin B12)	Part of an enzyme needed for making new cells; important to nerve function	Meat, poultry, fish, seafood, eggs, milk and milk products; not found in plant foods
Ascorbic acid (vitamin C)	Antioxidant; part of an enzyme needed for protein metabolism; important for immune system health; aids in iron absorption	Found only in fruits and vegetables, especially citrus fruits, vegetables in the cabbage family, cantaloupe, strawberries, peppers, tomatoes, potatoes, lettuce, papayas, mangoes, kiwifruit

Fat-soluble vitamins		
Vitamin	**Function**	**Sources**
Vitamin A (and its precursor*, beta-carotene) *A precursor is converted by the body to the vitamin.	Needed for vision, healthy skin and mucous membranes, bone and tooth growth, immune system health	Vitamin A from animal sources (retinol): fortified milk, cheese, cream, butter, fortified margarine, eggs, liver Beta-carotene (from plant sources): Leafy, dark green vegetables; dark orange fruits (apricots, cantaloupe) and vegetables (carrots, winter squash, sweet potatoes, pumpkin)
Vitamin D	Needed for proper absorption of calcium; stored in bones	Egg yolks, liver, fatty fish, fortified milk, fortified margarine. When exposed to sunlight, the skin can make vitamin D.
Vitamin E	Antioxidant; protects cell walls	Polyunsaturated plant oils (soybean, corn, cottonseed, safflower); leafy green vegetables; wheat germ; whole-grain products; liver; egg yolks; nuts and seeds
Vitamin K	Needed for proper blood clotting	Leafy green vegetables such as kale, collard greens, and spinach; green vegetables such as broccoli, Brussels sprouts, and asparagus; also produced in intestinal tract by bacteria

Surface tension for some interfaces		
Interface	**Temperature**	**Surface tension (mN/m)**
Water–air	20 °C	72.86 ± 0.05
Water–air	21.5 °C	72.75
Water–air	25 °C	71.99±0.05
Methylene iodide–air	20 °C	67.00
Methylene iodide–air	21.5 °C	63.11
Ethylene glycol–air	25 °C	47.3
Ethylene glycol–air	40 °C	46.3
Dimethyl sulfoxide–air	20 °C	43.54
Propylene carbonate–air	20 °C	41.1
Benzene–air	20 °C	28.88
Benzene–air	30 °C	27.56

Toluene–air	20 °C	28.52
Chloroform–air	25 °C	26.67
Propionic acid–air	20 °C	26.69
Butyric acid–air	20 °C	26.51
Carbon tetrachloride–air	25 °C	26.43
Butyl acetate–air	20 °C	25.09
Diethylene glycol–air	20 °C	30.09
Nonane–air	20 °C	22.85
Methanol–air	20 °C	22.50
Ethanol–air	20 °C	22.39
Ethanol–air	30 °C	21.55
Octane–air	20 °C	21.61
Heptane–air	20 °C	20.14
Ether–air	25 °C	20.14

Mercury–air	20 °C	486.5
Mercury–air	25 °C	485.5
Mercury–air	30 °C	484.5
NaCl–air	1073 °C	115
$KClO_3$–air	20 °C	81
Water–1-Butanol	20 °C	1.8
Water–Ethyl acetate	20 °C	6.8
Water–Heptanoic acid	20 °C	7.0
Water–Benzaldehyde	20 °C	15.5
Water–transformer oil	20 °C	37.2
Water–Mercury	20 °C	415
Ethanol–Mercury	20 °C	389
Water–1,2-Dichloroethane	20 °C	30.5 ± 0.3
Water–α,α,α-trifluorotoluene	20 °C	38.0 ± 0.5

Water–nitrobenzene	20 °C	24.4 ± 0.2
Water–nitromethane	20 °C	16.0 ± 0.2
Water–propylene carbonate	20 °C	2.9 ± 0.1

List of inorganic and organic reagents commonly used in chemistry

Name	**General Description**
Acetic acid	an organic acid; is one of the simplest carboxylic acids
Acetone	an organic compound; simplest example of the ketones
Acetylene	a hydrocarbon and the simplest alkyne; widely used as a fuel and chemical building block
Ammonia	inorganic; the precursor to most nitrogen-containing compounds; used to make fertilizer
Ammonium hydroxide	aqueous ammonia; used in traditional qualitative inorganic analysis
Azobisisobutyronitrile	organic compound; often used as a foamer in plastics and rubber and as a radical initiator

Baeyer's reagent	is an alkaline solution of potassium permanganate; used in organic chemistry as a qualitative test for the presence of unsaturation, such as double bonds;
N-Bromosuccinimide	used in radical substitution and electrophilic addition reactions in organic chemistry
Butanone (methyl ethyl ketone)	organic compound; similar solvent properties to acetone but has a significantly slower evaporation rate
Butylated hydroxytoluene	a fat-soluble organic compound that is primarily used as an antioxidant food additive
n-Butyllithium	an organolithium reagent; used as a polymerization initiator in the production of elastomers such as polybutadiene or styrene-butadiene-styrene (SBS)
Carbon disulfide	a non-polar solvent; used frequently as a building block in organic chemistry
Carbon tetrachloride	toxic, and its dissolving power is low; consequently, it has been largely superseded by deuterated solvents
Carbonyldiimidazole	often used for the coupling of amino acids for peptide synthesis and as a reagent in organic synthesis
Ceric ammonium nitrate	an inorganic compound; used as an oxidising agent in organic synthesis and as a standard oxidant in

	quantitative analysis
Chloridotris(triphenylphosphine) rhodium (I)	Coordination complex; used in homogeneous catalysis of alkenes to alkanes
Chloroform	organic compound; often used as CHCl3 (deuterated chloroform) as a solvent for NMR spectroscopy and as a general solvent.
Chromic acid	a strong and corrosive oxidising agent; an intermediate in chromium plating
Chromium trioxide	the acidic anhydride of chromic acid; mainly used in chrome-plating
Collins reagent	used to selectively oxidize primary alcohols to an aldehyde
Copper(I) iodide	useful in a variety of applications ranging from organic synthesis to cloud seeding
Dess–Martin periodinane	chemical reagent used to oxidize primary alcohols to aldehydes and secondary alcohols to ketones
Diborane	the central organic synthesis reagent for hydroboration
Dicyclohexylcarbodiimide	an organic compound; primary use is to couple amino acids during artificial peptide synthesis
Diethyl azodicarboxylate	a valuable reagent but also quite dangerous and explodes

	upon heating
Diethyl ether	organic compound; a common laboratory solvent
Dihydropyran	a heterocyclic compound; used as a protecting group for alcohols in organic synthesis.
Diisobutylaluminium hydride	an organoaluminium compound ; a reducing agent; converts esters and nitriles to aldehydes
Diisopropyl azodicarboxylate	the diisopropyl ester of azodicarboxylic acid; a reagent in the production of many organic compounds
Dimethyl ether	the simplest ether; a useful precursor to other organic compounds and an aerosol propellant
Dimethylformamide	organic compound; a common solvent for chemical reactions
Dimethylsulfide	organosulfur compound; used in petroleum refining and in petrochemical production processes; a reducing agent in ozonolysis reactions
Dimethyl sulfoxide	an organosulfur compound; an important polar aprotic solvent that dissolves both polar and nonpolar compounds
Dioxane	a heterocyclic organic compound; classified as an ether
Ethanol	a powerful psychoactive drug; used in alcoholic

	beverages, in thermometers, as a solvent, and as a fuel
Fehling's reagent	used to differentiate between water-soluble aldehyde and ketone functional groups
Fenton's reagent	a solution of hydrogen peroxide and an iron catalyst that is used to oxidize contaminants or waste waters
Formaldehyde	the simplest aldehyde; an important precursor to many other chemical compounds, such as polymers and polyfunctional alcohols
Formic acid	the simplest carboxylic acid; often used as a source of the hydride ion
Grignard reagents	the most common application is for alkylation of aldehydes and ketones
Hexamethylphosphoramide	a phosphoramide; useful polar aprotic solvent and additive in organic synthesis
Hydrazine	It's a good reducing agent and is used in the Wolff-Kishner reaction for reducing carbonyls to its corresponding alkanes. used as a foaming agent in preparing polymer foams; also a precursor to polymerization catalysts and pharmaceuticals; also as an Oxygen scavenger in Power Plants
Hydrazoic acid	used primarily for preservation of stock solutions, and as a reagent

Hydrochloric acid	a highly corrosive, strong mineral acid with many industrial uses
Hydrofluoric acid	valued source of fluorine, precursor to numerous pharmaceuticals; highly corrosive
Hydrogen peroxide	an oxidizer commonly used as a bleach
Imidazole	an organic compound; this aromatic heterocyclic is a diazole and is classified as an alkaloid
Isopropyl alcohol	simplest example of a secondary alcohol; dissolves a wide range of non-polar compounds
Lime	used in Flue Gas Desulphurisation in Power Plants
Limestone	used in Flue Gas Desulphurisation in Power Plants
Lithium aluminium hydride	a reducing agent in organic synthesis; used to prepare main group and transition metal hydrides from the corresponding metal halides
Lithium diisopropylamide	strong base used in organic chemistry for the deprotonation of weakly acidic compounds
Manganese dioxide	used as a pigment and as a precursor to other manganese compounds; used as a reagent in organic synthesis for the oxidation of allylic alcohols

Meta-Chloroperoxybenzoic acid	used as an oxidant in organic synthesis
Methyl tert-butyl ether	a gasoline additive; also used in organic chemistry as a relatively inexpensive solvent
Millon's reagent	an analytical reagent used to detect the presence of soluble proteins
Nitric acid	highly corrosive and toxic strong acid; used for the production of fertilizers, production of explosives, and as a component of aqua regia
Osmium tetroxide	in organic synthesis, is widely used to oxidise alkenes to the vicinal diols
Oxalyl chloride	used in organic synthesis for the preparation of acid chlorides from the corresponding carboxylic acids
Palladium(II) acetate	a catalyst for many organic reactions by combining with many common classes of organic compounds to form reactive adduct
Perchloric acid	a powerful oxidizing agent; readily forms explosive mixtures; mainly used in the production of rocket fuel
Phosphoric acid	a mineral acid with many industrial uses; commonly used in the laboratory preparation of hydrogen halides
Phosphorus pentachloride	one of the most important phosphorus chlorides; a chlorinating reagent. Also used as a dehydrating agent

	for oximes which turn them into nitriles.
Phosphorus tribromide	used for the conversion of alcohols to alkyl bromides
Phosphorus trichloride	most important of the three phosphorus chlorides; used to manufacture organophosphorus compounds; used to convert primary and secondary alcohols into alkyl chlorides, or carboxylic acids into acyl chlorides
Phosphoryl chloride	used to make phosphate esters such as tricresyl phosphate
Potassium dichromate	a common inorganic chemical reagent, most commonly used as an oxidizing agent in various laboratory and industrial applications
Potassium hydroxide	a strong base; precursor to most soft and liquid soaps as well as numerous potassium-containing chemicals
Potassium permanganate	a strong oxidizing agent; can be used to quantitatively determine the total oxidisable organic material in an aqueous sample; a reagent for the synthesis of organic compounds
Pyridinium chlorochromate	used to oxidize primary alcohols to aldehydes and secondary alcohols to ketones
Pyridinium dichromate (Cornforth reagent)	converts primary and secondary alcohols to ketones
Raney nickel	an alternative catalyst for the hydrogenation of vegetable

	oils; in organic synthesis, used for desulfurization
Sakaguchi's Reagent	Detects the presence of arginine
Samarium(II) iodide (Kagan Reagent)	a powerful reducing agent
Silver oxide	used to prepare other silver compounds; in organic chemistry, used as a mild oxidizing agent
Silver nitrate	precursor to many other silver compounds; commonly used in inorganic chemistry to abstract halides
Sodium amide	used in the industrial production of indigo, hydrazine, and sodium cyanide; used for the drying of ammonia; used as a strong base in organic chemistry
Sodium azide	gas-forming component in airbag systems; used in organic synthesis to introduce the azide functional group by displacement of halides
Sodium bis(trimethylsilyl)amide	a strong base; deprotonates ketones and esters to generate enolate derivative
Sodium borohydride	a versatile reducing agent; converts ketones and aldehydes to alcohols
Sodium chlorite	in organic synthesis, used for the oxidation of aldehydes to carboxylic acids
Sodium hydride	a strong base used in organic synthesis

Sodium hydroxide	strong base with many industrial uses; in the laboratory, used with acids to produce the corresponding salt, also used as an electrolyte
Sodium hypochlorite	frequently used as a disinfectant or a bleaching agent
Sodium nitrite	used to convert amines into diazo compounds
Sulfuric acid	strong mineral acid; major industrial use is the production of phosphoric acid
tert-Butyl hydroperoxide	used in a variety of oxidation processes; industrially, is used as a starter of radical polymerization
Tetrahydrofuran	one of the most polar ethers; a useful solvent; its main use is as a precursor to polymers
Tetrakis(triphenylphosphine)palladium(0)	a catalyst for palladium-catalyzed coupling reactions
Tetramethylammonium hydroxide	a quaternary ammonium salt; used as an anisotropic etchant of silicon; used as a basic solvent in the development of acidic photoresist in the photolithography process
Tetramethylsilane	the simplest tetraorganosilane; a building block in organometallic chemistry
Thionyl chloride	an inorganic compound; used in chlorination reactions; converts carboxylic acids to acyl chlorides

Thiophenol	an organosulfur compound; the simplest aromatic thiol
Titanium tetrachloride	an intermediate in the production of titanium metal and titanium dioxide
Tollens' reagent	a chemical test most commonly used to determine whether a known carbonyl-containing compound is an aldehyde or a ketone
Triphenylphosphine	used in the synthesis of organic and organometallic compounds

The Four Fundamental Interactions of Nature

Interaction	Current theory	Mediators	Relative strength	Range (m)
Weak	Electroweak theory (EWT)	W and Z bosons	10^{25}	10^{-18}
Strong	Quantum chromodynamics (QCD)	gluons	10^{38}	10^{-15}
Electromagnetic	Quantum electrodynamics (QED)	photons	10^{36}	∞
Gravitation	General relativity (GR)	gravitons (hypothetical)	1	∞

Table of liquid–vapor critical temperature and pressure for selected substances

Substance	Critical temperature	Critical pressure (absolute)
Argon	−122.4 °C (150.8 K)	48.1 atm (4,870 kPa)
Ammonia (NH_3)	132.4 °C (405.5 K)	111.3 atm (11,280 kPa)
R-134a	101.06 °C (374.21 K)	40.06 atm (4,059 kPa)
R-410A	72.8 °C (345.9 K)	47.08 atm (4,770 kPa)
Bromine	310.8 °C (584.0 K)	102 atm (10,300 kPa)
Caesium	1,664.85 °C (1,938.00 K)	94 atm (9,500 kPa)
Chlorine	143.8 °C (416.9 K)	76.0 atm (7,700 kPa)
Ethanol (C_2H_5OH)	241 °C (514 K)	62.18 atm (6,300 kPa)
Fluorine	−128.85 °C (144.30 K)	51.5 atm (5,220 kPa)
Helium	−267.96 °C (5.19 K)	2.24 atm (227 kPa)
Hydrogen	−239.95 °C (33.20 K)	12.8 atm (1,300 kPa)
Krypton	−63.8 °C (209.3 K)	54.3 atm (5,500 kPa)
Methane (CH_4)	−82.3 °C (190.8 K)	45.79 atm (4,640 kPa)

Neon	−228.75 °C (44.40 K)	27.2 atm (2,760 kPa)
Nitrogen	−146.9 °C (126.2 K)	33.5 atm (3,390 kPa)
Oxygen (O_2)	−118.6 °C (154.6 K)	49.8 atm (5,050 kPa)
Carbon dioxide (CO_2)	31.04 °C (304.19 K)	72.8 atm (7,380 kPa)
Nitrous oxide (N_2O)	36.4 °C (309.5 K)	71.5 atm (7,240 kPa)
Sulfuric acid (H_2SO_4)	654 °C (927 K)	45.4 atm (4,600 kPa)
Xenon	16.6 °C (289.8 K)	57.6 atm (5,840 kPa)
Lithium	2,950 °C (3,220 K)	652 atm (66,100 kPa)
Mercury	1,476.9 °C (1,750.1 K)	1,720 atm (174,000 kPa)
Sulfur	1,040.85 °C (1,314.00 K)	207 atm (21,000 kPa)
Iron	8,227 °C (8,500 K)	
Gold	6,977 °C (7,250 K)	5,000 atm (510,000 kPa)
Aluminum	7,577 °C (7,850 K)	
Water (H_2O)	373.946 °C (647.096 K)	217.7 atm (22,060 kPa)

List of Natural Satellites

Name of Natural Satellite	Planet of Origin
Moon	Earth
Mimas	Saturn
Enceladus	Saturn
Tethys	Saturn
Rhea	Saturn
Dione	Saturn
Titan	Saturn
Hyperion	Saturn
Iapetus	Saturn
Phobos	Mars
Deimos	Mars
Metis	Jupiter
Adrastea	Jupiter
Amalthea	Jupiter
Thebe	Jupiter
Io	Jupiter
Europa	Jupiter
Ganymede	Jupiter
Callisto	Jupiter
Themisto	Jupiter
Leda	Jupiter
Himalia	Jupiter
Lysithea	Jupiter
Elara	Jupiter
Dia	Jupiter
Carpo	Jupiter

S/2003 J 12	Jupiter
Euporie	Jupiter
S/2003 J 3	Jupiter
S/2011 J 1	Jupiter
S/2003 J 18	Jupiter
S/2010 J 2	Jupiter
Thelxinoe	Jupiter
Euanthe	Jupiter
Helike	Jupiter
Orthosie	Jupiter
S/2016 J 1	Jupiter
Iocaste	Jupiter
S/2003 J 16	Jupiter
Praxidike	Jupiter
Harpalyke	Jupiter
Mneme	Jupiter
Hermippe	Jupiter
Thyone	Jupiter
Ananke	Jupiter
Herse	Jupiter
Aitne	Saturn
Kale	Jupiter
Taygete	Jupiter
S/2003 J 19	Jupiter
Chaldene	Jupiter
S/2003 J 15	Jupiter
S/2003 J 10	Jupiter
S/2003 J 23	Jupiter
Erinome	Jupiter
Aoede	Jupiter

Kallichore	Jupiter
Kalyke	Jupiter
Carme	Jupiter
Callirrhoe	Jupiter
Eurydome	Jupiter
Pasithee	Jupiter
S/2010 J 1	Jupiter
Kore	Jupiter
Cyllene	Jupiter
S/2011 J 2	Jupiter
Eukelade	Jupiter
S/2017 J 1	Jupiter
S/2003 J 4	Jupiter
Pasiphae	Jupiter
Hegemone	Jupiter
Arche	Jupiter
Isonoe	Jupiter
S/2003 J 9	Jupiter
S/2003 J 5	Jupiter
Sinope	Jupiter
Sponde	Jupiter
Autonoe	Jupiter
Megaclite	Jupiter
S/2003 J 2	Jupiter
S/2009 S 1	Saturn
Pan	Saturn
Daphnis	Saturn
Atlas	Saturn
Peggy	Saturn
Prometheus	Saturn

Pandora	Saturn
Epimetheus	Saturn
Janus	Saturn
Aegaeon	Saturn
Mimas	Saturn
Methone	Saturn
Anthe	Saturn
Pallene	Saturn
Enceladus	Saturn
Tethys	Saturn
Telesto	Saturn
Calypso	Saturn
Dione	Saturn
Helene	Saturn
Polydeuces	Saturn
Rhea	Saturn
Titan	Saturn
Hyperion	Saturn
Iapetus	Saturn
Kiviuq	Saturn
Ijiraq	Saturn
Phoebe	Saturn
Paaliaq	Saturn
Skathi	Saturn
Albiorix	Saturn
S/2007 S 2	Saturn
Bebhionn	Saturn
Erriapus	Saturn
Skoll	Saturn
Siarnaq	Saturn

Tarqeq	Saturn
S/2004 S 13	Saturn
Greip	Saturn
Hyrrokkin	Saturn
Jarnsaxa	Saturn
Tarvos	Saturn
Mundilfari	Saturn
S/2006 S 1	Saturn
S/2004 S 17	Saturn
Bergelmir	Saturn
Narvi	Saturn
Suttungr	Saturn
Hati	Saturn
S/2004 S 12	Saturn
Farbauti	Saturn
Thrymr	Saturn
Aegir	Saturn
S/2007 S 3	Saturn
Bestla	Saturn
S/2004 S 7	Saturn
S/2006 S 3	Saturn
Fenrir	Saturn
Surtur	Saturn
Kari	Saturn
Ymir	Saturn
Loge	Saturn
Fornjot	Saturn
Themis (Destroyed)	Saturn
Chiron (Destroyed)	Saturn
Cordelia	Uranus

Ophelia	Uranus
Bianca	Uranus
Cressida	Uranus
Desdemona	Uranus
Juliet	Uranus
Portia	Uranus
Rosalind	Uranus
Cupid	Uranus
Belinda	Uranus
Perdita	Uranus
Puck	Uranus
Mab	Uranus
Miranda	Uranus
Ariel	Uranus
Umbriel	Uranus
Titania	Uranus
Oberon	Uranus
Francisco	Uranus
Caliban	Uranus
Stephano	Uranus
Trinculo	Uranus
Sycorax	Uranus
Margaret	Uranus
Prospero	Uranus
Setebos	Uranus
Ferdinand	Uranus
Naiad	Neptune
Thalassa	Neptune
Despina	Neptune
Galatea	Neptune

Larissa	Neptune
Hippocamp	Neptune
Proteus	Neptune
Triton	Neptune
Nereid	Neptune
Halimede	Neptune
Sao	Neptune
Laomedeia	Neptune
Psamathe	Neptune
Neso	Neptune
Charon	Pluto
Styx	Pluto
Nix	Pluto
Kerberos	Pluto
Hydra	Pluto
MK 2	Makemake
Namaka Hi'laka	Haumea
Dysnomia	Eris
Dactyl	243 Ida
Skamandrios	624 Hektor
Remus	87 Sylvia
Romulus	87 Sylvia
S/2001 (107) 1	107 Camilla
S/2016 (107) 1	107 Camilla
Petit-Prince	45 Eugenia
S/2004 (45) 1	45 Eugenia
S/2007 (225088) 1	Snow-White
S/2013 (285263) 1	(285263) 1998 QE_2
Alexhelios	216 Kleopatra

Cleoselene	216 Kleopatra
Weywot	50000 Quaoar
Didymoon	65803 Didymos

Groups	**Neurotransmitter**	**Function**
Acetylcholine	Acetylcholine	Excitatory
Amines	Epinephrine	Excitatory
	Norephinephrine	Excitatory
	Dopamine	Excitatory and Inhibitory
	Serotonin	Excitatory
Amino Acids	Glutamate	Excitatory
	Glycine	Mainly inhibitory
	g-Aminobutiric acid (GABA)	Inhibitory

Binary star	**Orbital period**
AM Canum Venaticorum	17.146 minutes
Beta Lyrae AB	12.9075 days
Alpha Centauri AB	79.91 years
Proxima Centauri – Alpha Centauri AB	500,000 years or more

Properties of Ionic Diatomic Molecules

Molecule	Dissociation Energy(eV)	Equilibrium Separation (nm) (Bond length)
NaCl	4.26	0.236
NaF	4.99	0.193
NaBr	3.8	0.250
NaI	3.1	0.271
NaH	2.08	0.189
LiCl	4.86	0.202
LiH	2.47	0.239
LiI	3.67	0.238
KCl	4.43	0.267
KBr	3.97	0.282
RbF	5.12	0.227
RbCl	4.64	0.279
CsI	3.57	0.337

Properties of Heteronuclear Diatomic Molecules

Molecule	Dissociation Energy(eV)	Equilibrium Separation (nm) (Bond length)
BN	4.0	0.128
CO	11.2	0.113
HBr	...	0.141
HCl	4.4	0.127
HF	5.8	0.092
NO	7.0	0.115
PbO	4.1	0.192
PbS	3.3	0.239

Thermal Conductivity and Debye Temperature

Li	Be	**Debye temperature and thermal conductivity**										B	C	N	O	F	Ne
344	1440	Low temperature limit of Debye temperature in Kelvin										...	2230	...	...	...	75
0.85	2.00	Thermal conductivity at 300K, in W/cmK										0.27	1.29	...	...	...	...
Na	Mg	...										Al	Si	P	S	Cl	Ar
158	400											428	645	...	...	...	92
1.41	1.56											2.37	1.48	...	...	...	...
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
91	230	360	420	380	630	410	470	445	450	343	327	320	374	282	90	...	72
1.02	...	0.16	0.22	0.31	0.94	0.08	0.80	1.00	0.91	4.01	1.16	0.41	0.6	0.50	0.02	...	...
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
56	147	280	291	275	450	...	600	480	274	225	209	108	200	211	153	...	64
0.58	...	0.17	0.23	0.54	1.38	0.51	1.17	1.50	0.72	4.29	0.97	0.82	0.67	0.24	0.02	...	...
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
38	110	142	252	240	400	430	500	420	240	165	71.9	78.5	105	119	...	...	64
0.36	...	0.14	0.23	0.58	1.74	0.48	0.88	1.47	0.72	3.17	...	0.46	0.35	0.08	...	...	...
Fr	Ra	Ac	...														
...	...	...															
...	...	...															
...			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	...
			...	...	...	...	...	...	200	...	210	...	...	...	120	210	
			0.11	0.13	0.16	...	0.13	...	0.11	0.11	0.11	0.16	0.14	0.17	0.35	0.16	
...			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	...
			163	...	207	...	...	...	...	...	...	...	...	...	...	...	
			0.54	...	0.28	0.06	0.07	...	...	...	...	...	...	...	...	...	

Vibrational frequencies of diatomic molecules

Molecule	Frequency (10^{13} Hz)
HH	13
NN	7.0
CO	6.4
NO	5.7
OO	4.7

Superconductor coherence lengths and penetration depths

Material	Coherence length ξ_0(nm)	London penetration depth λ_L(nm)	Ratio $\frac{\lambda_L}{\xi_0}$
Sn	230	34	0.16
Al	1600	16	0.010
Pb	83	37	0.45
Cd	760	110	0.14
Nb	38	39	1.02

Semiconductor Band Gaps

Material	Energy gap (eV)	
	0K	300K
Si	1.17	1.11
Ge	0.74	0.66
InSb	0.23	0.17
InAs	0.43	0.36
InP	1.42	1.27
GaP	2.32	2.25
GaAs	1.52	1.43
GaSb	0.81	0.68
CdSe	1.84	1.74
CdTe	1.61	1.44
ZnO	3.44	3.2
ZnS	3.91	3.6

Quarks						
Generation	Name	Symbol	Antiparticle	Spin	Charge (e)	Mass (MeV/c^2)
1	up	u	$\bar{u}$	$\frac{1}{2}$	$+\frac{2}{3}$	$2.2^{+0.6}_{-0.4}$
	down	d	$\bar{d}$	$\frac{1}{2}$	$-\frac{1}{3}$	$4.6^{+0.5}_{-0.4}$

2	charm	c	$\bar{c}$	$\frac{1}{2}$	$+\frac{2}{3}$	1,280±30
	strange	s	$\bar{s}$	$\frac{1}{2}$	$-\frac{1}{3}$	96^{+8}_{-4}
3	top	t	$\bar{t}$	$\frac{1}{2}$	$+\frac{2}{3}$	173,100±600
	bottom	b	$\bar{b}$	$\frac{1}{2}$	$-\frac{1}{3}$	$4{,}180^{+40}_{-30}$

Leptons						
Generation	**Name**	**Symbol**	**Antiparticle**	**Spin**	**Charge (e)**	**Mass (MeV/c^2)**
1	Electron	e^-	e^+	$\frac{1}{2}$	−1	0.511
	Electron neutrino	ν_e	$\overline{\nu_e}$	$\frac{1}{2}$	0	< 0.0000022
2	Muon	μ^-	μ^+	$\frac{1}{2}$	−1	105.7
	Muon neutrino	ν_μ	$\overline{\nu_\mu}$	$\frac{1}{2}$	0	< 0.170

3	Tau	τ^-	τ^+	$\frac{1}{2}$	−1	1,776.86±0.12
	Tau neutrino	ν_τ	$\bar{\nu}_\tau$	$\frac{1}{2}$	0	< 15.5

Bosons

Name	Symbol	Antiparticle	Spin	Charge (e)	Mass (GeV/c^2)	Interaction mediated	Observed
Photon	γ	Self	1	0	0	Electromagnetism	Yes
W boson	W^-	W^+	1	−1	80.385±0.015	Weak interaction	Yes
Z boson	Z	Self	1	0	91.1875±0.0021	Weak interaction	Yes
Gluon	g	Self	1	0	0	Strong interaction	Yes
Higgs boson	H^0	Self	0	0	125.09±0.24	Mass	Yes
Graviton	G	Self	2	2	0	Gravitation	No

Low-frequency dielectric constants of some common solvents

Solvent	Dielectric constant	Temperature (K)
benzene	2.3	298
diethyl ether	4.3	293
tetrahydrofuran (THF)	7.6	298
dichloromethane	9.1	293
liquid ammonia	17	273
ethanol	24.3	298
methanol	32.7	298
nitromethane	35.9	303
dimethyl formamide (DMF)	36.7	298
acetonitrile	37.5	293
water	78.4	298
formamide	109	293

Poisson's ratio values for different materials

Material	Poisson's ratio
rubber	0.4999
gold	0.42–0.44
saturated clay	0.40–0.49
magnesium	0.252–0.289
titanium	0.265–0.34
copper	0.33
aluminium-alloy	0.32
clay	0.30–0.45
stainless steel	0.30–0.31
steel	0.27–0.30
cast iron	0.21–0.26
sand	0.20–0.455
concrete	0.1–0.2
glass	0.18–0.3

metallic glasses	0.276–0.409
foam	0.10–0.50
cork	0.0

Material	**Typical values for shear modulus (GPa) (at room temperature)**
Diamond	478.0
Steel	79.3
Iron	52.5
Copper	44.7
Titanium	41.4
Glass	26.2
Aluminium	25.5
Polyethylene	0.117
Rubber	0.0006
Granite	24
Shale	1.6
Limestone	24
Chalk	3.2
Sandstone	0.4
Wood	4

Thermal diffusivity of selected materials and substances

Material	Thermal diffusivity (mm^2/s)
Wood (Yellow Pine)	0.082
Water vapour (1 atm, 400 K)	23.38
Water at 25 °C	0.143
Tin	40
Steel, stainless 310 at 25 °C	3.352
Steel, stainless 304A at 27 °C	4.2
Steel, AISI 1010 (0.1% carbon)	18.8
Steel, 1% carbon	11.72
Silver, pure (99.9%)	165.63
Silicon Dioxide (Polycrystalline)	0.83
Silicon	88
$Si_3 N_4$ with CNTs 26 °C	9.142
$Si_3 N_4$ without CNTs 26 °C	8.605
Sandstone	1.15

Rubber	0.089 - 0.13
Quartz	1.4
Pyrolytic graphite, parallel to layers	1220
Pyrolytic graphite, normal to layers	3.6
PVC (Polyvinyl Chloride)	0.08
PTFE (Polytetrafluorethylene) at 25 °C	0.124
PP (Polypropylene) at 25 °C	0.096
PC (Polycarbonate) at 25 °C	0.144
Paraffin at 25 °C	0.081
Oil, engine (saturated liquid, 100 °C)	0.0738
Nylon	0.09
Nitrogen (300 K, 1 atm)	22
Molybdenum (99.95%) at 25 °C	54.3
Iron	23
Inconel 600 at 25 °C	3.428
Ice at 0 °C	1.02

Hydrogen (300 K, 1 atm)	160
Helium (300 K, 1 atm)	190
Gold	127
Glass, window	0.34
Copper at 25 °C	111
Carbon/carbon composite at 25 °C	216.5
Brick, common	0.52
Brick, adobe	0.27
Argon (300 K, 1 atm)	22
Aluminium oxide (polycrystalline)	12.0
Aluminium 6061-T6 Alloy	64
Aluminium	97
Alcohol	0.07
Al-10Si-Mn-Mg (Silafont 36) at 20 °C	74.2
Al-5Mg-2Si-Mn (Magsimal-59) at 20 °C	44.0
Air (300 K)	19

Substance	Vapor pressure			Temperature (°C)
	(Pa)	(bar)	(mmHg)	
Tungsten	100 Pa	0.001	0.75	3203
Ethylene glycol	500 Pa	0.005	3.75	20
Xenon difluoride	600 Pa	0.006	4.50	25
Water (H_2O)	2.3 kPa	0.023	17.5	20
Propanol	2.4 kPa	0.024	18.0	20
Methyl isobutyl ketone	2.66 kPa	0.0266	19.95	25
Ethanol	5.83 kPa	0.0583	43.7	20
Freon 113	37.9 kPa	0.379	284	20
Acetaldehyde	98.7 kPa	0.987	740	20
Butane	220 kPa	2.2	1650	20
Formaldehyde	435.7 kPa	4.357	3268	20
Propane	997.8 kPa	9.978	7584	26.85
Carbonyl sulfide	1.255 MPa	12.55	9412	25
Nitrous oxide	5.660 MPa	56.60	42453	25
Carbon dioxide	5.7 MPa	57	42753	20

Antibody isotypes of mammals

Class	Subclasses	Description
IgA	2	Found in mucosal areas, such as the gut, respiratory tract and urogenital tract, and prevents colonization by pathogens. Also found in saliva, tears, and breast milk.
IgD	1	Functions mainly as an antigen receptor on B cells that have not been exposed to antigens. It has been shown to activate basophils and mast cells to produce antimicrobial factors.
IgE	1	Binds to allergens and triggers histamine release from mast cells and basophils, and is involved in allergy. Also protects against parasitic worms.
IgG	4	In its four forms, provides the majority of antibody-based immunity against invading pathogens. The only antibody capable of crossing the placenta to give passive immunity to the fetus.
IgM	1	Expressed on the surface of B cells (monomer) and in a secreted form (pentamer) with very high avidity. Eliminates pathogens in the early stages of B cell-mediated (humoral) immunity before there is sufficient IgG.

Antibody isotypes not found in mammals		
Class	**Types**	**Description**
IgY		Found in birds and reptiles; related to mammalian IgG.
IgW		Found in sharks and skates; related to mammalian IgD.

The luminosity L of a star is related to its apparent brightness b and its distance d to us by:

$$b = \frac{L}{4\pi d^2}$$

The luminosity L of a star is related to its radius R and its temperature T by:

$$L = 4\pi R^2 \sigma T^4$$

where σ is Stefan–Boltzmann constant.

Helmholtz free energy:

$$F = U - TS$$

Gibbs free energy:

$$G = H - TS$$

Enthalpy:

$$H = U + PV$$

where: H → enthalpy, P → pressure, V → volume, T → temperature, S → entropy and U → internal energy.

Limiting Magnitudes for Visual Observation at High Magnification

Telescope aperture (mm)	**Limiting Magnitude**
35	11.3
60	12.3
102	13.3
152	14.1
203	14.7
305	15.4
406	15.7
508	16.4

Neutron energy range names

Neutron energy	Energy range
0.0–0.025 eV	Cold neutrons
0.025 eV	Thermal neutrons
0.025–0.4 eV	Epithermal neutrons
0.4–0.5 eV	Cadmium neutrons
0.5–1 eV	EpiCadmium neutrons
1–10 eV	Slow neutrons
10–300 eV	Resonance neutrons
300 eV–1 MeV	Intermediate neutrons
1–20 MeV	Fast neutrons
> 20 MeV	Ultrafast neutrons

Black hole Equations:

- $R_s = \dfrac{2GM}{c^2}$
- $T = \dfrac{\hbar c^3}{8\pi GMk_B}$
- $P = \dfrac{\hbar c^6}{15360\pi G^2M^2}$
- $t_{ev} = \dfrac{5120\pi G^2M^3}{\hbar c^4} = \dfrac{480c^2V}{\hbar G}$
- $S = \dfrac{k_BA}{4L_{Planck}^2}$
- $A = \dfrac{16\pi G^2M^2}{c^4}$
- $dE = \dfrac{\kappa}{8\pi}\, dA + \Omega dJ + \phi dQ$
- $\dfrac{dA}{dt} \geq 0$
- $\rho = \dfrac{3c^6}{32\pi G^3M^2}$

where: M is the Mass, G is the gravitational constant, S is the Entropy, A is the Horizon area, t_{ev} is the evaporation time, T is the temperature, k_B is the Boltzmann constant, ρ is the density, c is the speed of light, $L_{Planck} = \sqrt{\dfrac{G\hbar}{c^3}}$ is the Planck length, V is the volume, R_s is the Schwarzschild radius, $E = Mc^2$ is the energy, κ is the surface gravity, Ω is the angular velocity, J is the angular momentum, ϕ is the electrostatic potential and Q is the electric charge.

Thermodynamics of the universe:

$$0 = dQ = dU + PdV$$

$$\boxed{dU = -\,PdV}$$

where Q is the total heat which is assumed to be constant, U is the internal energy of the matter and radiation in the universe, P is the pressure and V the volume.

Energy density $u = \dfrac{U}{V}$

$$du = -\,(P + u)\,\frac{dV}{V} = -\,3(P + u)\,\frac{da}{a}$$

For radiation, $p = \dfrac{u}{3}$ whereas for matter $p \ll u$ and the pressure can be neglected. Thus we get:

For radiation

$$du = -\,4u\,\frac{da}{a} \text{ thus u is proportional to } a^{-4}$$

For matter

$$du = -\,3u\,\frac{da}{a} \text{ thus u is proportional to } a^{-3}$$

a being the scale factor of the universe.

Redshift

$$\frac{\lambda_{\text{now}}}{\lambda_{\text{then}}} = \frac{a_{\text{now}}}{a_{\text{then}}}$$

$$\boxed{1 + z = \frac{a_{\text{now}}}{a_{\text{then}}}}$$

If the source moves away from the observer with velocity v, which is much less than the speed of light (v ≪ c), the redshift is given by:

$$z = \frac{v}{c}$$

Gravitational redshift:

$$1 + z = \frac{1}{\sqrt{1 - \frac{2GM}{rc^2}}}$$

where

- G is the gravitational constant,
- M is the mass of the object creating the gravitational field,
- r is the radial coordinate of the source (which is analogous to the classical distance from the center of the object, but is actually a Schwarzschild coordinate), and
- c is the speed of light.

Hubble's law:

$$v = HD$$

where

- v is the recessional velocity, typically expressed in km/s.
- H is the Hubble parameter
- D is the proper distance from the galaxy to the observer, measured in mega parsecs (Mpc)

$$\text{Hubble Distance} = \frac{c}{H}$$

$$\text{Hubble Time} = \frac{1}{H}$$

$$\boxed{\frac{dH}{dt} = -H^2 (1+ q)}$$

q being the deceleration parameter.

Critical density of the universe:

$$\rho_c = \frac{3H^2}{8\pi G}$$

Density parameter:

$$\Omega = \frac{\rho}{\rho_c} = \frac{8\pi G\rho}{3H^2}$$

- $\Omega = 0$: empty universe
- $\Omega < 1$: expansion overcomes gravity; universe expands forever
- $\Omega = 1$: critical density; mass is just enough to stop it expanding but not enough to make it recollapse
- $\Omega > 1$: gravity overcomes expansion; universe recollapse

General relativity: Ω determines the curvature (k), or "shape", of the universe:

- $\Omega = 1$: flat universe, $k = 0$

- $\Omega > 1$: closed (or bound) universe, $k = +1$
- $\Omega < 1$: open (or unbound) universe, $k = -1$

The **virial theorem** relates the total kinetic energy of a self-gravitating body due to the motions of its constituent parts, T to the gravitational potential energy, U of the body.

$$2T + U = 0$$

Chandrasekhar limit:

$$M_{limit} = \frac{\omega_3^0 \sqrt{3\pi}}{2} \times \frac{1}{\mu_e} \times \frac{(\text{Planck mass})^3}{(\text{proton mass})^2}$$

- μ_e is the average molecular weight per electron, which depends upon the chemical composition of the star.
- $\omega^0{}_3 \approx 2.018236$ is a constant connected with the solution to the Lane–Emden equation.

Schönberg–Chandrasekhar limit:

$$\frac{M_{core}}{M} \approx 0.37 \frac{\mu_{env}^2}{\mu_{core}^2}$$

- M_{core} − mass of the core.
- M − mass of the whole star.
- μ_{core} − mean molecular mass of the core.
- μ_{env} − mean molecular mass of the envelope.

Eddington luminosity:

$$L_{Edd} = \frac{4\pi G M m_p c}{\sigma_T}$$

Eddington Parameter

$$A = \frac{\text{Luminosity of the star}}{\text{Eddington Luminosity}}$$

where M is the mass of the star, G is the gravitational constant, m_p is the proton mass, c is the speed of light and σ_T is the Thomson cross section.

$$\boxed{\sigma_T = \frac{8\pi r_e^2}{3}}$$

Classical electron radius

$$r_e = \frac{e^2}{4\pi\varepsilon_0 m_e c^2}$$

where e is the elementary charge, m_e is the electron rest mass, c is the speed of light, and ε_0 is the permittivity of free space.

Fine-structure constant

$$\alpha = \frac{e^2}{4\pi\varepsilon_0 \hbar c}$$

where $\hbar = \frac{h}{2\pi}$ is the reduced Planck constant.

Gravitational coupling constant

$$\alpha_G = \frac{(\text{electron rest mass})^2}{(\text{Planck mass})^2}$$

$$\alpha_G = \frac{(\text{proton rest mass})^2}{(\text{Planck mass})^2}$$

Compton scattering

$$\boxed{\lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)}$$

where

λ is the initial wavelength,

λ' is the wavelength after scattering,

h is the Planck constant,

m_e is the electron rest mass,

c is the speed of light, and

θ is the scattering angle.

Photoelectric effect

Energy of the photon = Work function of the surface + Kinetic energy of the emitted electron

$$E = W + KE$$

$$\boxed{h\upsilon = h\upsilon_0 + \frac{m_0 v^2}{2}}$$

$\upsilon < \upsilon_0 \rightarrow$ no photoelectric emission

$$h\upsilon = h\upsilon_0 + eV_{stop}$$

where e is the electron charge and V_{stop} is the stopping voltage (or stopping potential).

Photoemission from atoms:

$$h\upsilon = \text{electron's binding energy} + KE$$

Photoemission from solids:

$$h\upsilon = W + \text{electron's binding energy} + KE$$

Photon gas

- $U = \frac{4\sigma T^4}{c} \times V$
- $\mu = 0$
- $P = \frac{U}{3V} = \frac{4\sigma T^4}{3c}$
- $S = \frac{4U}{3T}$
- $H = \frac{4U}{3}$
- $A = -\frac{U}{3}$
- $G = 0$

where U is the internal energy, Gibbs free energy, H is the Enthalpy, A is the Helmholtz free energy, S is the entropy, T is the temperature, V is the volume, μ is the chemical potential, c is the speed of light and $\sigma = \frac{\pi^2 k_B^2}{60\hbar^3 c^2}$ is the Stefan's constant.

Poynting–Robertson effect

The Poynting–Robertson force is equal to:

$$F_{PR} = \frac{v}{c^2} W = \frac{r^2 L_{sun}}{4c^2} \sqrt{\frac{GM_{sun}}{R^5}}$$

where v is the grain's velocity, c is the speed of light, W is the power of the incoming radiation, r the grain's radius, G is the universal gravitational constant, M_{sun} the Sun's mass, L_{sun} is the solar luminosity and R the grain's orbital radius.

The ratio of the force due to radiation pressure to the force of gravity on the particle:

$$\beta = \frac{F_R}{F_G} = \frac{3L_{sun}Q_{PR}}{16\pi GM_{sun}c\rho r}$$

where Q_{PR} is the Mie scattering coefficient and ρ is the density and r is the radius of the dust grain.

The **scale height** is related to the temperature (T) and mean molecular mass (m) of the atmosphere by the formula $H = \frac{k_B T}{mg}$ where k_B is Boltzmann's constant and g is the gravitational acceleration of the body.

If electrons are accelerated to a velocity v by a potential difference V and then allowed to collide with a metal target, the maximum frequency of the X-rays emitted is given by the equation:

$$\frac{m_0 v^2}{2} = eV = h\upsilon_{max}$$

Therefore:

$$\boxed{\upsilon_{max} = \frac{eV}{h}}$$

This shows that the maximum frequency is directly proportional to the accelerating voltage.

Fermi energy

The Fermi energy for a non-interacting ensemble of identical spin-$\frac{1}{2}$ fermions in a three-dimensional (non-relativistic) system is given by:

$$E_F = \frac{\hbar^2}{2m_0} \left(3\pi^2 \frac{N}{V} \right)^{2/3}$$

where N is the number of particles, m_0 the rest mass of each fermion, V the volume of the system, and ħ the reduced Planck constant.

$$E_F = k_B T_F$$

$$v_F = \frac{p_F}{m_0}$$

$$p_F = \hbar k_F$$

where T_F is the Fermi temperature, v_F is the Fermi velocity, p_F is the Fermi momentum and k_F is Fermi wave-vector.

Heat capacity ratio for various gases											
Temp.	**Gas**	**γ**		**Temp.**	**Gas**	**γ**		**Temp.**	**Gas**	**γ**
−181 °C	H_2	1.597		200 °C	Dry air	1.398		20 °C	NO	1.400
−76 °C		1.453		400 °C		1.393		20 °C	N_2O	1.310
20 °C		1.410		1000 °C		1.365		−181 °C	N_2	1.470
100 °C		1.404		15 °C		1.404				
400 °C		1.387		0 °C	CO_2	1.310		20 °C	Cl_2	1.340
1000 °C		1.358		20 °C		1.300		−115 °C	CH_4	1.410
2000 °C		1.318		100 °C		1.281		−74 °C		1.350
20 °C	He	1.660		400 °C		1.235		20 °C		1.320
20 °C	Water vapour	1.330		1000 °C		1.195		15 °C	NH_3	1.310
100 °C		1.324		20 °C	CO	1.400		19 °C	Ne	1.640
200 °C		1.310		−181 °C	O_2	1.450		19 °C	Xe	1.660
−180 °C	Ar	1.760		−76 °C		1.415		19 °C	Kr	1.680
20 °C		1.670		20 °C		1.400		15 °C	SO_2	1.290
0 °C	Dry air	1.403		100 °C		1.399		360 °C	Hg	1.670
20 °C		1.400		200 °C		1.397		15 °C	C_2H_6	1.220
100 °C		1.401		400 °C		1.394		16 °C	C_3H_8	1.130

The acid in our stomach is strong enough to dissolve razor blades

An average cumulus cloud weighs over a million pounds.

There are more trees on Earth than stars in our galaxy

Cold water heats up faster than hot water

Water can exist in all three states: solid (ice), liquid and gas (vapor) at the same time at a temperature called triple point.

Men are more likely to be colorblind than women

Sound waves almost always generate a little bit of heat when they travel and are absorbed by materials.

According to Albert Einstein's theory of Relativity, the farther you are from the **earth's surface**, the faster time passes.

Gravitational waves

$$P = -\frac{dE}{dt} = \frac{32G^4(m_1 m_2)^2}{5c^5} \times \frac{(m_1+m_2)}{r^5}$$

$$-\frac{dr}{dt} = \frac{64G^3(m_1 m_2)}{5c^5} \times \frac{(m_1+m_2)}{r^3}$$

$$t_{life} = \frac{5c^5 r^4}{256G^3(m_1 m_2)(m_1+m_2)}$$

where:

- P is the rate of loss of energy from the binary system through gravitational radiation.
- m_1, m_2 = masses of the orbiting bodies.
- t_{life} is the lifetime of distance "r" between the masses orbiting each other in highly circular orbit about their center of mass.

Relative size of a scattering particle is defined by **size parameter** which is the ratio of its characteristic dimension and wavelength of incident radiation

$$\boxed{\alpha = \frac{2\pi r}{\lambda}}$$

- $\alpha \ll 1$: Rayleigh scattering (small particle compared to wavelength of light)
- $\alpha \approx 1$: Mie scattering (particle about the same size as wavelength of light, valid only for spheres)
- $\alpha \gg 1$: geometric scattering (particle much larger than wavelength of light).

Laws of reflection:

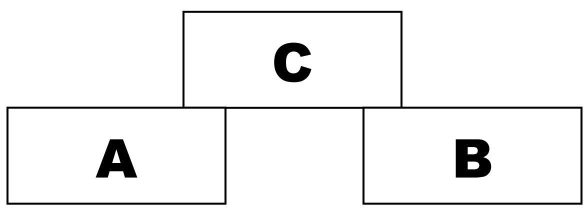
- The incident ray, the reflected ray and the normal ray at the point of incidence, lie in the same plane.
- The angle of incidence is equal to the angle of reflection

Laws of refraction:

- The incident ray refracted ray, and the normal to the interface of two media at the point of incidence all lie on the same plane.
- The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.

$$\boxed{\frac{\sin i}{\sin r} = \text{constant}}$$

Zeroth Law of Thermodynamics:



If two bodies A and B are in thermal equilibrium with third body C, then body A and B are also in thermal equilibrium with each other.

Tyndall effect

$\downarrow$

The scattering of light by very small particles suspended in a gas or liquid

Wiedemann-Franz Law:

$$\frac{\text{Thermal conductivity of the material}}{\text{Electrical conductivity of the material}} \propto \text{Temperature}$$

$$\boxed{\frac{\text{Thermal conductivity of the material}}{\text{Electrical conductivity of the material}} = \textbf{Lorenz number} \times \text{Temperature}}$$

Plant Cell	**Animal Cell**
Cell Shape	
Square or rectangular in shape	Irregular or round in shape
Cell Wall	
Present	Absent
Cell Membrane	
Present	Present
Endoplasmic Reticulum	
Present	Present
Nucleus	
Present and lies on one side of the cell	Present and lies in the centre of the cell
Lysosomes	
Present but are very rare	Present
Centrosomes	
Absent	Present
Golgi Apparatus	
Present	Present
Cytoplasm	
Present	Present
Ribosomes	

Present	Present
Plastids	
Present	Absent
Vacuoles	
Few large or a single, centrally positioned vacuole	Usually small and numerous
Cilia	
Absent	Present in most of the animal cells
Mitochondria	
Present but fewer in number	Present and are numerous
Mode of Nutrition	
Primarily autotrophic	Heterotrophic

Mitosis	**Meiosis**
It takes place in both Haploid cells and diploid cells	It takes place only in diploid cells.
It takes place in all body cells or vegetative cells or somatic.	It takes place in reproductive cells or germinal cells.
Nucleus divides once	Nucleus divides twice to produce 4 nuclei.
Daughter cells are identical to mother cells	Daughter cells are not identical.
Chromosomes do not pair	Homologous chromosomes (similar) pair to form bivalent ones.
Chiasmata is absent, Also there is no crossing over	Chiasmata present. Crossing over between non-sister chromatids occurs.
The chromosome number in the daughter cell is unchanged.	Chromosome number is reduced to half of the parent cell.
The entire cell division is short comparatively.	The duration of cell division is very large as it involves many steps.
It helps for the growth of the body and in lower forms like bacteria, to multiply organism numbers.	It helps in gamete formation for sexual reproduction.

Soap	**Detergent**
Sodium salt of Carboxylic acids	Sodium salts of benzene sulphonic acids.
Soaps are bio-degradable	Some detergents are non- biodegradable
Soaps do not lather in hard water	Detergent lather well in hard water
Weak cleansing action	Have strong cleansing action

Photosynthesis	**Respiration**
It is the process by which plants use sunlight, water, and carbon dioxide to create oxygen and energy in the form of sugar.	It refers to a metabolic pathway that breaks down glucose and produces ATP.
Occurs in plants containing chlorophyll and some bacteria	Occurs in all living organisms
It takes place in chloroplasts	It takes place in mitochondria
Anabolic process	Catabolic process
Endothermic reaction because it needs energy	Exergonic reaction because it releases energy
Produces food and captures the energy	Takes in oxygen and liberates out carbon dioxide
Requires sunlight because it is mandatory	Does not require sunlight as it takes place all the time
Absorbs carbon dioxide and water	Releases carbon dioxide and water
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Bragg's Law

$$\boxed{n\,\lambda = 2\,d\,\sin\theta}$$

where λ is the wavelength of the radiation used, d is the inter-planar spacing involved and θ is the angle between the incident (or diffracted) ray and the relevant crystal planes; n is an integer, referred to as the order of diffraction.

The **Nuclear radius** is given by the following relation:

$$\boxed{R = R_0\,A^{1/3}}$$

where R_0 is constant for all nuclei and its value is 1.2×10^{-15} m and A = Mass number of nucleus (the number of protons Z, plus the number of neutrons N).

Moore's law → the number of transistors in a dense integrated circuit (IC) doubles about every two years.

In a medium of constant refractive index, n, the **Optical path length** for a path of geometrical length L is just

$$OPL = nL$$

Optical depth = ln10 × **Absorbance**

Refractive index

$$n = \frac{c}{v}$$

where c is the speed of light in vacuum and v is the phase velocity of light in the medium. For example, the refractive index of water is 1.333, meaning that light travels 1.333 times as fast in vacuum as in water. The speed of light in a medium is $v = \frac{c}{n}$, and similarly the wavelength in that medium is $\lambda = \frac{\lambda_0}{n}$, where λ_0 is the wavelength of that light in vacuum.

Refractivity = (n – 1)

$$\boxed{\text{Specific refractivity} = \frac{\text{Refractivity of the medium}}{\text{Density of the medium}}}$$

Eyring equation

$$k = \kappa \frac{k_B T}{h} \exp\left(-\frac{\Delta G_*^0}{RT}\right)$$

where ΔG_*^0 is the standard Gibbs free energy of activation, κ is the transmission coefficient, k_B is Boltzmann's constant, T is the absolute temperature, k is the reaction rate constant, R is the gas constant and h is Planck's constant.

Michaelis–Menten equation

The Michaelis–Menten kinetics takes the form of an equation describing the rate of enzymatic reactions, by relating reaction rate v (rate of formation of product, [P]) to [S], the concentration of a substrate S. Its formula is given by:

$$v = \frac{d[P]}{dt} = \frac{v_{max}\,[S]}{K_m + [S]}$$

This equation is called the Michaelis–Menten equation. Here, v_{max} represents the maximum rate achieved by the system, happening at saturating substrate concentration. The value of the **Michaelis constant** K_m is numerically equal to the substrate concentration at which the reaction rate is half of v_{max}.

$$E + S \xrightarrow{k_1} ES$$

$$ES \xrightarrow{k_2} E + S$$

$$ES \xrightarrow{k_3} P + E$$

$$\boxed{K_m = \frac{(k_2 + k_3)}{k_1}}$$

The ratio $\frac{k_3}{K_m}$ (catalytic efficiency) is a measure of how efficiently an enzyme converts a substrate into product.

Monod equation

$$\mu = \mu_{max} \frac{S}{K_s + S}$$

where:

- μ is the specific growth rate of the microorganisms
- μ_{max} is the maximum specific growth rate of the microorganisms
- S is the concentration of the limiting substrate for growth
- K_s is the "half-velocity constant" or the value of S when $\frac{\mu}{\mu_{max}} = 0.5$

Nernst Equation

$$\boxed{E_{cell} = E^0_{cell} - \frac{RT}{nF} \ln Q}$$

where:

- E_{cell} = cell potential of the cell
- E^0_{cell} = cell potential under standard conditions
- R = universal gas constant
- T = temperature
- n = number of electrons transferred in the redox reaction
- F = Faraday constant
- Q = reaction quotient

Faraday's law of electrolysis

The mass **m** of elements deposited at an electrode in g is directly proportional to the Charge **Q** in Coulombs.

$$m = Z \times Q$$

Here, the constant of proportionality Z is called the Electro-Chemical Equivalent of the substance.

$$\boxed{\text{Chemical equivalent of a substance} = \frac{\text{atomic weight}}{\text{valency}}}$$

Activity of sample at instant t is given by $A = A_0 \, e^{\lambda t}$ where λ is the Decay constant

Activity per unit mass → Specific activity

$$\text{Half life: } T_{\frac{1}{2}} = \frac{0.693}{\lambda}$$

$$\text{Average life: } T_{av} = \frac{T_{\frac{1}{2}}}{0.693}$$

Quantum numbers

- Principal Quantum Number (n) = 1, 2, 3, …, ∞
- Orbital angular momentum of electron in any orbit = $\frac{nh}{2\pi}$
- Angular Momentum (Secondary, Azimuthal) Quantum Number (l) = 0,1, ..., (n −1).
- Number of orbitals in a subshell = $2l + 1$
- Maximum number of electrons in particular subshell = $2 \times (2l + 1)$
- Orbital angular momentum (L) = $\frac{h}{2\pi}\sqrt{l\,(l+1)}$

Name	Symbol	Orbital meaning	Range of values	Value examples
Principal quantum number	n	shell	$1 \le n$	$n = 1, 2, 3, \ldots$
Azimuthal quantum number (angular momentum)	l	subshell (s orbital is listed as 0, p orbital as 1 etc.)	$0 \le l \le n-1$	for $n = 3$: $l = 0, 1, 2$ (s, p, d)
Magnetic quantum number (projection of angular momentum)	m_l	energy shift (orientation of the subshell's shape)	$-l \le m_l \le l$	for $l = 2$: $m_l = -2, -1, 0, 1, 2$
Spin quantum number	m_s	spin of the electron ($-\frac{1}{2}$ = "spin down", $\frac{1}{2}$ = "spin up")	$-s \le m_s \le s$	for an electron $s = \frac{1}{2}$, so $m_s = -\frac{1}{2}, +\frac{1}{2}$

Nuclide	Ratio of atomic mass to mass number
^{1}H	1.00782505
^{2}H	1.0070508885
^{3}H	1.0053497592
^{3}He	1.0053431064
^{4}He	1.0006508135
^{6}Li	1.0025204658
^{12}C	1
^{14}N	1.0002195718
^{16}O	0.9996821637
^{56}Fe	0.9988381696
^{210}Po	0.9999184462
^{232}Th	1.0001640315
^{238}U	1.0002133958

$$\text{Equivalent weight of acid} = \frac{\text{Molar mass}}{\text{Basicity}}$$

Basicity → The number of hydrogen atoms replaceable by a base in a particular acid

$$\text{Equivalent weight of base} = \frac{\text{Molar mass}}{\text{Acidity}}$$

Acidity → The number of ionizable hydrogen ions (OH^-) present in one molecule of a base

Oxidation number = number of electrons in the valence shell – number of electrons left after bonding

$$\text{Hardness in ppm} = \frac{\text{mass of } CaCO_3}{\text{Total mass of water}} \times 10^6$$

Thermodynamic processes

- Isothermal process:

  Temperature = constant

- Isochoric process:

  Volume = constant

- Isobaric process:

  Pressure = constant

- Adiabatic process:

  Heat exchange with the surroundings = 0

Work done on the system = positive

Work done by the system = negative

Law of Equipartition Energy

Internal energy = $\frac{N}{2}$ × number of moles × universal gas constant × absolute temperature

where: N = number of active degrees of freedom (**Translational + Rotational**)

- N = 3 for monoatomic gas
- N=5 for diatomic or linear polyatomic gas
- N=6 for non-linear polyatomic gas

Second law of Thermodynamics

$$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surrounding} > 0 \text{ for a spontaneous process}$$

Third law of thermodynamics

The entropy change associated with any condensed system undergoing a reversible isothermal process approaches zero as the temperature at which it is performed approaches 0 K.

Criteria of spontaneity:

$$\Delta G = \Delta H - T\Delta S$$

- If ΔG is negative (< 0), the process is spontaneous.
- If ΔG is positive (> 0), the process is non spontaneous.

Endothermic → absorbs heat Exothermic → releases heat

Degree of dissociation

$$\alpha = \frac{\text{number of moles dissociated}}{\text{initial number of moles}}$$

$$\%\ \text{Dissociation} = \alpha \times 100$$

Relative humidity = $\dfrac{\text{partial pressure of water vapor}}{\text{equilibrium vapor pressure of water at a given temperature}}$

The quantum yield for the decomposition of a reactant molecule in a decomposition reaction is defined as:

$$\Phi = \frac{\text{number of molecules decomposed}}{\text{number of photons absorbed}}$$

Quantum yield can also be defined for other events, such as fluorescence:

$$\Phi = \frac{\text{number of photons emitted}}{\text{number of photons absorbed}}$$

Simple buffering agents

Buffering agent	pK_a	pH range
Citric acid	3.13, 4.76, 6.40	2.1–7.4
Acetic acid	4.8	3.8–5.8
KH_2PO_4	7.2	6.2–8.2
CHES	9.3	8.3–10.3
Borate	9.24	8.25–10.25

Acid Buffer: CH_3COOH and CH_3COONa (weak acid and salt of its conjugate base).

$$pH = pK_a + \log \frac{[\text{Salt}]}{[\text{Acid}]} \quad \text{(Henderson–Hasselbalch equation)}$$

Basic Buffer: NH_4OH and NH_4Cl (weak base and salt of its conjugate acid).

$$pH = pK_b + \log \frac{[\text{Salt}]}{[\text{Base}]}$$

Buffer capacity:

$$\beta = \frac{dC_b}{d(pH)}$$

where dC_b is an infinitesimal amount of added base

$$\beta = -\frac{dC_a}{d(pH)}$$

where dC_a is an infinitesimal amount of added acid. pH is defined as $-\log_{10}[H^+]$, and d(pH) is an infinitesimal change in pH.

van 't Hoff factor

$$i = \frac{\text{Observed value of colligative property}}{\text{Theoretical value of colligative property}}$$

Steric Number = (number of lone electron pairs on the central atom) + (number of atoms bonded to the central atom)

Steric Number	Predicted Shape	Bond angle (Degrees)
2	Linear	180
3	Trigonal Planar	120
4	Tetrahedral	109.5
5	Trigonal Bipyramidal	90,120
6	Octahedral	90

Table of Common Ligands

Type	Charge	Ligand	Formula	Name in Complexes
monodentate	**neutral**	ammonia	NH_3	ammine
		water	H_2O	aqua
		carbon monoxide	CO	carbonyl

		pyridine	pyr	pyridine
	minus one	azide	N_3^-	azido
		bromide	Br^-	bromido
		chloride	Cl^-	chlorido
		cyanide	CN^-	cyanido
		fluoride	F^-	fluorido
		hydroxide	OH^-	hydroxido
		nitrite	NO_2^-	nitrito
		thiocyanate	SCN^- or NCS^-	thiocyanato
bidentate	**neutral**	bipyridine	bipy	bipyridine
		ethylenediamine	en	ethylenediamine
	minus two	carbonate	CO_3^{2-}	carbonato
		oxide	O^{2-}	oxo
		oxalate	$C_2O_4^{2-}$	oxolato
		sulfate	SO_4^{2-}	sulfato

Hybridisation	Geometry	Coordination number
sp	linear	2
sp^2	Trigonal planar	3
sp^3	Tetrahedral	4
dsp^2	Square planar	4
dsp^3	Trigonal bipyramidal	5

dsp^3	Square-based pyramid	5
d^2sp^3	Octahedral	6

Bead test

Metal	**Color in Oxidizing flame**	**Color in Reducing flame**
Aluminum	colorless (hot and cold), opaque	colorless, opaque
Antimony	colorless, yellow or brown (hot)	gray and opaque
Barium	colorless	
Bismuth	colorless, yellow or brownish (hot)	gray and opaque
Cadmium	colorless	gray and opaque
Calcium	colorless	
Cerium	red (hot)	colorless (hot and cold)
Copper	sky blue (hot and cold), opaque	red, opaque
Iron	yellow (hot and cold), opaque	bottle-green, opaque
Manganese	pink (hot and cold), opaque	colorless, opaque

Cobalt	deep blue (hot and cold), opaque	deep blue, opaque
Nickel	yellow-brown (hot and cold), opaque	grey, opaque
Silver	colourless (hot and cold), opaque	grey, opaque
Vanadium	colourless (hot and cold), opaque	green, opaque
Uranium	yellow-brown (hot and cold), opaque	green, opaque
Chromium	green (hot and cold), opaque	green, opaque
Platinum	colourless (hot and cold), opaque	grey, opaque
Gold	yellow-brown (hot and cold), opaque	grey, opaque
Tin	colourless (hot and cold), opaque	colourless, opaque
Titanium	colourless (hot and cold), opaque	yellow, opaque (hot) violet (cold)
Tungsten	colourless (hot and cold), opaque	brown, opaque
Magnesium	colourless (hot and cold), opaque	colourless, opaque
Molybdenum	colourless (hot and cold), opaque	yellow or brown, opaque
Strontium	colourless (hot and cold), opaque	colourless, opaque
Thorium	colourless (hot and cold), opaque	colourless, opaque

Yttrium	colourless (hot and cold), opaque	colourless, opaque
Neodymium	colourless (hot and cold), opaque	colourless, opaque
Praseodymium	colourless (hot and cold), opaque	colourless, opaque
Silicon	colourless (hot and cold), opaque	colourless, opaque
Germanium	colourless (hot and cold), opaque	colourless, opaque

List of oncogenic bacteria

Species or genera	Possibly associated cancers
Bacteroides fragilis	Colon cancer.
Borrelia burgdorferi	MALT lymphoma.
Campylobacter jejuni	Immunoproliferative small intestinal disease (IPSID), which is rare a type of MALT lymphoma.
Chlamydia pneumonia	Lung MALT lymphoma.
Chlamydia trachomatis (chlamydia)	Cervical cancer.
Chlamydophila psittaci	Ocular/adnexal lymphoma (forms of eye cancer).
Clostridium ssp	Colon cancer.
Helicobacter bilis	Biliary cancers (such as gallbladder and biliary tract cancers).
Helicobacter bizzozeronii	Gastric MALT lymphoma.
Helicobacter felis	Gastric MALT lymphoma.
Helicobacter heilmannii	Marginal zone B-cell lymphoma of the stomach.
Helicobacter hepaticus	Biliary cancer.
Helicobacter pylori	Stomach cancer, Marginal zone B-cell lymphoma

	of the stomach, and bile duct cancer
Helicobacter salomonis	Gastric MALT lymphoma.
Helicobacter suis	Gastric MALT lymphoma.
Mycoplasma spp	Stomach, colon, ovarian, and lung cancers (particularly M. fermentans, M. penetrans, M. hyorhinis).
Neisseria gonorrhoeae (gonorrhea)	Bladder cancer and possibly prostate cancer.
Cutibacterium acnes	Bladder and prostate cancer.
Salmonella enterica serovar Paratyphi	Biliary cancer.
Salmonella enterica serovar Typhimurium	Biliary cancer.
Treponema pallidum (syphilis)	Bladder cancer and possibly prostate cancer.

List of infectious diseases

Infectious agent	**Common name**
Acinetobacter baumannii	Acinetobacter infections
Actinomyces israelii, Actinomyces gerencseriae and Propionibacterium propionicus	Actinomycosis
Trypanosoma brucei	African sleeping sickness (African trypanosomiasis)
HIV (Human immunodeficiency virus)	AIDS (acquired immunodeficiency syndrome)
Entamoeba histolytica	Amoebiasis
Anaplasma species	Anaplasmosis
Angiostrongylus	Angiostrongyliasis
Anisakis	Anisakiasis
Bacillus anthracis	Anthrax
Arcanobacterium haemolyticum	Arcanobacterium haemolyticum infection

Junin virus	Argentine hemorrhagic fever
Ascaris lumbricoides	Ascariasis
Aspergillus species	Aspergillosis
Astroviridae species	Astrovirus infection
Babesia species	Babesiosis
Bacillus cereus	Bacillus cereus infection
multiple bacteria	Bacterial meningitis
multiple bacteria	Bacterial pneumonia
List of bacterial vaginosis microbiota	Bacterial vaginosis
Bacteroides species	Bacteroides infection
Balantidium coli	Balantidiasis
Bartonella	Bartonellosis
Baylisascaris species	Baylisascaris infection
BK virus	BK virus infection
Piedraia hortae	Black piedra
Blastocystis species	Blastocystosis
Blastomyces dermatitidis	Blastomycosis
Machupo virus	Bolivian hemorrhagic fever
Clostridium botulinum; Note: Botulism is not an infection by Clostridium botulinum but caused by the intake of botulinum toxin.	Botulism (and Infant botulism)
Sabiá virus	Brazilian hemorrhagic fever
Brucella species	Brucellosis
Yersinia pestis	Bubonic plague
usually Burkholderia cepacia and other Burkholderia species	Burkholderia infection
Mycobacterium ulcerans	Buruli ulcer
Caliciviridae species	Calicivirus infection (Norovirus and Sapovirus)
Campylobacter species	Campylobacteriosis

usually Candida albicans and other Candida species	Candidiasis (Moniliasis; Thrush)
Intestinal disease by Capillaria philippinensis, hepatic disease by Capillaria hepatica and pulmonary disease by Capillaria aerophila	Capillariasis
Bartonella bacilliformis	Carrion's disease
Bartonella henselae	Cat-scratch disease
usually Group A Streptococcus and Staphylococcus	Cellulitis
Trypanosoma cruzi	Chagas disease (American trypanosomiasis)
Haemophilus ducreyi	Chancroid
Varicella zoster virus (VZV)	Chickenpox
Alphavirus	Chikungunya
Chlamydia trachomatis	Chlamydia
Chlamydophila pneumoniae	Chlamydophila pneumoniae infection (Taiwan acute respiratory agent or TWAR)
Vibrio cholerae	Cholera
usually Fonsecaea pedrosoi	Chromoblastomycosis
Batrachochytrium dendrabatidis	Chytridiomycosis
Clonorchis sinensis	Clonorchiasis
Clostridium difficile	Clostridium difficile colitis
Coccidioides immitis and Coccidioides posadasii	Coccidioidomycosis
Colorado tick fever virus (CTFV)	Colorado tick fever (CTF)
usually rhinoviruses and coronaviruses	Common cold (Acute viral rhinopharyngitis; Acute coryza)
Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)	Coronavirus disease 2019 (COVID-19)
PRNP	Creutzfeldt–Jakob disease (CJD)
Crimean-Congo hemorrhagic fever virus	Crimean-Congo hemorrhagic fever (CCHF)

Cryptococcus neoformans	Cryptococcosis
Cryptosporidium species	Cryptosporidiosis
usually Ancylostoma braziliense; multiple other parasites	Cutaneous larva migrans (CLM)
Cyclospora cayetanensis	Cyclosporiasis
Taenia solium	Cysticercosis
Cytomegalovirus	Cytomegalovirus infection
Dengue viruses (DEN-1, DEN-2, DEN-3 and DEN-4) – Flaviviruses	Dengue fever
Green algae Desmodesmus armatus	Desmodesmus infection
Dientamoeba fragilis	Dientamoebiasis
Corynebacterium diphtheriae	Diphtheria
Diphyllobothrium	Diphyllobothriasis
Dracunculus medinensis	Dracunculiasis
Ebolavirus (EBOV)	Ebola hemorrhagic fever
Echinococcus species	Echinococcosis
Ehrlichia species	Ehrlichiosis
Enterobius vermicularis	Enterobiasis (Pinworm infection)
Enterococcus species	Enterococcus infection
Enterovirus species	Enterovirus infection
Rickettsia prowazekii	Epidemic typhus
Parvovirus B19	Erythema infectiosum (Fifth disease)
Human herpesvirus 6 (HHV-6) and human herpesvirus 7 (HHV-7)	Exanthem subitum (Sixth disease)
Fasciola hepatica and Fasciola gigantica	Fasciolasis
Fasciolopsis buski	Fasciolopsiasis
PRNP	Fatal familial insomnia (FFI)
Filarioidea superfamily	Filariasis
Clostridium perfringens	Food poisoning by Clostridium perfringens

multiple	Free-living amebic infection
Fusobacterium species	Fusobacterium infection
usually Clostridium perfringens; other Clostridium species	Gas gangrene (Clostridial myonecrosis)
Geotrichum candidum	Geotrichosis
PRNP	Gerstmann-Sträussler-Scheinker syndrome (GSS)
Giardia lamblia	Giardiasis
Burkholderia mallei	Glanders
Gnathostoma spinigerum and Gnathostoma hispidum	Gnathostomiasis
Neisseria gonorrhoeae	Gonorrhea
Klebsiella granulomatis	Granuloma inguinale (Donovanosis)
Streptococcus pyogenes	Group A streptococcal infection
Streptococcus agalactiae	Group B streptococcal infection
Haemophilus influenzae	Haemophilus influenzae infection
Enteroviruses, mainly Coxsackie A virus and enterovirus 71 (EV71)	Hand, foot and mouth disease (HFMD)
Sin Nombre virus	Hantavirus Pulmonary Syndrome (HPS)
Heartland virus	Heartland virus disease
Helicobacter pylori	Helicobacter pylori infection
Escherichia coli O157:H7, O111 and O104:H4	Hemolytic-uremic syndrome (HUS)
Bunyaviridae species	Hemorrhagic fever with renal syndrome (HFRS)
Hendra virus	Hendra virus infection
Hepatitis A virus	Hepatitis A
Hepatitis B virus	Hepatitis B
Hepatitis C virus	Hepatitis C
Hepatitis D Virus	Hepatitis D
Hepatitis E virus	Hepatitis E

Herpes simplex virus 1 and 2 (HSV-1 and HSV-2)	Herpes simplex
Histoplasma capsulatum	Histoplasmosis
Ancylostoma duodenale and Necator americanus	Hookworm infection
Human bocavirus (HBoV)	Human bocavirus infection
Ehrlichia ewingii	Human ewingii ehrlichiosis
Anaplasma phagocytophilum	Human granulocytic anaplasmosis (HGA)
Human metapneumovirus (hMPV)	Human metapneumovirus infection
Ehrlichia chaffeensis	Human monocytic ehrlichiosis
One of the human papillomaviruses	Human papillomavirus (HPV) infection
Human parainfluenza viruses (HPIV)	Human parainfluenza virus infection
Hymenolepis nana and Hymenolepis diminuta	Hymenolepiasis
Epstein–Barr virus (EBV)	Epstein–Barr virus infectious mononucleosis (Mono)
Orthomyxoviridae species	Influenza (flu)
Isospora belli	Isosporiasis
unknown; evidence supports that it is infectious	Kawasaki disease
multiple	Keratitis
Kingella kingae	Kingella kingae infection
PRNP	Kuru
Lassa virus	Lassa fever
Legionella pneumophila	Legionellosis (Legionnaires' disease)
Legionella pneumophila	Pontiac fever
Leishmania species	Leishmaniasis
Mycobacterium leprae and Mycobacterium lepromatosis	Leprosy
Leptospira species	Leptospirosis
Listeria monocytogenes	Listeriosis
Borrelia burgdorferi, Borrelia garinii, and Borrelia	Lyme disease (Lyme borreliosis)

afzelii	
Wuchereria bancrofti and Brugia malayi	Lymphatic filariasis (Elephantiasis)
Lymphocytic choriomeningitis virus (LCMV)	Lymphocytic choriomeningitis
Plasmodium species	Malaria
Marburg virus	Marburg hemorrhagic fever (MHF)
Measles virus	Measles
Middle East respiratory syndrome coronavirus	Middle East respiratory syndrome (MERS)
Burkholderia pseudomallei	Melioidosis (Whitmore's disease)
multiple	Meningitis
Neisseria meningitidis	Meningococcal disease
usually Metagonimus yokagawai	Metagonimiasis
Microsporidia phylum	Microsporidiosis
Molluscum contagiosum virus (MCV)	Molluscum contagiosum (MC)
Monkeypox virus	Monkeypox
Mumps virus	Mumps
Rickettsia typhi	Murine typhus (Endemic typhus)
Mycoplasma pneumoniae	Mycoplasma pneumonia
Mycoplasma genitalium	Mycoplasma genitalium infection
numerous species of bacteria (Actinomycetoma) and fungi (Eumycetoma)	Mycetoma
parasitic dipterous fly larvae	Myiasis
most commonly Chlamydia trachomatis and Neisseria gonorrhoeae	Neonatal conjunctivitis (Ophthalmia neonatorum)
Nipah virus	Nipah virus infection
Norovirus	Norovirus (children and babies)
PRNP	(New) Variant Creutzfeldt–Jakob disease (vCJD, nvCJD)
usually Nocardia asteroides and other Nocardia species	Nocardiosis
Onchocerca volvulus	Onchocerciasis (River blindness)

Opisthorchis viverrini and Opisthorchis felineus	Opisthorchiasis
Paracoccidioides brasiliensis	Paracoccidioidomycosis (South American blastomycosis)
usually Paragonimus westermani and other Paragonimus species	Paragonimiasis
Pasteurella species	Pasteurellosis
Pediculus humanus capitis	Pediculosis capitis (Head lice)
Pediculus humanus corporis	Pediculosis corporis (Body lice)
Pthirus pubis	Pediculosis pubis (pubic lice, crab lice)
multiple	Pelvic inflammatory disease (PID)
Bordetella pertussis	Pertussis (whooping cough)
Yersinia pestis	Plague
Streptococcus pneumoniae	Pneumococcal infection
Pneumocystis jirovecii	Pneumocystis pneumonia (PCP)
multiple	Pneumonia
Poliovirus	Poliomyelitis
Prevotella species	Prevotella infection
usually Naegleria fowleri	Primary amoebic meningoencephalitis (PAM)
JC virus	Progressive multifocal leukoencephalopathy
Chlamydophila psittaci	Psittacosis
Coxiella burnetii	Q fever
Rabies virus	Rabies
Borrelia hermsii, Borrelia recurrentis, and other Borrelia species	Relapsing fever
Respiratory syncytial virus (RSV)	Respiratory syncytial virus infection
Rhinosporidium seeberi	Rhinosporidiosis
Rhinovirus	Rhinovirus infection

Rickettsia species	Rickettsial infection
Rickettsia akari	Rickettsialpox
Rift Valley fever virus	Rift Valley fever (RVF)
Rickettsia rickettsii	Rocky Mountain spotted fever (RMSF)
Rotavirus	Rotavirus infection
Rubella virus	Rubella
Salmonella species	Salmonellosis
SARS coronavirus	SARS (severe acute respiratory syndrome)
Sarcoptes scabiei	Scabies
Group A Streptococcus species	Scarlet fever
Schistosoma species	Schistosomiasis
multiple	Sepsis
Shigella species	Shigellosis (bacillary dysentery)
Varicella zoster virus (VZV)	Shingles (Herpes zoster)
Variola major or Variola minor	Smallpox (variola)
Sporothrix schenckii	Sporotrichosis
Staphylococcus species	Staphylococcal food poisoning
Staphylococcus species	Staphylococcal infection
Strongyloides stercoralis	Strongyloidiasis
Measles virus	Subacute sclerosing panencephalitis
Treponema pallidum	Bejel, Syphilis, and Yaws
Taenia species	Taeniasis
Clostridium tetani	Tetanus (lockjaw)
usually Trichophyton species	Tinea barbae (barber's itch)
usually Trichophyton tonsurans	Tinea capitis (ringworm of the scalp)
usually Trichophyton species	Tinea corporis (ringworm of the body)
usually Epidermophyton floccosum, Trichophyton rubrum, and Trichophyton mentagrophytes	Tinea cruris (Jock itch)

Trichophyton rubrum	Tinea manum (ringworm of the hand)
usually Hortaea werneckii	Tinea nigra
usually Trichophyton species	Tinea pedis (athlete’s foot)
usually Trichophyton species	Tinea unguium (onychomycosis)
Malassezia species	Tinea versicolor (Pityriasis versicolor)
Toxocara canis or Toxocara cati	Toxocariasis (ocular larva migrans (OLM))
Toxocara canis or Toxocara cati	Toxocariasis (visceral larva migrans (VLM))
Toxoplasma gondii	Toxoplasmosis
Chlamydia trachomatis	Trachoma
Trichinella spiralis	Trichinosis
Trichomonas vaginalis	Trichomoniasis
Trichuris trichiura	Trichuriasis (whipworm infection)
usually Mycobacterium tuberculosis	Tuberculosis
Francisella tularensis	Tularemia
Salmonella enterica subsp. enterica, serovar typhi	Typhoid fever
Rickettsia	Typhus fever
Ureaplasma urealyticum	Ureaplasma urealyticum infection
Coccidioides immitis or Coccidioides posadasii.	Valley fever
Venezuelan equine encephalitis virus	Venezuelan equine encephalitis
Guanarito virus	Venezuelan hemorrhagic fever
Vibrio vulnificus	Vibrio vulnificus infection
Vibrio parahaemolyticus	Vibrio parahaemolyticus enteritis
multiple viruses	Viral pneumonia
West Nile virus	West Nile fever
Trichosporon beigelii	White piedra (tinea blanca)
Yersinia pseudotuberculosis	Yersinia pseudotuberculosis infection
Yersinia enterocolitica	Yersiniosis
Yellow fever virus	Yellow fever

Zeaspora fungus	Zeaspora
Zika virus	Zika fever
Mucorales order (Mucormycosis) and Entomophthorales order (Entomophthoramycosis)	Zygomycosis

Pharmacokinetics

- Volume of Distribution = $\frac{\text{Total Dose}}{\text{Drug Concentration}}$
- Volume of Distribution = $\frac{\text{clearance}}{\text{elimination rate constant}}$
- Half Life = $\frac{0.693}{\text{elimination rate constant}}$
- Clearance = $\frac{\textbf{Bioavailability} \times \text{Dose}}{\text{area under curve}}$
- Dose Rate = Desired concentration of drug in plasma at steady state × Clearance
- Adjusted Dose Rate = Initial Dose Rate × $\frac{\text{Desired concentration of drug in plasma at steady state}}{\text{Measured concentration of drug in plasma at steady state}}$

Molecularity of Reaction

The molecularity of an elementary reaction is defined as the number of reactant molecules taking part in the chemical reaction.

Chemical Reaction	Molecularity
$PCl_5 \rightarrow PCl_3 + Cl_2$	Unimolecular
$2HI \rightarrow H_2 + I_2$	Bimolecular
$2SO_2 + O_2 \rightarrow 2SO_3$	Trimolecular
$NO + O_3 \rightarrow NO_2 + O_2$	Bimolecular
$2CO + O_2 \rightarrow 2CO_2$	Trimolecular
$2FeCl_3 + SnCl_2 \rightarrow SnCl_2 + 2FeCl_2$	Trimolecular

Common Multiferroic Materials

Material	Ferroelectric T_C [K]	magnetic T_N or T_C [K]	Type of Ferroelectricity
$BiFeO_3$	1100	653	lone pair
$HoMn_2O_5$	39		magnetically driven
$TbMnO_3$	27	42	magnetically driven
$Ni_3V_2O_8$	6.5		

$MnWO_4$	13.5		magnetically driven
CuO	230	230	magnetically driven
$ZnCr_2Se_4$	110	20	

Ranges of the Trig Functions

$$-1 \leq \sin\theta \leq 1$$

$$-1 \leq \cos\theta \leq 1$$

$$-\infty \leq \tan\theta \leq \infty$$

$$\csc\theta \geq 1 \text{ and } \csc\theta \leq -1$$

$$\sec\theta \geq 1 \text{ and } \sec\theta \leq -1$$

$$-\infty \leq \cot\theta \leq \infty$$

Periods of the Trig Functions

The period of a function is the number, T, such that $f(\theta + T) = f(\theta)$.

So, if ω is a fixed number and θ is any angle we have the following periods.

$$\sin(\omega\theta) \rightarrow T = \frac{2\pi}{\omega}$$

$$\cos(\omega\theta) \rightarrow T = \frac{2\pi}{\omega}$$

$$\tan(\omega\theta) \rightarrow T = \frac{\pi}{\omega}$$

$$\csc(\omega\theta) \rightarrow T = \frac{2\pi}{\omega}$$

$$\sec(\omega\theta) \rightarrow T = \frac{2\pi}{\omega}$$

$$\cot(\omega\theta) \rightarrow T = \frac{\pi}{\omega}$$

If n is an integer

$$\sin(\theta + 2\pi n) = \sin\theta$$

$$\cos(\theta + 2\pi n) = \cos\theta$$

$$\tan(\theta + \pi n) = \tan\theta$$

$$\csc(\theta + 2\pi n) = \csc\theta$$

$$\sec(\theta + 2\pi n) = \sec\theta$$

$$\cot(\theta + \pi n) = \cot\theta$$

Degrees to Radians Formulas

If x is an angle in degrees and t is an angle in radians then:

$$x = \frac{180^{o}t}{\pi}$$

Conic Sections

- Circle

Standard Form: $(x - h)^2 + (y - k)^2 = r^2$

where (h, k) = center and r = radius

- Ellipse

Standard Form for Horizontal Major Axis: $\frac{(x-h)^2}{a^2} + \frac{(y-k)^2}{b^2} = 1$

Standard Form for Vertical Major Axis: $\frac{(x-h)^2}{b^2} + \frac{(y-k)^2}{a^2} = 1$

where (h, k) = center

2a=length of major axis

2b=length of minor axis

$(0 < b < a)$

Foci can be found by using $c^2 = a^2 - b^2$

where c = foci length

- Hyperbola

Standard Form for Horizontal Transverse Axis: $\frac{(x-h)^2}{a^2} - \frac{(y-k)^2}{b^2} = 1$

Standard Form for Vertical Transverse Axis: $\frac{(y-k)^2}{a^2} - \frac{(x-h)^2}{b^2} = 1$

where (h, k) = center

a=distance between center and either vertex

Foci can be found by using $b^2 = c^2 - a^2$

where c is the distance between center and either focus. $(b > 0)$

- Parabola

$$\text{Vertical axis: } y = a(x - h)^2 + k$$

$$\text{Horizontal axis: } x = a(y - k)^2 + h$$

where (h, k) = vertex

a=scaling factor

Range of Trigonometric Expression:

$$-\sqrt{a^2 + b^2} \leq a\sin\theta + b\cos\theta \leq \sqrt{a^2 + b^2}$$

Coefficient of Determination Formula

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x^2)][n\Sigma y^2 - (\Sigma y^2)]}}$$

where,

- r = Correlation coefficient
- x = Values in first set of data
- y = Values in second set of data
- n = Total number of values.

Formula for Conditional Probability

Conditional Probability of A given B	$P(A\|B) = \frac{P(A \cap B)}{P(B)}$
Conditional Probability of B given A	$P(B\|A) = \frac{P(B \cap A)}{P(A)}$

Covariance Formula

Population Covariance Formula	**Cov(x, y)** = $\frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{N}$
Sample Covariance Formula	**Cov(x, y)** = $\frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{N-1}$

- x_i = data value of x
- y_i = data value of y
- $\bar{x}$ = mean of x
- $\bar{y}$ = mean of y
- N = number of data values.

Correlation = $\frac{\mathrm{Cov}(x,y)}{\sigma_x \sigma_y}$

where: Cov(x, y) is the covariance between x and y while σ_x and σ_y are the standard deviations of x and y.

Anova Formula

$$\text{Mean Square Factor} = \frac{\text{sum of squares factor}}{\text{degrees of freedom factor}}$$

$$\text{Mean Square Error} = \frac{\text{sum of squares error}}{\text{degrees of freedom error}}$$

Degrees of freedom factor = number of factor levels – 1

Degrees of freedom error = total number of observations − number of factor levels

$$\text{F-value} = \frac{\text{Mean square factor}}{\text{Mean square error}}$$

$$R^2 = \frac{\text{sum of squares error}}{\text{sum of squares total}}$$

$$R^2 \text{ (adjusted)} = 1 - \frac{\text{Mean Square error}}{\text{Sum of Squares total / degrees of freedom total}}$$

$$R^2 \text{ (predicted)} = 1 - \frac{\text{Predicted Residual Sum of squares}}{\text{Sum of Squares total}}$$

Process capability Formula

$$\text{Process capability} = \frac{\text{upper specification limit} - \text{lower specification limit}}{6 \times \text{standard deviation}}$$

Effect Size Formula

$$\text{Cohen's index} = \frac{\text{Mean of first observation} - \text{Mean of second observation}}{\sqrt{\frac{(\text{Standard deviation of first observation})^2 + (\text{Standard deviation of second observation})^2}{2}}}$$

$$\text{Effect-size coefficient} = \frac{d}{\sqrt{d^2 + 4}}$$

where: d denote the Cohen's index

Euler's Formula Equation

$$e^{ix} = \cos x + i \sin x$$

Exponential Equation Formula

$$y = ab^x$$

- x and y are the variables
- a and b are constants

Fibonacci Formula

$$F_n = F_{n-1} + F_{n-2}$$

where,

- F_n = n^{th} term of the series
- F_{n-1} and F_{n-2} are the $(n-1)^{th}$ and $(n-2)^{th}$ terms respectively

Gaussian Distribution Formula

The probability density function formula for Gaussian distribution is given by:

$$f(x, \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(\frac{-(x-\mu)^2}{2\sigma^2}\right)$$

where,

- x is the variable
- μ is the mean
- σ is the standard deviation

Infinite Series Formula

$$\sum_0^\infty r^n = \frac{1}{1-r}$$

Linear Interpolation Formula

$$y = y_1 + \frac{(x-x_1)}{(x_2-x_1)} \times (y_2 - y_1)$$

Percent Decrease Formula

$$\text{Percent Decrease} = \frac{\text{Decreased Value}}{\text{Original Value}} \times 100$$

Percentage Increase Formula

$$\text{Percent Increase} = \frac{\text{Increased Value}}{\text{Original Value}} \times 100$$

Percentile Formula

$$\text{Percentile} = \frac{\text{Number of Values Below "x"}}{\text{Total Number of Values}} \times 100$$

Perfect Square Trinomial Formula

$$(ax)^2 + 2abx + b^2 = (ax + b)^2$$

$$(ax)^2 - 2abx + b^2 = (ax - b)^2$$

Poisson Distribution Formula

Suppose we conduct a Poisson experiment, in which the average number of successes within a given region is μ. Then, the Poisson probability is:

$$P(x, \mu) = \frac{e^{-\mu}\, \mu^{x}}{x!}$$

where x is the actual number of successes that result from the experiment, and e is approximately equal to 2.71828.

Quartile Formula

When the set of observation is arranged in an ascending order, then the lower percentile is given by:

$$Q_1 = \left(\frac{N+1}{4}\right)^{th} \text{Term}$$

The middle quartile is given by:

$$Q_2 = \left(\frac{N+1}{2}\right)^{th} \text{Term}$$

The upper quartile is given by:

$$Q_3 = \left(\frac{3(N+1)}{4}\right)^{th} \text{Term}$$

$$\text{inter quartile range} = Q_3 - Q_1$$

- N → number of observations

Ratio Analysis Formula

- Liquidity Ratios

$$\text{Current Ratio} = \frac{\text{Current Asset}}{\text{Current Liabilities}}$$

$$\text{Quick Ratio} = \frac{(\text{Total Current Ratio} - \text{Inventory})}{\text{Total Current Liabilities}}$$

- Profitability Ratios

$$\text{Net Profit Ratio} = \frac{\text{Net profit after tax}}{\text{NetSales}} \times 100$$

$$\text{Gross Profit Ratio} = \frac{\text{GrossProfit}}{\text{NetSales}} \times 100$$

$$\text{Operating Ratio} = \frac{\text{Operating Cost}}{\text{NetSales}} \times 100$$

$$\text{Earnings per share} = \frac{\text{Net Income} - \text{Preferred Dividends}}{\text{average outstanding common shares}}$$

- Activity Ratios

$$\text{Inventory Turnover Ratio} = \frac{\text{Cost of goods sold}}{\text{Average Inventory}}$$

$$\text{Receivables Turnover Ratio} = \frac{\text{Net Credit Sales}}{\text{Average Trade Receivable}}$$

- Solvency Ratios

$$\text{Debt Equity Ratio} = \frac{\text{Total Liabilities}}{\text{Stakeholder Equity}}$$

$$\text{Proprietary Ratio} = \frac{\text{Stakeholder Equity}}{\text{Total Assets}} \times 100$$

Relative frequency formula

$$\text{relative frequency} = \frac{\text{number of times the data occurred in an observation}}{\text{total frequencies}}$$

Sampling Error Formula

$$\text{Sampling Error} = Z \times \frac{\sigma}{\sqrt{n}}$$

where,

- Z is the Z score value based on the confidence interval (approx = 1.96)
- σ is the population standard deviation
- n is the size of the sample

Stirling Formula

$$n! \approx \left(\frac{n}{e}\right)^n \sqrt{2\pi n}$$

Annulus Formula

$$A = \pi\,(R^2 - r^2)$$

where,

- A = Area of Annulus
- R = Outer radius
- r = Inner radius
- (Pi) π = is approximately 3.142

Bayes' theorem

$$P(A \mid B) = \frac{P(B \mid A)\,P(A)}{P(B)}$$

where A and B are events and $P(B) \neq 0$.

- P(A | B) is a conditional probability: the likelihood of event A occurring given that B is true.
- P(B | A) is also a conditional probability: the likelihood of event B occurring given that A is true.
- P(A) and P(B) are the probabilities of observing A and B respectively; they are known as the marginal probability.

9 × 1 = 0**9**

9 × 2 = 1**8**

9 × 3 = 2**7**

9 × 4 = 3**6**

9 × 5 = 4**5**

9 × 6 = 5**4**

9 × 7 = 6**3**

9 × 8 = 7**2**

9 × 9 = 8**1**

9 × 10 = 9**0**

$$\frac{19}{95} = \frac{19}{95} = \frac{1}{5}$$

$$\frac{16}{64} = \frac{16}{64} = \frac{1}{4}$$

$$\frac{26}{65} = \frac{26}{65} = \frac{1}{5}$$

35 × 11

3 + 5

3 8 5

$\boxed{35 \times 11 = 385}$

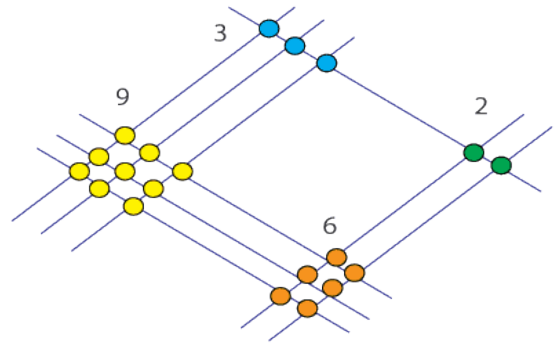
32 × 11

3 + 2

3 5 2

$\boxed{32 \times 11 = 352}$

32 × 31 = ?



$$\underbrace{9 \qquad 6+3=9 \qquad 2}_{992}$$

$\boxed{32 \times 31 = 992}$

374 × 43 = ?

- 374 = 300 + 70 + 4
- 43 = 40 + 3

	300	**70**	**4**
40	12000	2800	160
3	900	210	12

12000 + 2800 + 160 + 900 + 210 + 12 =16082

374 × 43 = 16082

Central Limit Theorem Formula

Central limit theorem is applicable for a sufficiently large sample sizes ($n \geq 30$). The formula for central limit theorem can be stated as follows:

$$\text{Sample mean} = \text{Population mean}$$

and

$$\text{Sample standard deviation} = \frac{\text{Population standard deviation}}{\sqrt{\text{Sample size}}}$$

Coefficient of Variation Formula

$$\text{Coefficient of variation} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100\%$$

Process capability index (Cpk) Formula

$$\text{Cpk} = \min\left(\frac{\text{upper specification limit} - \text{mean}}{3 \times \text{standard deviation}}, \frac{\text{mean} - \text{lower specification limit}}{3 \times \text{standard deviation}} \right)$$

Signal to Noise Ratio Formula

$$\text{signal to noise ratio} = \frac{\text{standard deviation}}{\text{mean of the given data}}$$

Uniform Distribution Formula

$$\text{Theoretical Mean} = \frac{x+y}{2}$$

$$\text{Standard Deviation} = \sqrt{\frac{(y-x)^2}{12}}$$

Z Score Formula

$$\text{Z Score} = \frac{\text{Standardized random variable} - \text{mean}}{\text{Standard deviation}}$$

Inductance Formula

The total series inductance is

$$L = L_1 + L_2 + L_3 + \ldots + L_n$$

The parallel inductance is

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots + \frac{1}{L_n}$$

where, L_1, L_2, L_3….. L_n denotes the inductance values.

Soil Erosion Formula

The universal soil loss equation predicts the annual soil loss per unit area. The universal soil loss equation is given by:

$$A = R \times K \times L \times S \times CP$$

where,

- A is the estimated annual soil loss
- R is the rainfall and runoff factor representing the summed erosive potential of all rainfall events in a year.
- L is the slope length
- S is the slope steepness
- K is the soil erodibility factor representing units of soil loss per unit of soil erosivity
- CP characterizes conservation management and land cover practices.

Critical Velocity Formula

$$\text{Critical velocity of a liquid flowing through a tube} = \frac{\mathrm{K} \times \eta}{\rho \times \mathrm{r}}$$

where:

- K is the Reynold's number
- η is the coefficient of the viscosity of the liquid
- r is the radius of the tube through which the liquid flows
- ρ is the density of the liquid

Horsepower Formula

One Horsepower equals to 33,000 lb. ft/min

$$\text{Horsepower (HP)} = \frac{\text{Torque} \times \text{Speed}}{5252}$$

$$\text{Horsepower (HP)} = \text{Weight} \times \left(\frac{\text{velocity}}{234}\right)^2$$

Beat Frequency Formula

The formula for beat frequency is the difference in frequency of the two superimposed waves.

$$f_b = f_2 - f_1$$

- f_1 and f_2 are the frequency of two waves

Voltage Drop Formula

$$\text{voltage drop across the circuit} = \text{Current in amperes} \times \text{impedance in } \Omega$$

Brewster's law Formula

$$\mu = \tan\theta_p$$

where,

- μ is the refractive index of the medium
- θ_p is the polarizing angle

Hagen–Poiseuille equation

$$\Delta p = \frac{8\pi\mu LQ}{A^2}$$

where:

- Δp is the pressure difference between the two ends,
- L is the length of pipe,
- μ is the dynamic viscosity,
- Q is the volumetric flow rate,

- R is the pipe radius,
- A is the cross section of pipe.

Pressure Drop Formula

$$J = fLv^2 / 2gD$$

where:

- J = pressure drop
- f = friction factor
- L = length of the tube
- v = velocity of the fluid
- g = acceleration due to gravity
- D = inner diameter of the tube

Strain Energy Formula

$$\text{strain energy} = \frac{F \times \delta}{2}$$

where,

- δ = compression,
- F = force applied.

$$\text{strain energy} = \frac{1}{2} V\sigma\varepsilon$$

where,

- σ = stress
- ε= strain
- V = volume of body

$$\text{strain energy} = \frac{\sigma^2}{2E \times V}$$

where,

- σ = stress,
- E = Young's modulus,
- V = volume of body.

Rate Law

- Zero order

$$-\frac{dC}{dt} = k$$

$$\boxed{t_{\frac{1}{2}} = \frac{C_0}{2k}}$$

- First order

$$-\frac{dC}{dt} = kC$$

$$\boxed{t_{\frac{1}{2}} = \frac{\ln 2}{2k}}$$

- Second

$$-\frac{dC}{dt} = kC^2$$

$$\boxed{t_{\frac{1}{2}} = \frac{1}{kC_0}}$$

- n^{th} order

$$-\frac{dC}{dt} = kC^n$$

- $n \rightarrow$ order of the reaction
- $C \rightarrow$ reactant concentration
- $C_0 \rightarrow$ initial reactant concentration
- $t_{\frac{1}{2}} \rightarrow$ Half life period
- $k \rightarrow$ rate constant

List of ester odorants

Ester name	**Odor or occurrence**
Allyl hexanoate	pineapple
Benzyl acetate	pear, strawberry, jasmine
Bornyl acetate	pine
Butyl acetate	apple, honey
Butyl butyrate	pineapple

Butyl propanoate	pear drops
Ethyl acetate	nail polish remover, model paint, model airplane glue
Ethyl benzoate	sweet, wintergreen, fruity, medicinal, cherry, grape
Ethyl butyrate	banana, pineapple, strawberry
Ethyl hexanoate	pineapple, waxy-green banana
Ethyl cinnamate	cinnamon
Ethyl formate	lemon, rum, strawberry
Ethyl heptanoate	apricot, cherry, grape, raspberry
Ethyl isovalerate	apple
Ethyl lactate	butter, cream
Ethyl nonanoate	grape
Ethyl pentanoate	apple
Geranyl acetate	geranium
Geranyl butyrate	cherry
Geranyl pentanoate	apple
Isobutyl acetate	cherry, raspberry, strawberry
Isobutyl formate	raspberry

Isoamyl acetate	pear, banana (flavoring in Pear drops)
Isopropyl acetate	fruity
Linalyl acetate	lavender, sage
Linalyl butyrate	peach
Linalyl formate	apple, peach
Methyl acetate	glue
Methyl anthranilate	grape, jasmine
Methyl benzoate	fruity, ylang ylang, feijoa
Methyl butyrate (methyl butanoate)	pineapple, apple, strawberry
Methyl cinnamate	strawberry
Methyl pentanoate (methyl valerate)	flowery
Methyl phenylacetate	honey
Methyl salicylate (oil of wintergreen)	Modern root beer, wintergreen, Germolene and Ralgex ointments (UK)
Nonyl caprylate	orange
Octyl acetate	fruity-orange

Octyl butyrate	parsnip
Amyl acetate (pentyl acetate)	apple, banana
Pentyl butyrate (amyl butyrate)	apricot, pear, pineapple
Pentyl hexanoate (amyl caproate)	apple, pineapple
Pentyl pentanoate (amyl valerate)	apple
Propyl acetate	pear
Propyl hexanoate	blackberry, pineapple, cheese, wine
Propyl isobutyrate	rum
Terpenyl butyrate	cherry

List of dyes with Colour Index International generic names and numbers

Common name	Synonyms	C.I. generic name	C.I. number
Alcian Blue 8GX	Alcian Blue	Ingrain Blue	74240
Alcian yellow GXS	Sudan orange	Ingrain yellow 1	12840

Alizarin		Mordant red 11	58000
Alizarin Red S		Mordant red 3	58005
Alizarin yellow GG		Mordant yellow 1	14025
Alizarin yellow R		Mordant orange 1	14030
Azophloxin	Azogeranin B	Acid red 1	18050
Bismarck brown R	Vesuvine brown	Basic brown 4	21010
Bismarck brown Y	Vesuvine Phenylene brown	Basic brown 1	21000
Brilliant cresyl blue	Cresyl blue BBS	Basic dye	51010
Chrysoidine R		Basic orange 1	11320
Chrysoidine Y		Basic orange 2	11270
Congo red		Direct red 28	22120
Crystal violet		Basic violet 3	42555
Ethyl Green			42590
Fuchsin acid		Acid violet 19	42685
Gentian violet		Basic violet 1	42535
Janus green		Basic dye	11050
Lissamine fast yellow	Yellow 2G	Acid yellow 17	18965

Malachite green			
Martius yellow		Acid yellow 24	10315
Meldola blue	Phenylene blue	Basic blue 6	51175
Metanil yellow		Acid yellow 36	13065
Methyl orange		Acid orange 52	13025
Methyl red		Acid red 2	13020
Naphthalene black 12B	Amido black 10B	Acid black 1	20470
Naphthol green B		Acid green 1	10020
Naphthol yellow S		Acid yellow 1	10316
Orange G		Acid orange 10	16230
Purpurin		Verantin	
Rose bengal		Acid red 94	45440
Sudan II		Solvent orange 7	12140
Titan yellow		Direct yellow 9	19540
Tropaeolin O	Sulpho orange	Acid orange 6	14270
Tropaeolin OO		Acid orange 5	13080
Tropaeolin OOO	Orange II	Acid orange 7	15510

Victoria blue 4R		Basic blue 8	42563
Victoria blue B		Basic blue 26	44045
Victoria blue R		Basic blue 11	44040
Xylene cyanol FF		Acid blue 147	42135

List of copper salts

Name	Chemical Formula	Anion
Copper silicide	Cu_5Si	Silicide (silane)
Copper(I) oxide	Cu_2O	Oxide (oxygen)
Copper(I) chloride	CuCl	Chloride (hydrochloric acid)
Copper(I) iodide	CuI	Iodide (hydroiodic acid)
Copper(I) cyanide	CuCN	Cyanide (hydrocyanic acid)
Copper(I) thiocyanate	CuSCN	Thiocyanate (thiocyanic acid)
Copper(I) sulfate	Cu_2SO_4	Sulfate (sulfuric acid)
Copper(I) sulfide	Cu_2S	Sulfide (hydrogen sulfide)
Copper(I) acetylide	Cu_2C_2	Acetylide (acetylene)
Copper(I) bromide	CuBr	Bromide (hydrobromic acid)
Copper(I) fluoride	CuF	Fluoride (hydrofluoric acid)
Copper(I) hydroxide	CuOH	Hydroxide (water)
Copper(I) hydride	CuH	Hydride (hydrogen gas)
Copper(I) nitrate	$CuNO_3$	Nitrate (nitric acid)
Copper(I) phosphide	Cu_3P	Phosphide (phosphine)
Copper(I) thiophene-2-carboxylate	$C_5H_3CuO_2S$	thiophene-2-carboxylate (thiophene-2-carboxylic acid)
Copper(I) *t*-butoxide	$C_{16}H_{36}Cu_4O_4$	*t*-butoxide (*t*-butyl alcohol)
Copper(II) sulfate	$CuSO_4$	Sulfate (sulfuric acid)

Copper(II) chloride	$CuCl_2$	Chloride (hydrochloric acid)
Copper(II) hydroxide	$Cu(OH)_2$	Hydroxide (water)
Copper(II) nitrate	$Cu(NO_3)_2$	Nitrate (nitric acid)
Copper(II) oxide	CuO	Oxide (oxygen)
Copper(II) acetate	$Cu(OAc)_2$	Acetate (acetic acid)
Copper(II) fluoride	CuF_2	Fluoride (hydrofluoric acid)
Copper(II) bromide	$CuBr_2$	Bromide (bromine)
Copper(II) carbonate	$CuCO_3$	Carbonate (carbonic acid)
Copper(II) carbonate hydroxide	$Cu_2CO_3(OH)_2$	Hydroxide (water) Carbonate (carbonic acid)
Copper(II) chlorate	$Cu(ClO_3)_2$	Chlorate (chloric acid)
Copper(II) arsenate	$Cu_3(AsO_4)_2$	Arsenate (arsenic acid)
Copper(II) azide	$Cu(N_3)_2$	Azide (hydrazoic acid)
Copper(II) acetylacetonate	$Cu(O_2C_5H_7)_2$	Acetylacetonate (acetylacetone)
Copper(II) aspirinate	$C_{36}H_{28}Cu_2O_{16}$	Acetylsalicylate (acetylsalicylic acid)
Copper(II) cyanurate	$CuC_3HN_3O_3$	Cyanurate (cyanuric acid)
Copper(II) glycinate	$Cu(H_2NCH_2CO_2)_2$	Glycinate (glycine)
Copper(II) phosphate	$Cu_3(PO_4)_2$	Phosphate (phosphoric acid)
Copper(II) perchlorate	$Cu(ClO_4)_2$	Perchlorate (perchloric acid)
Copper(II) selenite	$CuSeO_3$	Selenite (selenous acid)
Copper(II) sulfide	CuS	Sulfide (hydrogen sulfide)
Copper(II) thiocyanate	$Cu(SCN)_2$	Thiocyanate (thiocyanic acid)
Copper(II) triflate	$Cu(OSO_2CF_3)_2$	Triflate (triflic acid)
Copper(II) tetrafluoroborate	$Cu(BF_4)_2$	Tetrafluoroborate (tetrafluoroboric acid)

Copper(II) acetate triarsenite (Paris Green)	$Cu(C_2H_3O_2)_2 \cdot 3Cu(AsO_2)_2$	Acetate (acetic acid) Triarsenite (1,3,5,2,4,6-Trioxatriarsinane-2,4,6-triol)
Copper(II) benzoate	$Cu(C_6H_5CO_2)_2$	Benzoate (benzoic acid)
Copper(II) arsenite (Scheele's Green)	$AsCuHO_3$	Arsenite (Arsenous acid)
Copper(II) chromite	$Cu_2Cr_2O_5$	Chromite (chromic acid)
Copper(II) gluconate	$C_{12}H_{22}CuO_{14}$	Gluconate (gluconic acid)
Copper(II) peroxide	CuO_2	Peroxide (hydrogen peroxide)
Copper(II) usnate	$C_{18}H_{14}CuO_7$	Usnate (usnic acid)
Copper(III) oxide	Cu_2O_3	Oxide (oxygen)

List of purification methods in chemistry

- **Affinity purification** purifies proteins by retaining them on a column through their affinity to antibodies, enzymes, or receptors that have been immobilised on the column.
- **Filtration** is a mechanical method to separate solids from liquids or gases by passing the feed stream through a porous sheet such as a cloth or membrane, which retains the solids and allows the liquid to pass through.
- **Centrifugation** is a process that uses an electric motor to spin a vessel of fluid at high speed to make heavier components settle to the bottom of the vessel.
- **Evaporation** removes volatile liquids from non-volatile solutes, which cannot be done through filtration due to the small size of the substances.
- **Liquid–liquid extraction** removes an impurity or recovers a desired product by dissolving the crude material in a solvent in which other components of the feed material are soluble.
- **Crystallization** separates a product from a liquid feed stream, often in extremely pure form, by cooling the feed stream or adding precipitants that lower the solubility of the desired product so that it forms crystals. The pure solid crystals are then separated from the remaining liquor by filtration or centrifugation.
- **Recrystallization:** In analytical and synthetic chemistry work, purchased reagents of doubtful purity may be recrystallized, e.g. dissolved in a very pure solvent, and then crystallized, and the crystals recovered, in order to improve and/or verify their purity.

- **Trituration** removes highly soluble impurities from usually solid insoluble material by rinsing it with an appropriate solvent.
- **Adsorption** removes a soluble impurity from a feed stream by trapping it on the surface of a solid material, such as activated carbon, that forms strong non-covalent chemical bonds with the impurity.
- **Chromatography** employs continuous adsorption and desorption on a packed bed of a solid to purify multiple components of a single feed stream. In a laboratory setting, mixture of dissolved materials are typically fed using a solvent into a column packed with an appropriate adsorbent, and due to different affinities for solvent (moving phase) versus adsorbent (stationary phase) the components in the original mixture exit the column in the moving phase at different rates, which thus allows to selectively collect desired materials out of the initial mixture.
- **Smelting** produces metals from raw ore, and involves adding chemicals to the ore and heating it up to the melting point of the metal.
- **Refining** is used primarily in the petroleum industry, whereby crude oil is heated and separated into stages according to the condensation points of the various elements.
- **Distillation** is widely used in petroleum refining and in purification of ethanol separates volatile liquids on the basis of their relative volatilities. There is several type of distillation: simple distillation, steam distillation etc.
- **Water purification** combines a number of methods to produce potable or drinking water.
- **Downstream processing** refers to purification of chemicals, pharmaceuticals and food ingredients produced by fermentation or synthesized by plant and animal tissues, for example antibiotics, citric acid, vitamin E, and insulin.
- **Fractionation** refers to a purification strategy in which some relatively inefficient purification method is repeatedly applied to isolate the desired substance in progressively greater purity.
- **Electrolysis** refers to the breakdown of substances using an electric current. This removes impurities in a substance that an electric current is run through
- **Sublimation** is the process of changing of any substance (usually on heating) from a solid to a gas (or from gas to a solid) without passing through liquid phase. In terms of purification - material is heated, often under vacuum, and the vapors of the material are then condensed back to a solid on a cooler surface. The process thus in its essence is similar to distillation, however the material which is condensed on the cooler surface then has to be removed mechanically, thus requiring different laboratory equipment.
- **Bioleaching** is the extraction of metals from their ores through the use of living organisms.

Physics Glossary

- **Absolute zero:** The lowest possible temperature T, at which **substance**s contain no **heat** energy Q.
- **Acceleration:** The rate at which the speed of an object is changing and it is given by the equation $\mathbf{a} = \frac{\mathbf{dv}}{\mathbf{dt}}$.
- **Anthropic principle:** We see the universe the way it is because if it were different we would not be here to observe it through a gigantic telescopes pointing deep into the immense sky – merely stating that the **constants of nature** must be tuned to allow for intelligence (otherwise we would not be here). Some believe that this is the sign of a cosmic creator. Others believe that this is a sign of the multiverse.
- **Antiparticle:** Each type of matter particle has a corresponding antiparticle – first predicted to exist by P. A. M. Dirac. When a particle collides with its antiparticle, they annihilate, leaving only pure energy in the form of discrete bundle (or quantum) of electromagnetic (or light) energy called photons.
- **Atom:** The basic unit of ordinary matter, made up of a tiny nucleus (consisting of positively charged protons and electrically neutral neutrons – which obey the strong interactions) surrounded by orbiting negatively charged weakly interacting particles called the electrons.
- **Big Bang:** The **singularity** at the beginning of the universe. The titanic explosion that created the universe, sending the galaxies hurtling in all directions. When the universe was created, the temperature was extremely hot, and the density of material was enormous i.e., infinite. The big bang took place 13.7 billion years ago, according to the **WMAP** satellite. The afterglow of the big bang is seen today as the cosmic background microwave radiation (of temperature 2.7 degrees above absolute zero). There are three experimental "proofs" of the big bang: the redshift of the **galaxies**, the cosmic background microwave radiation, and **nucleosynethsis** of the elements.
- **Big crunch:** The singularity at the end of the universe i.e., The final collapse of the universe. If the density of matter is large enough (**Omega** – The parameter that measures the average density of matter in the universe – being larger than 1), then there is enough matter in the universe to reverse the original expansion and cause the universe to recollapse. Temperatures rise to infinity at the instant of the big crunch.
- **Big freeze:** The end of the universe when it reaches near absolute zero. The big freeze is probably the final state of our universe, because the sum of Omega and **Lambda** is believed to be 1.0, and

hence the universe is in a state of inflation. There is not enough matter and energy to reverse the original expansion of the universe, so it will probably expand forever.

- **Big Bang nucleosynthesis:** The production of deuterium, **Helium-3** and **Helium-4** (the latter to about 25% mass fraction) in the first 500 to 1000 sec of the early universe. These light **isotope**s, plus measurable amounts of **lithium-7** and trace amounts of elements B, Be, are the result of non-equilibrium nuclear reactions as the universe cooled to about 10 to the power of 8 K. Heavier isotopes were produced in stellar nucleosynthesis.
- **Black hole:** A region of space-time from which nothing, not even light, can escape, because gravity is so strong and **escape velocity** equals the speed of light. Because the speed of light is the ultimate velocity in the universe, this means that nothing can escape a black hole, once an object has crossed the event horizon. Black holes can be of various sizes. Galactic black holes, lurking in the center of galaxies and quasars, can weight millions to billions of solar masses. Stellar **black hole**s are the remnant of a dying star, perhaps originally up to forty times the mass of our Sun. Both of these black holes have been identified with our instruments. Mini–black holes may also exist, as predicted by theory, but they have not yet been seen in the laboratory conditions.
- **Black Hole Escape Velocity:** It is widely held by astrophysicists and astronomers that a black hole has an escape velocity c (or c, the speed of light in Vacuum). **Chandrasekhar** [Nobel laureate] remarked,

"Let me be more precise as to what one means by a black hole. One says that a black hole is formed when the gravitational forces on the surface become so strong that light cannot escape from it. ... A trapped surface is one from which light cannot escape to infinity."

According to Hawking,

"Eventually when a star has shrunk to a certain critical radius, the gravitational field at the surface becomes so strong that the light cones are bent inward so much that the light can no longer escape. According to the theory of relativity, nothing can travel faster than light. Thus, if light cannot escape, neither can anything else. Everything is dragged back by the gravitational field. So one has a set of events, a region of space-time from which it is not possible to escape to reach a distant observer. Its boundary is called the event horizon. It coincides with the paths of the light rays that just fail to escape from the black hole."

A neutron star has a radius of about ten miles, only a few times the critical radius at which a star becomes a black hole.

"I had already discussed with Roger Penrose the idea of defining a black hole as a set of events from which it is not possible to escape to a large distance. It means that the boundary of the black hole, the event horizon, is formed by rays of light that just fail to get away from the black hole. Instead, they stay forever hovering on the edge of the black hole."

However, according to the alleged properties of a black hole, nothing at all can even leave the black hole. In the very same paper **Chandrasekhar** made the following quite typical contradictory assertion:

"The problem we now consider is that of the gravitational collapse of a body to a volume so small that a trapped surface forms around it; as we have stated, from such a surface no light can emerge."

Hughes reiterates,

"Things can go into the horizon (from $r > 2M$ to $r < 2M$), but they cannot get out; once inside, all causal trajectories (time-like or null) take us inexorably into the classical singularity at $r = 0$."

The defining property of black holes is their event horizon. Rather than a true surface, black holes have a '**one-way membrane**' through which stuff can go in but cannot come out.

Taylor and **Wheeler** assert,

"... Einstein predicts that nothing, not even light, can be successfully launched outward from the horizon ... and that light launched outward EXACTLY at the horizon will never increase its radial position by so much as a millimeter."

- **Zero point Energy:** an intrinsic and unavoidable part of **quantum physics**. The ZPE has been studied, both theoretically and experimentally, since the discovery of **quantum mechanics** in the 1920s and there can be no doubt that the ZPE is a real physical effect.
- **Casimir effect:** The attractive pressure between two flat, parallel metal plates placed very near to each other in a vacuum. The pressure is due to a reduction in the usual number of **virtual particle**s in the space between the plates. This tiny effect has been measured in the laboratory. The **Casimir effect** may be used as the energy to drive a **time machine** or wormhole, if its energy is large enough.
- **Chandrasekhar limit:** The maximum possible mass of a stable cold star (i.e., 1.4 solar masses), above which it must collapse into a black hole.

- **Conservation of energy:** The law of science that states that energy (or its equivalent in mass) can neither be created nor destroyed i.e., they never change with time. For example, the conservation of matter and energy posits that the total amount of matter and energy in the universe is a constant.
- **Coordinates:** Numbers that specify the position of a point in **4 dimensional space-time**.
- **Cosmological constant:** A mathematical parameter (which measures the amount of dark energy in the universe) introduced by **Albert Einstein** to give space-time an inbuilt tendency to expand. At present, the data supports density parameter + **cosmological constant** = 1, which fits the prediction of inflation for a flat universe. Cosmological constant, which was once thought to be zero, is now known to determine the ultimate destiny of the universe.
- **Cosmology:** The study of the universe as a whole.
- **COBE:** The **Cosmic Observer Background Explorer satellite**.
- **Dark matter:** Invisible Matter usually found in a huge halo around galaxies, clusters, and possibly between clusters, that cannot be observed directly but can be detected by its gravitational effect and they does not interact with light. As much as 90 percent of the mass of the universe may be in the form of dark matter and they makes up 23 percent of the total matter/energy content of the universe. According to string theory, dark matter may be made of subatomic particles, such as the **neutralino**, which represent higher vibrations of the **superstring**.
- **Duality:** A correspondence between apparently different theories that lead to the same physical results.
- **Einstein-Rosen bridge:** A thin tube of space-time linking two black holes.
- **Electric charge:** A property of a particle by which it may repel (or attract) other particles that have a charge of similar (or opposite) sign.
- **Electromagnetic force:** The force of electricity and **magnetism** that arises between particles with electric charge; the second strongest of the four fundamental forces – which obeys **Maxwell's equations**.
- **Electron:** A negatively charged subatomic particle with negative electric charge that orbits the **nucleus of an atom** and determines the chemical properties of the atom.
- **Electroweak unification energy:** The energy (**around 100 GeV**) above which the distinction between the **electromagnetic force** and the weak force disappears.
- **Elementary particle:** A particle that, it is believed fundamental building block of Nature, cannot be subdivided and are not composed of other simpler particles.

- **Event:** A point in space-time, specified by its time and place.
- **Event horizon:** The boundary of a black hole. The point of no return, often called the horizon.
- **Exclusion principle:** The idea that two identical **spin-1/2 particles** cannot have (within the limits set by the uncertainty principle) both the same position and the same velocity. This means that two electrons cannot occupy precisely the same point with the same properties, so that there is a net force pushing the electrons apart (in addition to **electrostatic repulsion**).
- **Field:** Something that exists throughout 4 dimensional fabric of space -time, as opposed to a particle that exists at only one point at a time.
- **Frequency:** For a **wave**, the number of complete cycles per second.
- **Gamma rays: Electromagnetic rays** of very short wavelength, produced in **radio-active decay** or by collisions of elementary particles.
- **General relativity: Einstein's theory of gravity** based on the idea that the laws of science should be the same for all observers, no matter how they are moving. It explains the force of gravity in terms of the curvature of a four dimensional space-time; so that the curvature of space-time gives the illusion that there is a force of attraction called gravity. It has been verified experimentally to better than 99.7 percent accuracy and predicts the existence of black holes and the expanding universe. The theory, however, break down at the center of a black hole or the instant of creation, where the theory predicts nonsense. To explain these phenomena, one must resort to a theory of **subatomic physics**.
- **Geodesic:** The shortest (or longest) path between two points.
- **Grand unification energy:** The energy above which, it is believed, the electromagnetic force, weak force, and strong force become indistinguishable from each other.
- **Grand unified theory (GUT):** A theory which unifies the electromagnetic, strong, and weak forces (but not gravity). The proton is not stable in these theories and can decay into positrons. **GUT theories** are inherently unstable (unless one adds super symmetry). GUT theories also lack gravity. (Adding gravity to GUT theories makes them diverge with infinities.)
- **Imaginary time:** Time measured using imaginary numbers.
- **Inflation:** The theory which states that the universe underwent an incredible amount of **superliminal expansion** at the instant of its birth i.e., A distance of one **nanometer** was enlarged to a quarter of a billion light-years.
- **Hyperspace:** Dimensions higher than four.

- **Light cone:** A surface in space-time that marks out the possible directions for light rays passing through a given event.
- **Light year:** The distance light travels in one year, or approximately 5.88 trillion miles (9.46 trillion kilometers).
- **LIGO:** The Laser Interferometry Gravitational-Wave Observatory, based in Washington state and Louisiana,which is the world's largest gravity wave detector.
- **LISA:** The Laser Interferometry Space Antenna- which is a series of three space satellites using laser beams to measure **gravity waves.** It is sensitive enough to confirm or disprove the inflationary theory and possibly even string theory.
- **Magnetic field:** The field responsible for magnetic forces, now incorporated along with the **electric field**, into the electromagnetic field.
- **Muon:** A subatomic particle identical to the electron but with a much larger mass. It belongs to the second redundant generation of particles found in the Standard Model.
- **Mass:** The quantity of matter in a body; its inertia, or resistance to acceleration.
- **Microwave background radiation:** The remnant radiation (with a temperature of about 2.7 degrees K) from the glowing of the hot early universe (**big bang**), now so greatly red-shifted that it appears not as light but as microwaves (radio waves with a wavelength of a few centimeters). Tiny deviations in this background radiation give scientists valuable data that can verify or rule out many **cosmological theories**.
- **Naked singularity:** A space-time singularity not surrounded by a black hole.
- **Neutrino:** An extremely light (possibly massless) subatomic particle that react very weakly with other particles and may penetrate several light-years of lead without ever interacting with anything and is affected only by the weak force and gravity.
- **Neutron:** A neutral subatomic particle, very similar to the proton, which accounts for roughly half the particles in an atomic nucleus.
- **Neutron star:** A cold collapsed star consisting of a solid mass of neutrons — which is usually about 10 to 15 miles across — supported by the exclusion principle repulsion between neutrons. If the mass of the neutron stars exceeds (3- 4 solar masses) i.e., if the number of neutrons becomes $\geq 5.9 \times 10^{57}$, then the degenerate neutron pressure will not be large enough to overcome the gravitational contraction and the star collapses into the next stage called black holes.
- **No boundary condition:** The idea that the universe is finite but has **no boundary** (rooted in the **Euclidean formalism**) to account for the initial conditions in the big bang.

- **Nuclear fusion:** The process by which two nuclei collide and coalesce to form a single, heavier nucleus.
- **Nucleus:** The tiny core of an atom, which is roughly 10^{-13} cm across, consisting only of protons and neutrons, held together by the strong force.
- **Particle accelerator:** A machine — based in Geneva, Switzerland — that, using electromagnets, can accelerate moving charged particles, giving them more energy.
- **Phase:** For a wave, the position in its cycle at a specified time: a measure of whether it is at a crest, a trough, or somewhere in between.
- **Photon:** A quantum of light (which was first proposed by Einstein to explain the photoelectric effect—that is, the fact that shining light on a metal results in the ejection of electrons).
- **Planck's quantum principle:** The idea that light (or any other classical waves) can be emitted or absorbed only in discrete quanta, whose energy E is proportional to their wavelength λ (i.e., $E = \frac{hc}{\lambda}$).
- **Positron:** The (positively charged) antiparticle of the electron.
- **Primordial black hole:** A black hole created in the very early universe.
- **Negative energy:** Energy that is less than zero.
- **Proton:** A positively charged subatomic particle, very similar to the neutron, that accounts for roughly half the particles in the nucleus of most atoms. They are stable, but Grand Unification theory predicts that they may decay over a long period of time.
- **Pulsar:** A rotating neutron star that emits regular pulses of **radio wave**s.
- **Quantum:** The indivisible unit in which waves may be emitted or absorbed.
- **Quark:** A subatomic particle that makes up the proton and neutron and feels the strong force. Three quarks make up a proton or neutron, and a **quark** and **antiquark** pair makes up a meson.
- **Quantum chromodynamics (QCD):** The theory that describes the interactions of quarks and **gluon**s.
- **Quantum mechanics:** The theory developed from wave equations, Planck's quantum principle and **Heisenberg's uncertainty principle**. No deviation from quantum mechanics has ever been found in the laboratory. Its most advanced version today is called quantum field theory, which combines special relativity and **quantum mechanics**. A fully quantum mechanical theory of gravity, however, is exceedingly difficult.

- **Quasar:** Quasi-stellar object. They are huge galaxies that were formed shortly after the gigantic explosion called the big bang.
- **Quantum foam:** Tiny, foam like distortions of 4 dimensional fabric of space-time at the level of the Planck length.
- **Radioactivity:** The spontaneous breakdown of one type of atomic nucleus into another.
- **Red shift:** The reddening or decrease in **frequency** of light from a star that is moving away from us, due to the Doppler effect.
- **Singularity:** A point in space-time at which the space-time curvature becomes infinite – which represent a breakdown of general relativity, forcing the introduction of a **quantum theory of gravity**.
- **Singularity theorem:** A theorem that states that the universe must have started with a singularity.
- **Space-time:** The four-dimensional space whose points are events.
- **Spatial dimension:** Any of the three dimensions that are space like – that is, any except the time dimension.
- **Special relativity:** Einstein's 1905 theory based on the idea that the laws of science should be the same for all observers, no matter how they are moving, in the absence of gravitational phenomena. Consequences include: time slows down, mass increases, and distances shrink the faster you move. Also, matter and energy are related via $\mathbf{E = mc^2}$. One consequence of special relativity is the **atomic bomb**.
- **Spectrum:** The different colors or component frequencies that make up a wave. By analyzing the spectrum of starlight, one can determine that stars are mainly made of hydrogen and helium.
- **Spin:** An internal property of elementary particles.
- **Stationary state:** One that is not changing with time.
- **Supernova:** An exploding star. They are so energetic that they can sometimes outshine a galaxy.
- **String theory:** A theory of physics based on tiny vibrating strings, such that each particle is described as a wave on a string. It is the only theory that can combine gravity with the quantum theory, making it the leading candidate for a **theory of everything**.
- **Strong force:** The strongest of the four fundamental forces, with the shortest range of all. It holds the quarks together within protons and neutrons, and holds the protons and neutrons together to form atoms.
- **Steady state theory:** The theory which states that the universe had no beginning but constantly generates new matter as it expands, keeping the same density.

- **Uncertainty principle:** The principle, formulated by Heisenberg, that one can never be exactly sure of both the position and the velocity of a particle; the more accurately one knows the one, the less accurately one can know the other.

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

$$\Delta E \, \Delta t \geq \frac{\hbar}{2}$$

- **Avogadro's Number:** 6.022×10^{23}. The number of nucleons (protons and neutrons) in 1 gram of matter.
- **Virtual particle:** In quantum mechanics, a particle that briefly dart in and out of the vacuum but can never be directly detected, but whose existence does have measurable effects. They violate known conservation laws but only for a short period of time, via the uncertainty principle.
- **Baryon**: A particle that is composed of three quarks, such as the proton or neutron.
- **Baryon Asymmetry Problem**: The fact that the universe contains a billion times as many baryons (ordinary matter) as antibaryons (antimatter), when they would be expected to have been produced in equal quantities in the early universe.
- **Brownian Motion:** The random motion of macroscopic particles that results from their being bombarded by molecules.
- **Copernican Principle:** The earth is not the center of the universe.
- **Curie Point:** The temperature below which iron becomes magnetic.
- **Generalized Copernican Principle:** There is no center of the universe, no special point in space or time.
- **Hilbert Space:** An abstract mathematical space used to describe quantum mechanical states.
- **Occam's Razor:** The principle that one should introduce no more hypotheses than are necessary to explain the data.
- **Wave / particle duality:** The concept in quantum mechanics that there is no distinction between waves and particles; particles may sometimes behave like waves, and waves like particles.

- **Wavelength:** For a wave, the distance between two adjacent troughs or two adjacent crests.
- **Weak force:** The second weakest of the four fundamental forces – which is carried by the W- and Z-**boson**s- that makes possible nuclear decay. It affects all matter particles, but not force carrying particles.
- **Selectron:** The supersymmetric partner of the electron. Not yet observed.
- **Weight:** The force exerted on a body by a gravitational field. It is proportional to, but not the same as, its mass.
- **Principle of Galilean Relativity:** Velocity is relative. There is no difference between being in motion at constant velocity and being at rest.
- **Parity Violation:** The observation that the mirror image of a natural process is not always fundamentally equivalent to the original process.
- **Quantum Electrodynamics (QED)**: The quantum theory of electromagnetism.
- **White dwarf:** A stable cold star consisting of lower elements such as oxygen, lithium, carbon, and so forth, supported by the **exclusion principle repulsion** between electrons.
- **Wormhole:** A passageway between two universes or a thin tube of space-time connecting distant regions of the universe. **Wormholes** might also link to parallel or baby universes and could provide the possibility of **time travel**.
- **Neutrino-Dominated Universe**: The model in which neutrinos with mass constitute the dark matter of the universe.

Gravitational binding energy of the star:

$$U = -\frac{3GM^2}{5R}$$

where:

- M and R denote the mass and radius of the star
- G is the Gravitational constant

Core pressure of the star:

$$P_{core} = \frac{5GM^2}{4\pi R^2}$$

Core density of the star:

$$\rho_{core} = \frac{3M}{\pi R^3}$$

Core Temperature of the star:

$$T_{core} = \frac{5\mu m_H GM}{3k_B R}$$

where:

- μ denotes mean molecular weight of the matter insider the star
- m_H is the mass of hydrogen nucleus
- k_B is the Boltzmann constant

The ideal gas equation $PV = Nk_BT$ does not hold good for the matter present inside a star. Because, most stars are made up of more than one kind of particle and the gas inside the star is ionized. There is no indication of these facts in the above equation. We need to change the ideal gas equation, so that it holds good for the material present inside the star. It can be shown that the required equation can be written as

$$PV = \frac{1}{\mu}\frac{Mk_BT}{m_H}$$

where μ denotes mean molecular weight of the matter inside the star, M is the mass of the star and m_H is the mass of hydrogen nucleus.

Stellar timescales

- **Nuclear timescale:**

$$t_{nuc} = \frac{\text{total mass of fuel available}}{\text{rate of fuel consumption}} \times \text{fraction of star over which fuel is burned}$$

$$t_{nuc} = \frac{MX}{\frac{L}{Q}} \times F$$

where M is the mass of the star, X is the fraction of the star (by mass) that is composed of the fuel, L is the **star's luminosity**, Q is the energy released per mass of the fuel from nuclear fusion, and F is the fraction of the star where the fuel is burned.

- **Einstein timescale:**

$$t_E = \frac{Mc^2}{L}$$

- **Thermal time scale**

$$t_{th} \approx \frac{GM^2}{2RL}$$

- **Dynamical timescale**

$$t_{dyn} = \sqrt{\frac{R^3}{GM}}$$

where c is the speed of light

Richardson-Dushman Equation:

The Richardson-Dushman equation relates the current density of a thermionic emission (j_s) to the work function (W) and temperature (T) of the emitting material:

$$j_s = A\, T^2\, e^{\frac{-W}{k_B T}}$$

where A denotes the **Richardson's constant** and k_B is the Boltzmann constant.

In a **nuclear reaction**:

$$M_A + M_B \rightarrow M_C + M_D$$

$$Q = (M_A + M_B - M_C - M_D)\, c^2$$

The amount of energy released or absorbed in a nuclear reaction is called the Q value, or reaction energy.

If $M_A + M_B > M_C + M_D \rightarrow Q > 0 \equiv$ **exoergic reaction**

If $M_A + M_B < M_C + M_D \rightarrow Q < 0 \equiv$ **endoergic reaction**

An endoergic reaction will not proceed unless the incoming particle provides the reaction energy "Q".

Drake equation:

$$N = R_* \times f_p \times n_E \times f_l \times f_i \times f_c \times L$$

where:

- N = the number of civilizations in our galaxy with which communication might be possible.
- R_* = the average rate of star formation in our galaxy.
- f_p = the fraction of those stars that have planets.
- n_E = the average number of planets that can potentially support life per star that has planets.
- f_l = the fraction of planets that could support life that actually develop life at some point.
- f_i = the fraction of planets with life that actually go on to develop intelligent life (civilizations).
- f_c = the fraction of civilizations that develop a technology that releases detectable signs of their existence into space.
- L = the length of time for which such civilizations release detectable signals into space.

Borda–Carnot equation

$$\Delta E = \xi \frac{1}{2} \rho \, (v_1 - v_2)^2$$

where:

- ΔE is the fluid mechanical energy loss,
- ξ is an empirical loss coefficient, which is dimensionless and has a value between zero and one, $0 \leq \xi \leq 1$
- ρ is the fluid density
- v_1 and v_2 are the mean flow velocities before and after the expansion.

Kepler's equation

$$M = E - e \sin E$$

where M is the mean anomaly, E is the eccentric anomaly, and e is the eccentricity.

Maxwell's Equations

Gauss's law for electricity	$\nabla \bullet E = \frac{\rho}{\varepsilon_0}$
Gauss's law for magnetism	$\nabla \bullet B = 0$
Maxwell–Faraday equation (Faraday's law of induction)	$\nabla \times E = -\frac{\partial B}{\partial t}$
Ampere's circuital law	$\nabla \times B = \mu_0 \left(J + \varepsilon_0 \frac{\partial E}{\partial t} \right)$

where:

- ∇ = Laplace operator
- E = Electric field
- ρ = charge density
- B = Magnetic field
- ε_0 = absolute permittivity
- J = current density
- μ_0 = absolute permeability

Prony equation

The Prony equation is a historically important equation in hydraulics, used to calculate the head loss due to friction within a given run of pipe. It is an empirical equation developed by Frenchman **Gaspard de Prony** in the 19th century:

$$h_f = \frac{L}{D}(aV + bV^2)$$

where "h_f" is the head loss due to friction, calculated from: the ratio of the length to diameter of the pipe "$\frac{L}{D}$", the velocity of the flow "V", and two empirical factors "a" and "b" to account for friction.

Rankine-Hugoniot conditions

In a coordinate system that is moving with the shock, the Rankine–Hugoniot conditions can be expressed as:

$$\rho_1 u_s = \rho_2 (u_s - u_2) \rightarrow \textit{Conservation of mass}$$

$$p_2 - p_1 = \rho_2 u_2 (u_s - u_2) = \rho_1 u_2 u_s \rightarrow \textit{Conservation of momentum}$$

$$p_2 u_2 = \rho_1 u_s \left(\frac{1}{2} u_2^2 + e_2 - e_1\right) \rightarrow \textit{Conservation of energy}$$

where u_s is the shock wave speed, ρ_1 and ρ_2 are the mass density of the fluid behind and inside the shock, u_2 is the particle velocity of the fluid inside the shock, p_1 and p_2 are the pressures in the two regions, and e_1 and e_2 are the specific (with the sense of per unit mass) internal energies in the two regions.

Sackur–Tetrode equation

The Sackur–Tetrode equation expresses the entropy S of a monatomic ideal gas in terms of its thermodynamic state − specifically, its volume V, internal energy U, and the number of particles N:

$$\frac{S}{k_B N} = \ln \left[\frac{V}{N} \left(\frac{4\pi m U}{3h^2 N} \right)^{3/2} \right] + \frac{5}{2}$$

where:

- k_B = Boltzmann's constant
- m =Mass of a gas particle
- h = Planck's constant

Butler–Volmer equation

$$j = j_0 \left\{ \exp \left[\frac{\alpha_a z F \eta}{RT} \right] - \exp \left[- \frac{\alpha_c z F \eta}{RT} \right] \right\}$$

where:

- j: electrode current density, A/m^2 (defined as j = I/S)
- j_0: exchange current density, A/m^2
- E: electrode potential, V
- E_{eq}: equilibrium potential, V
- T: absolute temperature, K
- z: number of electrons involved in the electrode reaction
- F: Faraday constant
- R: universal gas constant
- α_c: so-called cathodic charge transfer coefficient, dimensionless
- α_a: so-called anodic charge transfer coefficient, dimensionless
- η: activation overpotential (defined as $\eta = E - E_{eq}$).

Lotka–Volterra equations

$$\frac{dx}{dt} = \alpha x - \beta xy$$

$$\frac{dy}{dt} = \delta xy - \gamma y$$

where:

- x is the number of prey (for example, rabbits)
- y is the number of some predator (for example, foxes)
- $\frac{dy}{dt}$ and $\frac{dx}{dt}$ represent the instantaneous growth rates of the two populations
- t represents time
- α, β, γ, δ are positive real parameters describing the interaction of the two species

Black–Scholes equation

In mathematical finance, the **Black–Scholes equation** is a partial differential equation (**PDE**) governing the price evolution of a European call or European put under the Black–Scholes model. Broadly speaking, the term may refer to a similar **PDE** that can be derived for a variety of options, or more generally, derivatives. For a European call or put on an underlying stock paying no dividends, the equation is:

$$\frac{\partial V}{\partial t} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + rS\frac{\partial V}{\partial S} - rV = 0$$

where V is the price of the option as a function of stock price S and time t, r is the risk-free interest rate, and σ is the volatility of the stock.

Password length parameter

In telecommunication, a **password length parameter** is a basic parameter the value of which affects password strength against brute force attack and so is a contributor to computer security. One use of the password length parameters is in the expression $P = L \times \frac{R}{S}$, where P is the probability that a password can be guessed in its lifetime, L is the maximum lifetime a password can be used to log into a system, R is the number of guesses per unit of time, and S is the number of unique algorithm-generated passwords.

Stellar structure

- **The Equation of mass conservation**

$$\frac{dm}{dr} = 4\pi r^2 \rho$$

where: ρ is the matter density and m is the cumulative mass inside the shell at r and G is the gravitational constant.

- **The Equation of hydrostatic equilibrium**

$$\frac{dP}{dr} = -\frac{Gm}{r^2}\rho$$

where: P is the total pressure (matter plus radiation).

- **The Equation of energy generation**

$$\frac{dL}{dr} = 4\pi r^2 \rho q$$

where: L is the luminosity and q is the rate of energy generation per unit mass

- **The Equation of energy transport**

$$\frac{dT}{dr} = -\frac{3\kappa\rho L}{64\pi r^2 \sigma T^3}$$

where: T is the temperature, κ is the opacity of the matter and σ is the Stefan–Boltzmann constant

For stars:

$$t_{dyn} < t_{th} < t_{nuc}$$

- t_{dyn} = timescale of collapsing star, e.g. supernova
- t_{th} = timescale of star before nuclear fusion starts, e.g. pre-main sequence lifetime
- t_{nuc} = timescale of star during nuclear fusion, i.e. main-sequence lifetime

Taft equation

$$\log\left(\frac{k_s}{k_{CH_3}}\right) = \rho^* \sigma^* + \delta E_s$$

where log ($\frac{k_s}{k_{CH_3}}$) is the ratio of the rate of the substituted reaction compared to the reference reaction, σ* is the polar substituent constant that describes the field and inductive effects of the substituent, E_s is the steric substituent constant, ρ* is the sensitivity factor for the reaction to polar effects, and δ is the sensitivity factor for the reaction to steric effects.

Hammett equation

$$\log\left(\frac{k}{k_0}\right) = \sigma\rho$$

where:

- σ = substituent constant
- ρ = reaction constant
- k_0 is the reference reaction rate of the unsubstituted reactant, and k that of a substituted reactant.

$$\boxed{\Delta s^2 = -c^2\Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2}$$

- $\Delta s^2 < 0$ is a timelike interval. Events separated by this interval can be causally related.
- $\Delta s^2 = 0$ is a lightlike interval. Events separated by this interval can be causally related, but only by a light speed signal.
- $\Delta s^2 > 0$ is a spacelike interval. Events separated by this interval cannot be causally related.

Basic terms in chemistry

- **Chemistry -** a science that deals with the structure and properties of substances and their reactions, it studies matter and energy
- **Organic chemistry** – the branch of chemistry that deals with the chemistry of carbon and living organisms
- **Analytical chemistry** – the branch of chemistry that studies the properties of materials and analyzes materials
- **Matter -** the thing that forms physical objects and occupies space, it exists in four main states as solids, liquids, gases and plasma
- **Solid** – a substance that has a definite shape and a definite volume, it is not compressible
- **Liquid** – a substance (state of matter) which has an indefinite shape and a definite volume, not easily compressible
- **Gas** – a substance with an indefinite shape and volume, easily compressible
- **Melting point** – the temperature at which solids turn into liquid
- **Condensation** – the phase change when gas forms a liquid
- **Sublimation** – the phase change when a solid state changes into a gaseous state
- **Evaporation** – the phase change when a substance changes from a liquid state into a gaseous state
- **Atom** – the smallest unit of matter which has all the chemical properties of a particular element
- **Molecule** − the smallest possible amount of a particular substance that has all the characteristics of that substance
- **Neutron** − a particle found in the nucleus of an atom which has the same mass as a proton but no charge
- **Element** – a substance that consists only of one type of atom
- **Compound** – a chemical substance that consists of two or more elements that together form a molecule
- **Mixture** − a material system made up of two or more different substances which are mixed but are not combined chemically

- **Solvent** − A liquid in which a substance (**solute**) dissolves.
- **Acid** − a chemical with a sour taste that forms a salt when mixed with a base
- **Base** − a chemical that reacts with an acid to form a salt, it has a pH higher than 7
- **Atomic number** – the number of protons in an atom
- **Mass number** – the sum of the number of protons and neutrons in one atom
- **Bond** − a force that holds together the atoms in a molecule, an attraction between atoms or molecules
- **Ion** − an atom or group of atoms that has a positive or negative electric charge from losing or gaining one or more electrons
- **Covalent bond** – a type of bond between non-metal atoms, consists of a shared pair of electrons
- **Shell / orbital** – region a of space around the nucleus of an atom where an electron is likely to be found
- **Steric hindrance** − the phenomenon of physical blockage of a particular site within a molecule by the presence of local atoms or groups of atoms.
- **Structural isomerism** − isomers which differ in the order of bonding of the constituent atoms.
- **Reactant** – an original substance that changes when it is combined with another substance in a chemical reaction
- **Product** – resulting substance of a chemical reaction
- **Mole** − A formula mass expressed in grams
- **Nucleophile** − a substance which donates a pair of electrons in the reaction considered.
- **Chemical equation** – a shorthand representation of a chemical reaction with formulas of reactants to the left of an arrow and the formulas of the products to the right of an arrow
- **Catalyst** – a substance that speeds up the rate of a chemical reaction
- **Enzyme** − A biological catalyst.
- **Combination (synthesis) reaction** – chemical change in which two or more substances react to form a single (one) new substance
- **Period** − A horizontal row in the periodic table.

- **Beaker** − a wide glass with a lip for pouring that is used for holding and measuring liquids
- **Test tube** − a glass container that is shaped like a tube which is closed at one end and that is used especially in science experiments
- **Funnel** − a device shaped like a hollow cone with a tube extending from the point which is used for pouring something (such as a liquid) into a narrow opening
- **Flask** − a glass bottle used in scientific laboratories that is used to carry liquids
- **Thermometer** − an instrument used for measuring temperature
- **Condenser** − a device used for changing a gas into a liquid
- **Forceps / tweezers** − a tool that is used for grasping or holding little things
- **Spatula** − a tool that has a long handle which is bent upward and a wide, thin blade used for lifting and turning chemicals
- **Bunsen burner** − a piece of equipment that produces a hot flame and that is used in scientific experiments
- **Dropper** − a glass or plastic tube that is used to measure out liquids by drops
- **Tongs** − a tool used for lifting or holding objects that is made of two long pieces connected in the middle
- **Tautomerism** − a form of structural isomerism where the two structures are interconvertible by means of the migration of a proton.
- **Crucible** − a pot in which metals or other substances are heated to a very high temperature or melted
- **Clamp** − a device that holds or presses parts tightly together
- **Petri dish** − a small, shallow dish that has a loose cover and that is is used in scientific experiments especially for growing bacteria
- **Analytical balance** − a device that measures weight and shows how heavy things are.
- **Fume hood** − a piece of laboratory equipment designed to limit exposure to dangerous fumes
- **Markownikow's rule** − in the ionic addition of hydrogen halides to a carbon-carbon double bond the halogen attaches itself to the carbon atom bearing the least number of hydrogen atoms.

Greek Alphabet and SI Prefixes

Α	α	alpha	Ν	ν	nu
Β	β	beta	Ξ	ξ	xi
Γ	γ	gamma	Ο	o	omicron
Δ	δ	delta	Π	π	pi
Ε	ϵ, ε	epsilon	Ρ	ρ	rho
Ζ	ζ	zeta	Σ	σ, ς	sigma
Η	η	eta	Τ	τ	tau
Θ	θ, ϑ	theta	Υ	υ	upsilon
Ι	ι	iota	Φ	φ, ϕ	phi
Κ	κ	kappa	Χ	χ	chi
Λ	λ	lambda	Ψ	ψ	psi
Μ	μ	mu	Ω	ω	omega

$$\text{Double Factorial } n!! = \begin{cases} n \times (n-2) \times \ldots \times 5 \times 3 \times 1 & \textbf{for n > 0 odd} \\ n \times (n-2) \times \ldots \times 6 \times 4 \times 2 & \textbf{for n > 0 even} \\ 1 & \textbf{for n = −1, 0} \end{cases}$$

Convergence Tests

D'Alembert's ratio test

In a series, $\sum_{n=1}^{\infty} a_n$, let the ratio R = $\lim_{n\to\infty} (\frac{a_{n+1}}{a_n})$

- If R < 1 the series is convergent

- If R > 1 the series is divergent
- If R = 1 the test fails.

The Integral Test

A sum to infinity of a_n converges if $\int_1^\infty a_n \, dn$ is finite. This can only be applied to series where a_n is positive and decreasing as n gets larger.

Maxwell's thermodynamic relations

$$\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$$

$$\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$

$$\left(\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial S}{\partial P}\right)_T$$

$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$$

Cramer's Rule

Two simultaneous equations in unknowns x and y,

$$a_1x + b_1y = c_1 \text{ and } a_2x + b_2y = c_2,$$

have the solutions

$$x = \frac{\begin{vmatrix} c_1 & b_1 \\ c_2 & b_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}} = \frac{c_1b_2 - c_2b_1}{a_1b_2 - a_2b_1}$$

and

$$y = \frac{\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}} = \frac{a_1c_2 - a_2c_1}{a_1b_2 - a_2b_1}$$

When a surface intercepts electromagnetic radiation, a force and a pressure are exerted on the surface. If the radiation is totally absorbed by the surface, the force is

$$F = \frac{IA}{c} \text{ (total absorption),}$$

in which I is the intensity of the radiation, c is the speed of light, and A is the area of the surface perpendicular to the path of the radiation. If the radiation is totally reflected back along its original path, the force is

$$F = \frac{2IA}{c} \text{ (total reflection back along path).}$$

The radiation pressure p_r is the force per unit area:

$$p_r = \frac{I}{c} \text{ (total absorption)}$$

and

$$p_r = \frac{2I}{c} \text{ (total reflection back along path).}$$

$$I = \frac{E^2}{c\mu_0}$$

Because E = c × B and c is such a very large number: the energy associated with the electric field is much greater than that associated with the magnetic field.

The rate per unit area at which energy is transported via an electromagnetic wave is given by the Poynting vector:

$$\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$$

Masses are usually measured in atomic mass units, where

$$1\ \text{u} = 1.660\ 538\ 86 \times 10^{-27}\ \text{kg}$$

and energies are usually measured in electron-volts or multiples of it, where

$$1\ \text{eV} = 1.602\ 176\ 462 \times 10^{-19}\ \text{J}.$$

$$\text{Angular wave number} = \frac{2\pi}{\text{Wavelength}}$$

The probability that a given particle of mass m and energy E will tunnel through a barrier of height U_b and thickness L is given by the transmission coefficient T:

$$T \approx e^{-2bL}$$

where $b = \sqrt{\frac{8\pi^2 m(U_b - E)}{h^2}}$ (h: Planck's constant)

Because it is a matter wave, an electron confined to an infinite potential well can exist in only certain discrete states. If the well is one-dimensional with length L, the energies associated with these quantum states are

$$E_n = \frac{h^2 n^2}{8mL^2} \text{ for } n = 1, 2, 3. . .$$

where m is the electron mass and n is a quantum number.

Moseley's law

$$\upsilon = A \times (Z - b)^2$$

where:

- υ is the frequency of the observed X-ray emission line
- Z is the atomic number
- A and b are constants that depend on the type of line (that is, K, L, etc. in X-ray notation)

Number of conduction electrons in sample = number of atoms in sample × number of valence electrons per atom.

1 becquerel = 1 Bq = 1 decay per second.

1 curie = 1 Ci = 3.7×10^{10} Bq

Physical Data Often Used

Average Earth–Moon distance	3.84×10^{8} m
Average Earth–Sun distance	1.496×10^{11} m
Average Radius of the Earth	6.37×10^{6} m
Density of air (20°C and 1 atm)	1.20 kg/m^3
Density of water (20°C and 1 atm)	1.00×10^{3} kg/m^3
Free-fall acceleration	9.80 m/s^2
Mass of the Earth	5.98×10^{24} kg
Mass of the Moon	7.36×10^{22} kg
Mass of the Sun	1.99×10^{30} kg
Standard atmospheric pressure	1.013×10^{5} Pa

- Distance from the Earth to the most remote known quasar: 1.4×10^{26} m
- Distance from the Earth to the most remote normal galaxies: 9×10^{25} m
- Distance from the Earth to the nearest large galaxy (Andromeda): 2×10^{22} m
- Distance from the Sun to the nearest star (Proxima Centauri): 4×10^{16} m
- One light-year: 9.46×10^{15} m
- Mean orbit radius of the Earth about the Sun: 1.50×10^{11} m
- Mean distance from the Earth to the Moon: 3.84×10^{8} m
- Distance from the equator to the North Pole: 1.00×10^{7} m
- Typical altitude (above the surface) of a satellite orbiting the Earth: 2×10^{5} m
- Length of a housefly: 5×10^{-3} m
- Size of smallest dust particles: $\sim 10^{-4}$ m

- Size of cells of most living organisms: $\sim 10^{-5}$ m
- Diameter of a hydrogen atom: $\sim 10^{-10}$ m
- Diameter of an atomic nucleus: $\sim 10^{-14}$ m
- Diameter of a proton: $\sim 10^{-15}$ m
- Age of the Universe: 5×10^{17} s
- Age of the Earth: 1.3×10^{17} s
- One year: 3.2×10^{7} s
- One day: 8.6×10^{4} s
- Time interval between normal heartbeats: 8×10^{-1} s
- Period of audible sound waves: $\sim 10^{-3}$ s
- Period of typical radio waves: $\sim 10^{-6}$ s
- Period of vibration of an atom in a solid: $\sim 10^{-13}$ s
- Period of visible light waves: $\sim 10^{-15}$ s
- Duration of a nuclear collision: $\sim 10^{-22}$ s
- Time interval for light to cross a proton: $\sim 10^{-24}$ s
- 1000 kg = 1 t (metric ton)
- 1 slug = 14.59 kg

$$\boxed{\text{Compressibility Factor (Z)} = \frac{PV}{nRT}}$$

where P is the pressure, n is the number of moles of gas, T is the absolute temperature, and R is the gas constant.

Garland or mala product:

A product of numbers remains the same when read from left to right or vice.

$$139 \times 139 = 15151$$

$$152207 \times 73 = 11111111$$

$$14287143 \times 7 = 100010001$$

$$12345679 \times 9 = 111111111$$

$$142857143 \times 7 = 1000000001$$

$$11011011 \times 91 = 1002002001$$

$$27994681 \times 441 = 12345654321$$

$$333333666667 \times 33 = 11000011000011$$

Kaprekar Numbers:

8426

Ascending order: 2468

Descending order: 8642

Difference: 6174

4671

Ascending order: 1467

Descending order: 7641

Difference: 6174

1, 9, 45, 55, 703, 2223 … are known as **Kaprekar numbers**.

Stoke's Law of Viscosity:

$$F = 6\pi\eta r v$$

- F= Drag Force
- η = Viscosity Coefficient
- r = Radius of the Particle
- v = Relative velocity of the Particle

Reynolds Number:

$$R_e = \frac{r \times \rho \times v}{\mu}$$

- R_e = Reynolds Number
- r = The diameter or length (basically length of the shape of the object)
- ρ = The density of the fluid
- v = The velocity of the object
- μ = Viscosity of the fluid;

Eotvos Ramsay-Shield relation:

$$\left[\frac{M}{\rho}\right]^{\frac{2}{3}} \gamma = k\,(T_c - T - 6)$$

- M=Molecular Weight
- ρ = density
- γ = Surface Tension
- *k* = Eotvos-Ramsay Coefficient
- T_c = Critical Temperature
- T = System Temperature

Young-Laplace Equation:

$$P_{in} = P_{out} + \frac{2\gamma}{r}$$

- P_{in} = Pressure Inside the Curved Surface
- P_{out} = Pressure Outside the Curved Surface
- γ = Surface Tension
- r = Radius of Curvature of the Curved Surface

Dieterici Equation of State:

$$P\, e^{\frac{an}{RTV}}\ (V - nb) = nRT$$

- P = Pressure
- V = Volume
- a , b = Dieterici Constants
- n = Number of Moles
- R = Universal Gas Constant
- T = Temperature

Energy of Polyatomic Gas (Non-Linear):

$$E = 3\,(n - 1)\,RT$$

- E = Average energy per mole
- n = Number of atoms in a non-linear Molecule
- R= Gas Constant
- T= Temperature

Energy of Polyatomic Gas (Linear):

$$E = \frac{5}{2}\,RT + (3n - 5)\,RT$$

- E = Average energy per mole
- n = Number of atoms in a linear Molecule
- R= Gas Constant
- T= Temperature

Collision Frequency of a single gas:

$$Z_{AA} = \frac{\pi\, n\, \sigma\, c_{ave}}{\sqrt{2}}$$

- Z_{AA}=Collision frequency
- n = Molecules per unit Volume
- σ = Diameter of the gas molecules
- c_{ave} = Average Velocity of the gas molecules

Root Mean Square, Average, Median Velocity of Gas:

$$c_{rms} = \sqrt{\frac{3RT}{M}}$$

$$c_{ave} = \sqrt{\frac{8RT}{\pi M}}$$

$$c_m = \sqrt{\frac{2RT}{M}}$$

- c_{rms}, c_{ave} , c_m = Root Mean Square, Average Velocity and Most Probable Velocity of gas molecules
- M= Molecular Weight
- T =Temperature
- R= Universal Gas Constant

Clausius Clapeyron Equation:

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_m}{R}\left[\frac{1}{T_1} - \frac{1}{T_2}\right]$$

- P_1 and P_2 = Initial and Final Pressure
- ΔH_m = Molar Enthalpy of vaporization
- T_1 and T_2 = Initial and Final Temperature
- R= Gas Constant

Relative Population of rotational energy states:

$$\frac{N_j}{N_0} = \exp\left(-\frac{B\,h\,c\,J\,(J+1)}{k_B T}\right)$$

- N_J = Number of molecule in J state
- N_0 = Number of molecule in the ground state (J= 0)
- k_B =Boltzmann Constant
- T = Temperature
- B = Rotational Constant
- h = Plank Constant
- c = Velocity of light
- J = Rotational Quantum Number

Double Bond Equivalent (DBE) $= C + 1 - \frac{H}{2} - \frac{X}{2} + \frac{N}{2}$

- C= Number of Carbon atoms present
- H = Number of Hydrogen atoms present
- X= Number of Halogen atoms present (Cl, Br, I or F)
- N= Number of Nitrogen atoms present

Langmuir Isotherm:

$$\theta = \frac{KP}{1+KP}$$

- K = Equilibrium Constant of Adsorption
- P = Partial Pressure or Concentration of the absorbate
- θ = The fraction of adsorbent surface covered by adsorbate

Slater's Rule:

$$Z_{eff} = Z - \sigma$$

- Z_{eff} = Effective nuclear charge
- Z = Atomic Number
- σ = number of shielding electrons

Interplanar Spacing of Cubic Lattice:

$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

- d_{hkl} = Lattice Spacing
- a = Lattice Constant
- h , k , l = Miller Indices

Interplanar Spacing of Tetragonal Lattice:

$$\frac{1}{d^2} = \frac{h^2 + k^2}{a^2} + \frac{l^2}{c^2}$$

- d= Interplanar Spacing
- h , k, l = Miller Indices
- a, c = Lattice Constants

The Dead Sea is much denser and heavier than freshwater because of its salt content, which would make it impossible for us to sink.

Pi is an irrational number, which means that it is a real number that cannot be expressed by a simple fraction.

If we travel faster than the speed of light, we will age less.

Gravitational potential energy increases as height increases.

Adding a resistor in series increases the total resistance of a circuit.

Adding a resistor in parallel decreases the total resistance of a circuit.

The insulator does not permit the free flow of electrons

Light slows down, bends toward the normal and has a shorter wavelength when it enters a medium with a higher index of refraction

A prism produces a rainbow from white light by the phenomenon of dispersion

Spectrum of Electromagnetic Radiation				
Region	**Wavelength (Angstroms)**	**Wavelength (centimeters)**	**Frequency (Hz)**	**Energy (eV)**
Radio	$> 10^9$	> 10	$< 3 \times 10^9$	$< 10^{-5}$
Microwave	$10^9 - 10^6$	$10 - 0.01$	$3 \times 10^9 - 3 \times 10^{12}$	$10^{-5} - 0.01$
Infrared	$10^6 - 7000$	$0.01 - 7 \times 10^{-5}$	$3 \times 10^{12} - 4.3 \times 10^{14}$	$0.01 - 2$
Visible	$7000 - 4000$	$7 \times 10^{-5} - 4 \times 10^{-5}$	$4.3 \times 10^{14} - 7.5 \times 10^{14}$	$2 - 3$
Ultraviolet	$4000 - 10$	$4 \times 10^{-5} - 10^{-7}$	$7.5 \times 10^{14} - 3 \times 10^{17}$	$3 - 10^3$
X−Rays	$10 - 0.1$	$10^{-7} - 10^{-9}$	$3 \times 10^{17} - 3 \times 10^{19}$	$10^3 - 10^5$
Gamma Rays	< 0.1	$< 10^{-9}$	$> 3 \times 10^{19}$	$> 10^5$

Doppler Effect

When a wave source moves toward us, we will perceive waves with a shorter wavelength and higher frequency than the waves emitted by the source.

When a wave source moves away from us, we will perceive waves with a longer wavelength and lower frequency.

At the **critical angle** a wave will be refracted to 90 degrees. At angles larger than the **critical angle**, light is reflected not refracted.

Natural abundance of some elements

Isotope	% Natural Abundance	Atomic Mass
^{1}H	99.985	1.007825
^{2}H	0.015	2.0140
^{12}C	98.89	12 (formerly by definition)
^{13}C	1.11	13.00335
^{14}N	99.64	14.00307
^{15}N	0.36	15.00011
^{16}O	99.76	15.99491
^{17}O	0.04	16.99913
^{18}O	0.2	17.99916
^{28}Si	92.23	27.97693
^{29}Si	4.67	28.97649
^{30}Si	3.10	29.97376
^{32}S	95.0	31.97207
^{33}S	0.76	32.97146
^{34}S	4.22	33.96786

^{35}Cl	75.77	34.96885
^{37}Cl	24.23	36.96590
^{79}Br	50.69	78.9183
^{81}Br	49.31	80.9163

There are 2 basic types of elementary particles: Hadrons and Leptons

There are 2 types of Hadrons: Baryons and Mesons

Made up of 3 quarks

Made up of a quark and antiquark

As the frequency of an **electromagnetic radiation** increases, its energy increases and its wavelength decreases and its velocity remains constant as long as it doesn't enter a medium with a different refractive index

Ionized gases conduct electric current using positive ions, negative ions and electrons.

Thermal DeBroglie wavelength of an electron:

$$\lambda_D = \sqrt{\frac{h^2}{2\pi m_e k_B T}}$$

where: h is the Planck's constant, m_e is the mass of the electron, k_B is the Boltzmann's constant, and T is the temperature.

$$\boxed{\text{Debye screening wave vector} = \frac{1}{\text{Debye length}}}$$

The Debye length of semiconductors:

$$L_D = \sqrt{\frac{\varepsilon k_B T}{q^2 N_{dop}}}$$

where:

- ε is the dielectric constant,
- k_B is the Boltzmann's constant,
- T is the absolute temperature in Kelvins,
- q is the elementary charge, and
- N_{dop} is the net density of dopants (either donors or acceptors).

The **Bjerrum length** is given by:

$$\lambda_B = \frac{e^2}{4\pi\varepsilon_0\varepsilon_r k_B T}$$

where: e is the elementary charge, ε_r is the relative dielectric constant of the medium and ε_0 is the vacuum permittivity.

Drift velocity= electrical mobility of the particle × magnitude of the applied electric field

$$\text{Fusion energy gain factor} = \frac{P_{fusion}}{P_{heating}}$$

- P_{fusion} = power produced in a nuclear fusion reactor
- $P_{heating}$ = power of external heating required to keep fusion going

The **Hall parameter**, β, in a plasma is the ratio between the electron gyrofrequency, Ω_e, and the electron-heavy particle collision frequency, ν:

$$\beta = \frac{\Omega_e}{\nu} = \frac{eB}{\nu m_e}$$

where:

- e is the elementary charge (approximately 1.6×10^{-19} C)
- B is the magnetic field (in teslas)

- m_e is the electron mass (approximately 9.1×10^{-31} kg)

Magnetic Reynolds number:

$$R_m = \frac{UL}{\eta}$$

where:

- U is a typical velocity scale of the flow
- L is a typical length scale of the flow
- η is the magnetic diffusivity

Péclet number = $\dfrac{\text{advective transport rate}}{\text{diffusive transport rate}}$

Nusselt number = $\dfrac{hL}{k}$

where h is the convective heat transfer coefficient of the flow, L is the characteristic length, k is the thermal conductivity of the fluid.

Magnetic Prandtl number = $\dfrac{\text{momentum diffusivity}}{\text{magnetic diffusivity}}$

The **magnetic pressure** P_B is given in SI units (P in Pa, B in T, μ_0 in H/m) by:

$$P_B = \frac{B^2}{2\mu_0}$$

where: B is the strength of magnetic field and μ_0 is the permeability of free space.

$$\text{Static resistance} = \frac{\text{voltage}}{\text{current}}$$

$$\textbf{Differential resistance} = \frac{\text{small change in voltage}}{\text{small change in current}}$$

$$\text{Static conductance} = \frac{1}{\text{Static resistance}}$$

$$\text{Differential conductance} = \frac{\text{small change in current}}{\text{small change in voltage}}$$

The **acceleration gradient** for a linear plasma wave is:

$$E = c\sqrt{\frac{m_e n_e}{\varepsilon_0}}$$

In this equation, E is the electric field, c is the speed of light in vacuum, m_e is the mass of the electron, n_e is the plasma electron density (in particles per metre cubed), and ε_0 is the permittivity of free space.

Bond distance **d** in **Rydberg matter** is given by:

$$d = 2.9\ n^2 a_0$$

where n is the principal quantum number and a_0 is the Bohr radius.

The **ram pressure** is a function of wind speed and density. The formula is

$$P = m_p\ n\ v^2$$

where m_p is the proton mass, pressure P is in nPa (nanopascals), n is the density in particles/cm^3 and v is the speed in km/s of the solar wind.

For a gas composed of a single atomic species, the **Saha equation** is written:

$$\frac{n_{i+1} n_e}{n_i} = \frac{2}{\lambda^3} \frac{g_{i+1}}{g_i} \exp\left[- \frac{\varepsilon_{i+1} - \varepsilon_i}{k_B T}\right]$$

where: n_{i+1} and n_i are the number of atoms in the $(i + 1)^{th}$ and ith ionization states, respectively; g_{i+1} and g_i describe how energy is partitioned among the $(i + 1)^{th}$ and i^{th} ionization states; ε_{i+1}

and ε_i are the energies of the ionization states; n_e is the number of electrons; and T is the temperature. $\lambda = \sqrt{\frac{h^2}{2\pi m_e k_B T}}$ is the thermal de Broglie wavelength of an electron. The other quantities in the equation are physical constants: m_e is the mass of the electron, k_B is the Boltzmann's constant, and h is Planck's constant.

$$\textbf{Bowen ratio} = \frac{\text{sensible heating}}{\text{latent heating}}$$

Bejan number =

$$\frac{\text{entropy generation contributed by heat transfer}}{\text{entropy generation contributed by heat transfer} + \text{entropy generation contributed by fluid friction}}$$

Antoine equation

$$\log_{10} p = A - \frac{B}{C + T}$$

where: p is the vapor pressure, T is temperature and A, B and C are component-specific constants.

Kopp–Neumann law:

The **Kopp–Neumann law**, named for Kopp and Franz Ernst Neumann, is a common approach for determining the specific heat C (in $J \cdot kg^{-1} \cdot K^{-1}$) of compounds using the following equation:

$$C = \sum_{i=1}^{N}(C_i \cdot f_i)$$

where: N is the total number of compound constituents, and C_i and f_i denote the specific heat and mass fraction of the i^{th} constituent. This law works surprisingly well at room-temperature conditions, but poorly at elevated temperatures.

$$\textbf{Stefan number} = \frac{\text{sensible heat}}{\text{latent heat}}$$

Duhem–Margules equation:

$$\left(\frac{d\ln P_A}{d\ln x_A}\right)_{T,P} = \left(\frac{d\ln P_B}{d\ln x_B}\right)_{T,P}$$

where P_A and P_B are the partial vapor pressures of the two constituents and x_A and x_B are the mole fractions of the liquid.

$$\text{Airway Conductance} = \frac{1}{\text{Airway Resistance}}$$

$$\text{Airway Resistance} = \frac{\text{Atmospheric Pressure} - \text{Alveolar Pressure}}{\text{Volumetric Airflow}}$$

$$\text{Cardiac index} = \frac{\text{Cardiac output}}{\text{Body surface area}} = \frac{\text{Stroke volume} \times \text{Heart rate}}{\text{Body surface area}}$$

$$\text{Stroke volume} = \text{End-systolic volume} - \text{End-diastolic volume}$$

Mean arterial pressure = (cardiac output × systemic vascular resistance) + central venous pressure

In practice, the contribution of **central venous pressure** (which is small) is generally ignored and so:

Mean arterial pressure = cardiac output × systemic vascular resistance

Pulse pressure = systolic pressure − diastolic pressure

$$\textbf{Ejection fraction (\%)} = \frac{\text{stroke volume}}{\text{end diastolic volume}} \times 100$$

$$\textbf{Body mass index} = \frac{\text{body mass}}{(\text{body height})^2}$$

Low-density lipoprotein:

$$\text{LDL} = \text{C} - \text{HDL} - \text{kT}$$

where: HDL is High Density Lipoprotein, C is total cholesterol, T denote the triglycerides, and k is 0.20 if the quantities are measured in mg/dl and 0.45 if in mmol/l.

Widmark formula:

$$\text{Blood Alcohol Content} = \frac{\text{Alcohol consumed in grams}}{\text{Body weight in grams} \times \text{r}} \times 100$$

In this formula, "r" is the gender constant: r = 0.55 for females and 0.68 for males.

Creatinine Clearance:

$$\text{CrCl (male)} = \frac{(140 - \text{age})\ (\text{weight in kg})}{72 \times \text{serum creatinine}}$$

For women, this result is multiplied by the factor 0.85.

The **Doppler frequency shift for active radar** is as follows, where F_D is Doppler frequency, F_T is transmit frequency, v_R is radial velocity, and c is the speed of light:

$$F_D = 2 \times F_T \times \frac{v_R}{c}$$

For Passive radar:

$$F_D = F_T \times \frac{v_R}{c}$$

Output voltage of the transducer:

$$\boxed{V_{out} = \frac{P \times K \times V_{sa}}{V_{si}}}$$

where:

- P is the actual measured pressure.
- K is the nominal transducer scale factor.
- V_{sa} is the actual transducer supply voltage.
- V_{si} is the ideal transducer supply voltage.

$$\boxed{\textbf{Critical damping coefficient} = \frac{\text{actual damping}}{\text{critical damping}}}$$

$$\text{True Positive Rate} = \frac{\text{True Positive}}{\text{True Positive} + \text{False Negative}}$$

$$\text{False Positive Rate} = \frac{\text{False Positive}}{\text{True Negative} + \text{False Positive}}$$

The specific intensity I_ν of radiation is defined by:

$$I_\nu = \frac{dP}{(\cos\theta\ d\sigma)\ d\nu\ d\Omega}$$

where dP is the power received by a detector with projected area ($\cos\theta$ $d\sigma$) in the solid angle $d\Omega$ and in the frequency range ν to $\nu + d\nu$.

I_λ is the brightness per unit wavelength:

$$I_\lambda = \frac{dP}{(\cos\theta\ d\sigma)\ d\lambda\ d\Omega}$$

These two quantities are related by:

$$\frac{I_\lambda}{I_\nu} = \frac{d\nu}{d\lambda} = \frac{c}{\lambda^2}$$

The spectral energy density of radiation is:

$$u_\nu = \frac{1}{c} \int I_\nu\ d\Omega$$

The mean photon energy of blackbody radiation is:

$$E = 2.7\ k_B T$$

The flux density of isotropic radiation is:

$$S_\nu = \pi\, I_\nu$$

The Nyquist approximation for the spectral power generated by a warm resistor in the limit $h\nu \ll k_B T$ is

$$P_\nu = k_B T$$

At any frequency, the exact **Nyquist formula** is

$$P_\nu = \frac{h\nu}{\exp\left(\frac{h\nu}{k_B T}\right) - 1}$$

The CMB temperature at redshift z is

$$\boxed{T = T_0\ (1 + z)}$$

T_0 is the temperature of the CMB as observed in the present day (2.725 K)

The total power emitted by an accelerated charge is given by Larmor's formula:

$$P = \frac{q^2 a^2}{6\pi\varepsilon_0 c^3} \quad \text{which is valid only if } v << c$$

where a is the proper acceleration, q is the charge, and c is the speed of light.

If an antenna delivers P_o watts to the load connected to its output terminals (e.g. the receiver) when irradiated by a uniform field of power density S watts per square meter, the antenna's aperture A_e in square meters is given by: $A_e = \frac{P_o}{S}$

$$\frac{P_N}{B} = k_B T$$

where:

- P_N is the noise power
- B is the total bandwidth over which that noise power is measured
- k_B is the Boltzmann constant (1.381×10^{-23} J/K)
- T is the noise temperature

The minimum mean density of a pulsar with period P is:

$$\rho > \frac{3\pi}{GP^2}$$

- G is the Newtonian constant of gravitation

The spin-down luminosity of a pulsar is:

$$-\ \frac{dE_{rot}}{dt} = \frac{-4\pi^2 I}{P^3} \times \ \frac{dP}{dt}$$

- I is the moment of inertia
- E_{rot} is the rotational kinetic energy

The characteristic age of a pulsar is defined by:

$$\tau = \frac{P}{2\times \frac{dP}{dt}}$$

Bremermann's limit:

$$\frac{c^2}{h} \approx 1.36 \times 10^{50} \text{ bits per second per kilogram}$$

is a limit on the maximum rate of computation that can be achieved in a self-contained system in the material universe.

Bekenstein bound:

$$S \leq \frac{2\pi k_B RE}{\hbar c}$$

where S is the entropy, k_B is Boltzmann's constant, R is the radius of a sphere that can enclose the given system, E is the total mass–energy including any rest masses, $\hbar$ is the reduced Planck constant, and c is the speed of light.

In informational terms, with $S = k_B \times I \times \ln 2$, the bound is given by

$$I \leq \frac{2\pi RE}{\hbar c \ln 2}$$

where I is the information expressed in number of bits contained in the quantum states in the sphere. The ln 2 factor comes from defining the information as the logarithm to the base 2 of the number of quantum states. Using mass–energy equivalence ($E=Mc^2$), the informational limit may be reformulated as

$$I \leq \frac{2\pi cRM}{\hbar \ln 2}$$

Band ratio (TM)	Mineral
5/7	clay, carbonate, silica, mica group
3/1	heamtite goethite and jarosite
5/4	bare rock and soil

Geology:

$$\text{Drainage density} = \frac{\text{total length of channel in a drainage basin}}{\text{total area}}$$

$$\text{Asymmetry factor} = \frac{\text{area of the basin to the right of the trunk stream}}{\text{total area of the drainage basin}} \times 100$$

$$\text{Bifurcation ratio} = \frac{\text{The number of streams of one order}}{\text{The number of streams of the next higher order in a drainage network}}$$

Discharge = width of the channel × depth of the channel × velocity of flow

$$\text{Channel sinuosity} = \frac{\text{the length of the stream channel}}{\text{the straight line distance between the end points of the selected channel reach}}$$

$$\text{Ripple index} = \frac{\text{ripple wavelength}}{\text{ripple height}}$$

$$\text{Symmetry index} = \frac{\text{stoss length}}{\text{lee length}}$$

- Tonnage = Volume of ore-block × Specific gravity
- Metal content = tonnage × grade (or assay value)
- Mineral matter = 1.1 × Ash content
- Weight loss due to Volatile Matter = Total Weight loss – moisture
- % Volatile Matter = $\frac{\text{Weight loss due to volatile matter}}{\text{Weight of sample}} \times 100$
- Fixed carbon = 100 – (% moisture + % Ash content + % volatile matter)
- % moisture = $\frac{\text{Weight loss due to moisture}}{\text{Weight of sample}} \times 100$
- % Ash content = $\frac{\text{Weight of residue}}{\text{Weight of sample}} \times 100$
- Dry mineral matter free volatile matter = $100 -$ Dry mineral matter free Fixed carbon
- % Fixed carbon on dry ash free basis = 100 – (% moisture + % Ash content)
- Analysis on dry ash free basis = $\frac{\text{\% Volatile Matter}}{100-(\text{\% moisture + \% Ash content})} \times 100$
- **Darcy's law:**

$$\boxed{\text{Instantaneous flow rate} = -\frac{\text{permeability}}{\text{dynamic viscosity of the fluid}} \times \text{pressure drop}}$$

- Plasticity index = Liquid limit – Plastic limit
- Consistency index = $\frac{\text{Liquid limit – water content}}{\text{Liquid limit – Plastic limit}}$
- Bulk density of soil = $\frac{\text{dry weight of soil}}{\text{volume of soil}}$

- Particle density of soil = $\frac{\text{dry weight of soil}}{\text{volume of solid}}$

- Mass wetness = $\frac{\text{mass of water}}{\text{mass of soil}}$

- Void ratio = $\frac{\text{volume of voids}}{\text{volume of solids}}$

- Porosity = $\frac{\text{void volume}}{\text{total volume}}$

- Degree of saturation = $\frac{\text{volume of water in a soil}}{\text{volume of voids}} \times 100$

- Uniformity coefficient = $\frac{\text{The size opening that will just pass 60\% of the sand (d60 value)}}{\text{The size opening that will just pass 10\% of the sand sample (d10 value)}}$

- **Coefficient of curvature:**

$C_c = \frac{(\text{Size of particle corresponding to 30\% finer})^2}{\text{Size of the particle corresponding to 60\% finer} \times \text{Size of the particle corresponding to 10\% finer}}$

- Relative density = $\frac{\text{the density of a substance}}{\text{the density of a given reference material}}$

- Total core recovery = $\frac{\text{Sum of length of core pieces}}{\text{Total length of core run}} \times 100$

- Solid core recovery = $\frac{\text{Sum of length of solid , cylindrical, core pieces} > \text{core diameter}}{\text{Total length of core run}} \times 100$

- Rock quality designation = $\frac{\text{Sum of length of core pieces} > \text{100mm}}{\text{Total length of core run}} \times 100$

Rock quality designation	**Rock mass quality**
< 25%	Very poor
25-50%	Poor
51-75%	Fair
76-90%	Good
91-100%	Excellent

- Rock quality designation (RQD) = 115 − 3.5 J_n
- Rock tunneling index $= \frac{\mathrm{RQD}}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{\mathrm{SRF}}$

  where:
  - J_n = Joint set number (1−20)
  - J_r = Joint roughness (1−20)
  - J_a = Joint alteration number
  - J_w = Joint water flow (1−20)
  - SRF = stress reduction factor
- Geological strength index = $9\log[\frac{\mathrm{RQD}}{J_n} \times \frac{J_r}{J_a}] + 44$
- Slake durability index $= \frac{C-D}{A-D} \times 100$

  where:
  - D = dry drum mass
  - A = drum mass with rock before run
  - C = drum mass with rock after run
- Modular ratio = $\frac{\text{elastic modulus of a particular material in a cross-section}}{\text{elastic modulus of the base or the reference material}}$
- **Point load index** (I_s) → The force needed to fracture a sample of rock between conical points: $I_s = \frac{P}{D^2}$, where P is force and D is the distance between the points, both at failure. I_s is related **to uniaxial compressive strength** (approximately equal to $I_s \times 24$)
- **Wyllie time-average equation:**

$$\frac{1}{\text{wave velocity in rock}} = \frac{\text{porosity in rock}}{\text{velocity of the fluid in the pores}} + \frac{(1-\text{porosity in rock})}{\text{velocity of the rock matrix}}$$

$$\sin C = \frac{1}{n}$$

where:

- C is the critical angle.
- n is the refractive index of the medium.

Substance medium	Refractive index	Critical angle
Water	1.33	48.75°
Crown glass	1.52	41.14°
Dense flint glass	1.62	37.31°
Diamond	2.42	24.41°

Science	Technology
Explores new knowledge methodically through observation and experimentation.	The application of scientific knowledge for various purposes.

The wave nature of light was demonstrated convincingly for the first time in 1801 by **Thomas Young** by a wonderfully simple experiment. He let a ray of sunlight into a dark room, placed a dark screen in front of it, pierced with two small pinholes, and beyond this, at some distance, a white screen. He then saw two darkish lines at both sides of a bright line, which gave him sufficient encouragement to repeat the experiment, this time with spirit flame as light source, with a little salt in it to produce the bright yellow sodium light. This time he saw a number of dark lines, regularly spaced; the first clear proof that light added to light can produce darkness. This phenomenon is called interference. Thomas Young had expected it because he believed in the wave theory of light.

– Dennis Gabor

Physical quantities with same dimensional formula:

Physical Quantity	Dimensional Formula
Momentum and impulse	$[M^1L^1T^{-1}]$
Angular momentum and Planck's constant	$[M^1L^2T^{-1}]$
Work, Energy, Moment of a force, Torque and couple	$[M^1L^2T^{-2}]$
Frequency, Angular Frequency, Angular velocity and Velocity gradient	$[M^0L^0T^{-1}]$
Pressure, Stress, Elastic constant and Energy density	$[M^1L^{-1}T^{-2}]$
Force constant (spring), Surface Tension and surface energy	$[M^1L^0T^{-2}]$
Radius of gyration, light year and wavelength	$[M^0L^1T^0]$

The Spectral Lines for Atomic Hydrogen:

Series	n_1	n_2	Spectral Region
Lyman	1	2, 3 …	Ultraviolet
Balmer	2	3, 4 …	Visible
Paschen	3	4, 5 …	Infrared
Brackett	4	5, 6 …	Infrared
Pfund	5	6, 7 …	Infrared

$$\left(\begin{array}{c}\textbf{Formal charge}\\ \text{(F.C.) on an atom}\\ \text{in a Lewis structure}\end{array}\right) = \left(\begin{array}{c}\text{Total number of}\\ \text{valence electrons in}\\ \text{the free atom}\end{array}\right) - \left(\begin{array}{c}\text{Total number of}\\ \text{non bonding}\\ \text{(lone pair)}\\ \text{electrons}\end{array}\right) - \frac{1}{2}\left(\begin{array}{c}\text{Total number of}\\ \text{bonding (shared)}\\ \text{electrons}\end{array}\right)$$

Bonding molecular orbital	Anti Bonding molecular orbital
Molecular orbitals formed by the additive effect of the atomic orbitals	Molecular orbitals formed by the subtractive effect of atomic orbitals
Probability of finding the electrons is more	Probability of finding the electrons is less

$$\Delta G^0 = \Delta H^0 - T\Delta S^0$$

ΔH^0	ΔS^0	ΔG^0	Description
–	+	–	Reaction spontaneous at all temperatures
–	–	– (at low Temperature)	Reaction spontaneous at low temperature
–	–	+ (at high Temperature)	Reaction non-spontaneous at high temperature
+	+	+ (at low Temperature)	Reaction Non-spontaneous at low temperature
+	+	– (at high Temperature)	Reaction spontaneous at high temperature
+	–	+ (at all Temperature)	Reaction non-spontaneous at all temperatures

Temperature Corrected Density **= (Density of Fuel Oil @ 15^{0}C) × [1− {(T−15) × 0.00064}]**

where: T = temperature of oil in bunker tanks in degree Celsius

Metric Tonnes = (Actual Sounder Volume) × (Temperature Corrected Density)

Specific Fuel Oil Consumption (SFOC):

$$\text{SFOC (g/KWh)} = \frac{\text{Mass of fuel consumed per hour}}{\text{Power developed in KW}}$$

Engine distance in nautical mile = (Pitch × revolutions per day)

List of physical quantities:

Base quantity	Description	SI base unit
Length	The one-dimensional extent of an object	metre
Mass	A measure of resistance to acceleration	kilogram
Time	The duration of an event	second
Electric Current	Rate of flow of electrical charge per unit time	ampere
Temperature	Average kinetic energy per degree of freedom of a system	Kelvin
Amount of substance	The quantity proportional to the number of particles in a sample, with the Avogadro constant as the proportionality constant	mole
Luminous intensity	Wavelength-weighted power of emitted light per unit solid angle	candela

Derived quantity	Description	SI derived unit
Young's modulus	Ratio of stress to strain	pascal (Pa = N/m^2)
Work	Transferred energy	joule (J)
Weight	Gravitational force on an object	newton (N = $kg \cdot m/s^2$)

Derived quantity	Description	SI derived unit
Wavevector	Repetency or spatial frequency vector: the number of cycles per unit distance	m^{-1}
Wavenumber	Repetency or spatial frequency: the number of cycles per unit distance	m^{-1}
Wavelength	Perpendicular distance between repeating units of a wave	m
Volumetric flow rate	Rate of change of volume with respect to time	$m^3 \cdot s^{-1}$
Volume	Three dimensional extent of an object	m^3
Velocity	Moved distance per unit time: the first time derivative of position	m/s
Torque	Product of a force and the perpendicular distance of the force from the point about which it is exerted	newton-metre (N·m)
Thermal resistivity	Measure for the ease with which a material resists conduction of heat	K·m/W
Thermal resistance	Measure for the ease with which an object resists conduction of heat	K/W
Thermal conductivity	Measure for the ease with which a material conducts heat	W/(m·K)
Thermal conductance	Measure for the ease with which an object conducts heat	W/K

Derived quantity	Description	SI derived unit
Temperature gradient	steepest rate of temperature change at a particular location	K/m
Surface tension	Energy change per unit change in surface area	N/m or J/m^2
Stress	Force per unit oriented surface area	Pa
Strain	Extension per unit length	unitless
Spin	Quantum-mechanically defined angular momentum of a particle	$kg \cdot m^2 \cdot s^{-1}$
Specific volume	Volume per unit mass (reciprocal of density)	$m^3 \cdot kg^{-1}$
Specific heat capacity	Heat capacity per unit mass	J/(K·kg)
Specific energy	Energy density per unit mass	$J \cdot kg^{-1}$
Solid angle	Ratio of area on a sphere to its radius squared	steradian (sr)
Reluctance	resistance to the flow of magnetic flux	H^{-1}
Refractive index	Factor by which the phase velocity of light is reduced in a medium	unitless
Reaction rate	Rate of a chemical reaction for unit time	mol/($m^3 \cdot s$)
Radiant intensity	Power of emitted electromagnetic radiation per unit solid angle	W/sr
Radiance	Power of emitted electromagnetic radiation	W/($m^2 \cdot sr$)

Derived quantity	Description	SI derived unit
	per unit solid angle per emitting source area	
Pressure	Force per unit area	pascal (Pa = N/m^2)
Power	Rate of transfer of energy per unit time	watt (W)
Pop	Rate of change of crackle per unit time: the sixth time derivative of position	m/s^6
Plane angle	Ratio of circular arc length to radius	radian (rad)
Permittivity	Measure for how the polarization of a material is affected by the application of an external electric field	F/m
Permeability	Measure for how the magnetization of material is affected by the application of an external magnetic field	H/m
Optical power	Measure of the effective curvature of a lens or curved mirror; inverse of focal length	dioptre (dpt = m^{-1})
Momentum	Product of an object's mass and velocity	kg·m/s
Moment of inertia	Inertia of an object with respect to angular acceleration	$kg \cdot m^2$
Molar heat capacity	Heat capacity of a material per unit amount of substance	J/(K·mol)
Molar entropy	Entropy per unit amount of substance	J/(K·mol)
Molar energy	Amount of energy present in a system per	J/mol

Derived quantity	Description	SI derived unit
	unit amount of substance	
Molar concentration	Amount of substance per unit volume	$mol \cdot m^{-3}$
Mean lifetime	Average time for a particle of a substance to decay	s
Mass fraction	Mass of a substance as a fraction of the total mass	kg/kg
Magnetization	Amount of magnetic moment per unit volume	A/m
Magnetic flux density	Measure for the strength of the magnetic field	tesla ($T = Wb/m^2$)
Magnetic flux	Measure of magnetism, taking account of the strength and the extent of a magnetic field	weber (Wb)
Magnetic field strength	Strength of a magnetic field	A/m
Mach number (or mach)	Ratio of flow velocity to the local speed of sound	unitless
Luminous flux (or luminous power)	Perceived power of a light source	lumen ($lm = cd \cdot sr$)
Linear density	Mass per unit length	$kg \cdot m^{-1}$
Jounce (or snap)	Change of jerk per unit time: the fourth time derivative of position	m/s^4
Jerk	Change of acceleration per unit time: the	m/s^3

Derived quantity	Description	SI derived unit
	third time derivative of position	
Irradiance	Electromagnetic radiation power per unit surface area	W/m^2
Intensity	Power per unit cross sectional area	W/m^2
Inductance	Magnetic flux generated per unit current through a circuit	henry (H)
Impulse	Transferred momentum	newton-second ($N{\cdot}s = kg{\cdot}m/s$)
Impedance	Resistance to an alternating current of a given frequency, including effect on phase	ohm (Ω)
Illuminance	Luminous flux per unit surface area	lux ($lx = cd{\cdot}sr/m^2$)
Heat flux density	Heat flow per unit time per unit surface area	W/m^2
Heat capacity	Energy per unit temperature change	J/K
Heat	Thermal energy	joule (J)
Half-life	Time for a quantity to decay to half its initial value	s
Frequency	Number of (periodic) occurrences per unit time	hertz ($Hz = s^{-1}$)
Force	Transfer of momentum per unit time	newton ($N = kg{\cdot}m{\cdot}s^{-2}$)
Entropy	Logarithmic measure of the number of available states of a system	J/K

Derived quantity	Description	SI derived unit
Energy density	Energy per unit volume	$J \cdot m^{-3}$
Energy	Energy	J
Electrical resistivity	Bulk property equivalent of electrical resistance	ohm-metre ($\Omega \cdot m$)
Electrical resistance	Electric potential per unit electric current	ohm ($\Omega = V/A$)
Electrical conductivity	Measure of a material's ability to conduct an electric current	S/m
Electrical conductance	Measure for how easily current flows through a material	siemens ($S = \Omega^{-1}$)
Electric potential	Energy required to move a unit charge through an electric field from a reference point	volt ($V = J/C$)
Electric field strength	Strength of the electric field	V/m
Electric displacement field	Strength of the electric displacement	C/m^2
Electric charge density	Electric charge per unit volume	C/m^3
Electric charge	The force per unit electric field strength	coulomb ($C = A \cdot s$)
Dynamic viscosity	Measure for the resistance of an incompressible fluid to stress	$Pa \cdot s$
Dose equivalent	Received radiation adjusted for the effect on biological tissue	sievert ($Sv = m^2/s^2$)

Derived quantity	**Description**	**SI derived unit**
Current density	Electric current per unit cross-section area	A/m^2
Crackle	Change of jounce per unit time: the fifth time derivative of position	m/s^5
Chemical potential	Energy per unit change in amount of substance	J/mol
Centrifugal force	Inertial force that appears to act on all objects when viewed in a rotating frame of reference	$N\cdot rad = kg\cdot m\cdot rad\cdot s^{-2}$
Catalytic activity concentration	Change in reaction rate due to presence of a catalyst per unit volume of the system	$kat\cdot m^{-3}$
Capacitance	Stored charge per unit electric potential	farad (F = C/V)
Area density	Mass per unit area	$kg\cdot m^{-2}$
Area	Extent of a surface	m^2
Angular velocity	The angle incremented in a plane by a segment connecting an object and a reference point per unit time	rad/s
Angular momentum	Measure of the extent and direction of an object rotates about a reference point	$kg\cdot m^2/s$
Angular acceleration	Change in angular velocity per unit time	rad/s^2
Acceleration	Rate of change of velocity per unit time: the second time derivative of position	m/s^2

Derived quantity	Description	SI derived unit
Absorbed dose rate	Absorbed dose received per unit of time	Gy/s
Absement	Measure of sustained displacement: the first integral with respect to time of displacement	m·s
(Radioactive) Dose	Ionizing radiation energy absorbed by biological tissue per unit mass	gray (Gy = m^2/s^2)
(Radioactive) Activity	Number of particles decaying per unit time	becquerel (Bq = Hz)
(Mass) Density (**or volume density**)	Mass per unit volume	kg/m^3

The Earth spins at 1,000 mph but it travels through space at an incredible 67,000 mph.

Every year over one million earthquakes shake the Earth.

The dinosaurs (a diverse group of reptiles of the clade Dinosauria) became extinct before the Rockies or the Alps were formed.

The first synthetic human chromosome was constructed by US scientists in 1997.

There are 60,000 miles of blood vessels in the human body.

If the Sun were the size of a beach ball then Jupiter would be the size of a golf ball and the Earth would be as small as a pea.

List of Nobel laureates in Physics

1901	**Wilhelm Röntgen**	"in recognition of the extraordinary services he has rendered by the discovery of the remarkable rays subsequently named after him"
1902	**Hendrik Lorentz**	"in recognition of the extraordinary service they rendered by their researches into the influence of magnetism upon radiation phenomena"
	Pieter Zeeman	
1903	**Antoine Henri Becquerel**	"for his discovery of spontaneous radioactivity"
	Pierre Curie	"for their joint researches on the radiation phenomena discovered by Professor Henri Becquerel"
	Marie Skłodowska-Curie	
1904	**Lord Rayleigh**	"for his investigations of the densities of the most important gases and for his discovery of argon in connection with these studies"
1905	**Philipp Eduard Anton von Lenard**	"for his work on cathode rays"
1906	**Joseph John Thomson**	"for his theoretical and experimental investigations on the conduction of electricity by gases"
1907	**Albert Abraham Michelson**	"for his optical precision instruments and the spectroscopic and metrological investigations

		carried out with their aid"
1908	**Gabriel Lippmann**	"for his method of reproducing colours photographically based on the phenomenon of interference"
1909	**Guglielmo Marconi**	"for their contributions to the development of wireless telegraphy"
	Karl Ferdinand Braun	
1910	**Johannes Diderik van der Waals**	"for his work on the equation of state for gases and liquids"
1911	**Wilhelm Wien**	"for his discoveries regarding the laws governing the radiation of heat"
1912	**Nils Gustaf Dalén**	"for his invention of automatic valves designed to be used in combination with gas accumulators in lighthouses and buoys"
1913	**Heike Kamerlingh-Onnes**	"for his investigations on the properties of matter at low temperatures which led, inter alia, to the production of liquid helium"
1914	**Max von Laue**	"For his discovery of the diffraction of X-rays by crystals", an important step in the development of X-ray spectroscopy.
1915	**William Henry Bragg**	"'For their services in the analysis of crystal structure by means of X-rays', an important step in the development of X-ray crystallography"
	William Lawrence Bragg	

1916	**Not awarded due to World War I**	
1917	**Charles Glover Barkla**	"'For his discovery of the characteristic Röntgen radiation of the elements', another important step in the development of X-ray spectroscopy"
1918	**Max Planck**	"for the services he rendered to the advancement of physics by his discovery of energy quanta"
1919	**Johannes Stark**	"for his discovery of the Doppler effect in canal rays and the splitting of spectral lines in electric fields"
1920	**Charles Édouard Guillaume**	"for the service he has rendered to precision measurements in physics by his discovery of anomalies in nickel-steel alloys"
1921	**Albert Einstein**	"for his services to theoretical physics, and especially for his discovery of the law of the photoelectric effect"
1922	**Niels Bohr**	"for his services in the investigation of the structure of atoms and of the radiation emanating from them"
1923	**Robert Andrews Millikan**	"for his work on the elementary charge of electricity and on the photoelectric effect"
1924	**Manne Siegbahn**	"for his discoveries and research in the field of X-ray spectroscopy"
1925	**James Franck**	"for their discovery of the laws governing the impact of

	Gustav Hertz	an electron upon an atom"
1926	**Jean Baptiste Perrin**	"for his work on the discontinuous structure of matter, and especially for his discovery of sedimentation equilibrium"
1927	**Arthur Holly Compton**	"for his discovery of the effect named after him"
	Charles Thomson Rees Wilson	"for his method of making the paths of electrically charged particles visible by condensation of vapour"
1928	**Owen Willans Richardson**	"for his work on the thermionic phenomenon and especially for the discovery of the law named after him"
1929	**Louis Victor Pierre Raymond, 7th Duc de Broglie**	"for his discovery of the wave nature of electrons"
1930	**Chandrasekhara Venkata Raman**	"for his work on the scattering of light and for the discovery of the effect named after him"
1931	**Not awarded**	
1932	**Werner Heisenberg**	"for the creation of quantum mechanics, the application of which has, inter alia, led to the discovery of the allotropic forms of hydrogen"
1933	**Erwin Schrödinger**	"for the discovery of new productive forms of atomic theory"
	Paul Dirac	

1934	**Not awarded**	
1935	**James Chadwick**	"for the discovery of the neutron"
1936	**Victor Francis Hess**	"for his discovery of cosmic radiation"
	Carl David Anderson	"for his discovery of the positron"
1937	**Clinton Joseph Davisson**	"for their experimental discovery of the diffraction of electrons by crystals"
	George Paget Thomson	
1938	**Enrico Fermi**	"for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons"
1939	**Ernest Lawrence**	"for the invention and development of the cyclotron and for results obtained with it, especially with regard to artificial radioactive elements"
1940	**Not awarded due to World War II**	
1941		
1942		
1943	**Otto Stern**	"for his contribution to the development of the molecular ray method and his discovery of the magnetic moment of

		the proton"
1944	**Isidor Isaac Rabi**	"for his resonance method for recording the magnetic properties of atomic nuclei"
1945	**Wolfgang Pauli**	"for the discovery of the Exclusion Principle, also called the Pauli principle"
1946	**Percy Williams Bridgman**	"for the invention of an apparatus to produce extremely high pressures, and for the discoveries he made there within the field of high pressure physics"
1947	**Edward Victor Appleton**	"for his investigations of the physics of the upper atmosphere especially for the discovery of the so-called Appleton layer"
1948	**Patrick Maynard Stuart Blackett**	"for his development of the Wilson cloud chamber method, and his discoveries therewith in the fields of nuclear physics and cosmic radiation"
1949	**Hideki Yukawa**	"for his prediction of the existence of mesons on the basis of theoretical work on nuclear forces"
1950	**Cecil Frank Powell**	"for his development of the photographic method of studying nuclear processes and his discoveries regarding mesons made with this method"
1951	**John Douglas Cockcroft**	"for their pioneer work on the transmutation of atomic nuclei by artificially accelerated atomic particles"
	Ernest Thomas Sinton	

	Walton	
1952	**Felix Bloch**	"for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith"
	Edward Mills Purcell	
1953	**Frits Zernike**	"for his demonstration of the phase contrast method, especially for his invention of the phase contrast microscope"
1954	**Max Born**	"for his fundamental research in quantum mechanics, especially for his statistical interpretation of the wavefunction"
	Walther Bothe	"for the coincidence method and his discoveries made therewith"
1955	**Willis Eugene Lamb**	"for his discoveries concerning the fine structure of the hydrogen spectrum"
	Polykarp Kusch	"for his precision determination of the magnetic moment of the electron"
1956	**John Bardeen**	"for their researches on semiconductors and their discovery of the transistor effect"
	Walter Houser Brattain	
	William Bradford Shockley	

1957	**Tsung-Dao Lee**	"for their penetrating investigation of the so-called parity laws which has led to important discoveries regarding the elementary particles"
	Chen-Ning Yang	
1958	**Pavel Alekseyevich Cherenkov**	"for the discovery and the interpretation of the Cherenkov effect"
	Ilya Frank	
	Igor Yevgenyevich Tamm	
1959	**Emilio Gino Segrè**	"for their discovery of the antiproton"
	Owen Chamberlain	
1960	**Donald Arthur Glaser**	"for the invention of the bubble chamber"
1961	**Robert Hofstadter**	"for his pioneering studies of electron scattering in atomic nuclei and for his thereby achieved discoveries concerning the structure of the nucleons"
	Rudolf Ludwig Mössbauer	"for his researches concerning the resonance absorption of gamma radiation and his discovery in this connection of the effect which bears his name"
1962	**Lev Davidovich Landau**	"for his pioneering theories for condensed matter, especially liquid helium"
1963	**Eugene Paul Wigner**	"for his contributions to the theory of the atomic

		nucleus and the elementary particles, particularly through the discovery and application of fundamental symmetry principles"
	Maria Goeppert-Mayer	"for their discoveries concerning nuclear shell structure"
	J. Hans D. Jensen	
1964	**Nicolay Gennadiyevich Basov**	"for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser–laser principle"
	Alexander Prokhorov	
	Charles Hard Townes	
1965	**Richard Phillips Feynman**	"for their fundamental work in quantum electrodynamics (QED), with deep-ploughing consequences for the physics of elementary particles"
	Julian Schwinger	
	Shin'ichirō Tomonaga	
1966	**Alfred Kastler**	"for the discovery and development of optical methods for studying Hertzian resonances in atoms"
1967	**Hans Albrecht Bethe**	"for his contributions to the theory of nuclear reactions, especially his discoveries concerning the energy production in stars"
1968	**Luis Walter Alvarez**	"for his decisive contributions to elementary particle physics, in particular the discovery of a large number

		of resonance states, made possible through his development of the technique of using hydrogen bubble chamber and data analysis"
1969	**Murray Gell-Mann**	"for his contributions and discoveries concerning the classification of elementary particles and their interactions"
1970	**Hannes Olof Gösta Alfvén**	"for fundamental work and discoveries in magneto-hydrodynamics with fruitful applications in different parts of plasma physics"
	Louis Néel	"for fundamental work and discoveries concerning antiferromagnetism and ferrimagnetism whic h have led to important applications in solid state physics"
1971	**Dennis Gabor**	"for his invention and development of the holographic method"
1972	**John Bardeen**	"for their jointly developed theory of superconductivity, usually called the BCS-theory"
	Leon Neil Cooper	
	John Robert Schrieffer	
1973	**Leo Esaki**	"for their experimental discoveries regarding tunneling phenomena in semiconductors and superconductors, respectively"
	Ivar Giaever	
	Brian David Josephson	"for his theoretical predictions of the properties of

		a supercurrent through a tunnel barrier, in particular those phenomena which are generally known as the Josephson effect"
1974	**Martin Ryle**	"for their pioneering research in radio astrophysics: Ryle for his observations and inventions, in particular of the aperture synthesis technique, and Hewish for his decisive role in the discovery of pulsars"
	Antony Hewish	
1975	**Aage Bohr**	"for the discovery of the connection between collective motion and particle motion in atomic nuclei and the development of the theory of the structure of the atomic nucleus based on this connection"
	Ben Roy Mottelson	
	Leo James Rainwater	
1976	**Samuel Chao Chung Ting**	"for their pioneering work in the discovery of a heavy elementary particle of a new kind"
	Burton Richter	
1977	**Philip Warren Anderson**	"for their fundamental theoretical investigations of the electronic structure of magnetic and disordered systems"
	Nevill Francis Mott	
	John Hasbrouck Van Vleck	
1978	**Pyotr Leonidovich Kapitsa**	"for his basic inventions and discoveries in the area of low-temperature physics"

	Arno Allan Penzias	"for their discovery of cosmic microwave background radiation"
	Robert Woodrow Wilson	
1979	**Sheldon Lee Glashow**	"for their contributions to the theory of the unified weak and electromagnetic interaction between elementary particles, including, inter alia, the prediction of the weak neutral current"
	Abdus Salam	
	Steven Weinberg	
1980	**James Watson Cronin**	"for the discovery of violations of fundamental symmetry principles in the decay of neutral K-mesons"
	Val Logsdon Fitch	
1981	**Nicolaas Bloembergen**	"for their contribution to the development of laser spectroscopy"
	Arthur Leonard Schawlow	
	Kai Manne Börje Siegbahn	"for his contribution to the development of high-resolution electron spectroscopy"
1982	**Kenneth G. Wilson**	"for his theory for critical phenomena in connection with phase transitions"
1983	**Subrahmanyan Chandrasekhar**	"for his theoretical studies of the physical processes of importance to the structure and evolution of the stars"

	William Alfred Fowler	"for his theoretical and experimental studies of the nuclear reactions of importance in the formation of the chemical elements in the universe"
1984	**Carlo Rubbia**	"for their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction"
	Simon van der Meer	
1985	**Klaus von Klitzing**	"for the discovery of the quantized Hall effect"
1986	**Ernst Ruska**	"for his fundamental work in electron optics, and for the design of the first electron microscope"
	Gerd Binnig	"for their design of the scanning tunneling microscope"
	Heinrich Rohrer	
1987	**Johannes Georg Bednorz**	"for their important break-through in the discovery of superconductivity in ceramic materials"
	Karl Alexander Müller	
1988	**Leon Max Lederman**	"for the neutrino beam method and the demonstration of the doublet structure of the leptons through the discovery of the muon neutrino"
	Melvin Schwartz	
	Jack Steinberger	
1989	**Norman Foster Ramsey**	"for the invention of the separated oscillatory fields method and its use in the hydrogen maser and

		other atomic clocks"
	Hans Georg Dehmelt	"for the development of the ion trap technique"
	Wolfgang Paul	
1990	**Jerome I. Friedman**	"for their pioneering investigations concerning deep inelastic scattering of electrons on protons and bound neutrons, which have been of essential importance for the development of the quark model in particle physics"
	Henry Way Kendall	
	Richard E. Taylor	
1991	**Pierre-Gilles de Gennes**	"for discovering that methods developed for studying order phenomena in simple systems can be generalized to more complex forms of matter, in particular to liquid crystals and polymers"
1992	**Georges Charpak**	"for his invention and development of particle detectors, in particular the multiwire proportional chamber"
1993	**Russell Alan Hulse**	"for the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation"
	Joseph Hooton Taylor Jr.	
1994	**Bertram Brockhouse**	"for the development of neutron spectroscopy" and "for pioneering contributions to the development of neutron scattering techniques for studies of condensed matter"
	Clifford Glenwood	"for the development of the neutron diffraction technique" and "for pioneering contributions

	Shull	to the development of neutron scattering techniques for studies of condensed matter"
1995	**Martin Lewis Perl**	"for the discovery of the tau lepton" and "for pioneering experimental contributions to lepton physics"
	Frederick Reines	"for the detection of the neutrino" and "for pioneering experimental contributions to lepton physics"
1996	**David Morris Lee**	"for their discovery of superfluidity in helium-3"
	Douglas D. Osheroff	
	Robert Coleman Richardson	
1997	**Steven Chu**	"for development of methods to cool and trap atoms with laser light."
	Claude Cohen-Tannoudji	
	William Daniel Phillips	
1998	**Robert B. Laughlin**	"for their discovery of a new form of quantum fluid with fractionally charged excitations"
	Horst Ludwig Störmer	
	Daniel Chee Tsui	
1999	**Gerard 't Hooft**	"for elucidating the quantum structure of electroweak

	Martinus J. G. Veltman	interactions in physics"
2000	**Zhores Ivanovich Alferov**	"for developing semiconductor heterostructures used in high-speed- and optoelectronics"
	Herbert Kroemer	
	Jack St. Clair Kilby	"for his part in the invention of the integrated circuit"
2001	**Eric Allin Cornell**	"for the achievement of Bose–Einstein condensation in dilute gases of alkali atoms, and for early fundamental studies of the properties of the condensates"
	Carl Edwin Wieman	
	Wolfgang Ketterle	
2002	**Raymond Davis Jr.**	"for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"
	Masatoshi Koshiba	
	Riccardo Giacconi	"for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources"
2003	**Alexei Alexeyevich Abrikosov**	"for pioneering contributions to the theory of superconductors and superfluids"
	Vitaly Lazarevich Ginzburg	
	Anthony James	

	Leggett	
2004	**David J. Gross**	"for the discovery of asymptotic freedom in the theory of the strong interaction"
	Hugh David Politzer	
	Frank Wilczek	
2005	**Roy J. Glauber**	"for his contribution to the quantum theory of optical coherence"
	John L. Hall	"for their contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique"
	Theodor W. Hänsch	
2006	**John C. Mather**	"for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation"
	George F. Smoot	
2007	**Albert Fert**	"for the discovery of giant magnetoresistance"
	Peter Grünberg	
2008	**Makoto Kobayashi**	"for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature"
	Toshihide Maskawa	
	Yoichiro Nambu	"for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics"

2009	**Charles K. Kao**	"for groundbreaking achievements concerning the transmission of light in fibers for optical communication"
	Willard S. Boyle	"for the invention of an imaging semiconductor circuit – the CCD sensor"
	George E. Smith	
2010	**Andre Geim**	"for groundbreaking experiments regarding the two-dimensional material graphene"
	Konstantin Novoselov	
2011	**Saul Perlmutter**	"for the discovery of the accelerating expansion of the Universe through observations of distant supernovae"
	Brian P. Schmidt	
	Adam G. Riess	
2012	**Serge Haroche**	"for ground-breaking experimental methods that enable measuring and manipulation of individual quantum systems."
	David J. Wineland	
2013	**François Englert**	"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"
	Peter Higgs	

2014	**Isamu Akasaki**	"for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources"
	Hiroshi Amano	
	Shuji Nakamura	
2015	**Takaaki Kajita**	"for the discovery of neutrino oscillations, which shows that neutrinos have mass"
	Arthur B. McDonald	
2016	**David J. Thouless**	"for theoretical discoveries of topological phase transitions and topological phases of matter"
	F. Duncan M. Haldane	
	John M. Kosterlitz	
2017	**Rainer Weiss**	"for decisive contributions to the LIGO detector and the observation of gravitational waves"
	Kip Thorne	
	Barry Barish	
2018	**Arthur Ashkin**	"for groundbreaking inventions in the field of laser physics", in particular "for the optical tweezers and their application to biological systems"
	Gérard Mourou	"for groundbreaking inventions in the field of laser physics", in particular "for their method of generating high-intensity, ultra-short optical pulses"
	Donna Strickland	

2019	**James Peebles**	"for theoretical discoveries in physical cosmology"
	Michel Mayor	"for the discovery of an exoplanet orbiting a solar-type star"
	Didier Queloz	
2020	**Roger Penrose**	"for the discovery that black hole formation is a robust prediction of the general theory of relativity"
	Reinhard Genzel	"for the discovery of a supermassive compact object at the centre of our galaxy"
	Andrea Ghez	

Each rubber molecule is made of 65,000 individual atoms.

Around a million, billion neutrinos from the Sun will pass through our body every day.

Quasars are the most distant objects in the Universe which emit more energy than 100 giant galaxies.

List of Nobel laureates in Chemistry

1901	**Jacobus Henricus van 't Hoff**	"[for his] discovery of the laws of chemical dynamics and osmotic pressure in solutions"
1902	**Hermann Emil Fischer**	"[for] his work on sugar and purine syntheses"
1903	**Svante August Arrhenius**	"[for] his electrolytic theory of dissociation"
1904	**Sir William Ramsay**	"[for his] discovery of the inert gaseous elements in air, and his determination of their place in the periodic system"
1905	**Adolf von Baeyer**	"[for] the advancement of organic chemistry and the chemical industry, through his work on organic dyes and hydroaromatic compounds"
1906	**Henri Moissan**	"[for his] investigation and isolation of the element fluorine, and for [the] electric furnace called after him"
1907	**Eduard Buchner**	"for his biochemical researches and his discovery of cell-free fermentation"
1908	**Ernest Rutherford**	"for his investigations into the disintegration of the elements, and the chemistry of radioactive substances"
1909	**Wilhelm Ostwald**	"[for] his work on catalysis and for his investigations into the fundamental principles

		governing chemical equilibria and rates of reaction"
1910	**Otto Wallach**	"[for] his services to organic chemistry and the chemical industry by his pioneer work in the field of alicyclic compounds"
1911	**Maria Skłodowska-Curie**	"[for] the discovery of the elements radium and polonium, by the isolation of radium and the study of the nature and compounds of this remarkable element"
1912	**Victor Grignard**	"for the discovery of the [...] Grignard reagent"
	Paul Sabatier	"for his method of hydrogenating organic compounds in the presence of finely disintegrated metals"
1913	**Alfred Werner**	"[for] his work on the linkage of atoms in molecules [...] especially in inorganic chemistry"
1914	**Theodore William Richards**	"[for] his accurate determinations of the atomic weight of a large number of chemical elements"
1915	**Richard Martin Willstätter**	"for his researches on plant pigments, especially chlorophyll"
1916	**Not awarded**	
1917		

1918	**Fritz Haber**	"for the synthesis of ammonia from its elements"
1919	**Not awarded**	
1920	**Walther Hermann Nernst**	"[for] his work in thermochemistry"
1921	**Frederick Soddy**	"for his contributions to our knowledge of the chemistry of radioactive substances, and his investigations into the origin and nature of isotopes"
1922	**Francis William Aston**	"for his discovery, by means of his mass spectrograph, of isotopes, in a large number of non-radioactive elements, and for his enunciation of the whole-number rule"
1923	**Fritz Pregl**	"for his invention of the method of micro-analysis of organic substances"
1924	**Not awarded**	
1925	**Richard Adolf Zsigmondy**	"for his demonstration of the heterogeneous nature of colloid solutions and for the methods he used"
1926	**The (Theodor) Svedberg**	"for his work on disperse systems"
1927	**Heinrich Otto Wieland**	"for his investigations of the constitution of the bile acids and related substances"

1928	**Adolf Otto Reinhold Windaus**	"[for] his research into the constitution of the sterols and their connection with the vitamins"
1929	**Arthur Harden**	"for their investigations on the fermentation of sugar and fermentative enzymes"
	Hans Karl August Simon von Euler-Chelpin	
1930	**Hans Fischer**	"for his researches into the constitution of haemin and chlorophyll and especially for his synthesis of haemin"
1931	**Carl Bosch**	"[for] their contributions to the invention and development of chemical high pressure methods"
	Friedrich Bergius	
1932	**Irving Langmuir**	"for his discoveries and investigations in surface chemistry"
1933	**Not awarded**	
1934	**Harold Clayton Urey**	"for his discovery of heavy hydrogen"
1935	**Frédéric Joliot**	"[for] their synthesis of new radioactive elements"
	Irène Joliot-Curie	
1936	**Peter Debye**	"[for his work on] molecular structure through his investigations on dipole moments and

		the diffraction of X-rays and electrons in gases"
1937	**Walter Norman Haworth**	"for his investigations on carbohydrates and vitamin C"
	Paul Karrer	"for his investigations on carotenoids, flavins and vitamins A and B_2"
1938	**Richard Kuhn**	"for his work on carotenoids and vitamins"
1939	**Adolf Friedrich Johann Butenandt**	"for his work on sex hormones"
	Leopold Ruzicka	"for his work on polymethylenes and higher terpenes"
1940	**Not awarded**	
1941		
1942		
1943	**George de Hevesy**	"for his work on the use of isotopes as tracers in the study of chemical processes"
1944	**Otto Hahn**	"for his discovery of the fission of heavy nuclei"
1945	**Artturi Ilmari Virtanen**	"for his research and inventions in agricultural and nutrition chemistry, especially for his fodder

		preservation method"
1946	**James Batcheller Sumner**	"for his discovery that enzymes can be crystallized"
	John Howard Northrop	"for their preparation of enzymes and virus proteins in a pure form"
	Wendell Meredith Stanley	
1947	**Sir Robert Robinson**	"for his investigations on plant products of biological importance, especially the alkaloids"
1948	**Arne Wilhelm Kaurin Tiselius**	"for his research on electrophoresis and adsorption analysis, especially for his discoveries concerning the complex nature of the serum proteins"
1949	**William Francis Giauque**	"for his contributions in the field of chemical thermodynamics, particularly concerning the behaviour of substances at extremely low temperatures"
1950	**Otto Paul Hermann Diels**	"for their discovery and development of the diene synthesis"
	Kurt Alder	
1951	**Edwin Mattison McMillan**	"for their discoveries in the chemistry of transuranium elements"

	Glenn Theodore Seaborg	
1952	**Archer John Porter Martin**	"for their invention of partition chromatography"
	Richard Laurence Millington Synge	
1953	**Hermann Staudinger**	"for his discoveries in the field of macromolecular chemistry"
1954	**Linus Pauling**	"for his research into the nature of the chemical bond and its application to the elucidation of the structure of complex substances"
1955	**Vincent du Vigneaud**	"for his work on biochemically important sulphur compounds, especially for the first synthesis of a polypeptide hormone"
1956	**Sir Cyril Norman Hinshelwood**	"for their researches into the mechanism of chemical reactions"
	Nikolay Nikolaevich Semenov	
1957	**Lord (Alexander R.) Todd**	"for his work on nucleotides and nucleotide co-enzymes"
1958	**Frederick Sanger**	"for his work on the structure of proteins,

		especially that of insulin"
1959	**Jaroslav Heyrovský**	"for his discovery and development of the polarographic methods of analysis"
1960	**Willard Frank Libby**	"for his method to use carbon-14 for age determination in archaeology, geology, geophysics, and other branches of science"
1961	**Melvin Calvin**	"for his research on the carbon dioxide assimilation in plants"
1962	**Max Ferdinand Perutz**	"for their studies of the structures of globular proteins"
	John Cowdery Kendrew	
1963	**Karl Ziegler**	"for their discoveries in the field of the chemistry and technology of high polymers"
	Giulio Natta	
1964	**Dorothy Crowfoot Hodgkin**	"for her determinations by X-ray techniques of the structures of important biochemical substances"
1965	**Robert Burns Woodward**	"for his outstanding achievements in the art of organic synthesis"
1966	**Robert S. Mulliken**	"for his fundamental work concerning chemical bonds and the electronic structure of molecules by the molecular orbital method"

1967	**Manfred Eigen**	"for their studies of extremely fast chemical reactions, effected by disturbing the equilibrium by means of very short pulses of energy"
	Ronald George Wreyford Norrish	
	George Porter	
1968	**Lars Onsager**	"for the discovery of the reciprocal relations bearing his name, which are fundamental for the thermodynamics of irreversible processes"
1969	**Derek H. R. Barton**	"for their contributions to the development of the concept of conformation and its application in chemistry"
	Odd Hassel	
1970	**Luis F. Leloir**	"for his discovery of sugar nucleotides and their role in the biosynthesis of carbohydrates"
1971	**Gerhard Herzberg**	"for his contributions to the knowledge of electronic structure and geometry of molecules, particularly free radicals"
1972	**Christian B. Anfinsen**	"for his work on ribonuclease, especially concerning the connection between the amino acid sequence and the biologically active conformation"
	Stanford Moore	"for their contribution to the understanding of the

	William H. Stein	connection between chemical structure and catalytic activity of the active centre of the ribonuclease molecule"
1973	**Ernst Otto Fischer**	"for their pioneering work, performed independently, on the chemistry of the organometallic, so called sandwich compounds"
	Geoffrey Wilkinson	
1974	**Paul J. Flory**	"for his fundamental work, both theoretical and experimental, in the physical chemistry of macromolecules"
1975	**John Warcup Cornforth**	"for his work on the stereochemistry of enzyme-catalyzed reactions"
	Vladimir Prelog	"for his research into the stereochemistry of organic molecules and reactions"
1976	**William N. Lipscomb**	"for his studies on the structure of boranes illuminating problems of chemical bonding"
1977	**Ilya Prigogine**	"for his contributions to non-equilibrium thermodynamics, particularly the theory of dissipative structures"
1978	**Peter D. Mitchell**	"for his contribution to the understanding of biological energy transfer through the formulation of the chemiosmotic theory"

1979	**Herbert C. Brown**	"for their development of the use of boron- and phosphorus-containing compounds, respectively, into important reagents in organic synthesis"
	Georg Wittig	
1980	**Paul Berg**	"for his fundamental studies of the biochemistry of nucleic acids, with particular regard to recombinant-DNA"
	Walter Gilbert	"for their contributions concerning the determination of base sequences in nucleic acids"
	Frederick Sanger	
1981	**Kenichi Fukui**	"for their theories, developed independently, concerning the course of chemical reactions"
	Roald Hoffmann	
1982	**Aaron Klug**	"for his development of crystallographic electron microscopy and his structural elucidation of biologically important nucleic acid-protein complexes"
1983	**Henry Taube**	"for his work on the mechanisms of electron transfer reactions, especially in metal complexes"
1984	**Robert Bruce Merrifield**	"for his development of methodology for chemical synthesis on a solid matrix"
1985	**Herbert A. Hauptman**	"for their outstanding achievements in

	Jerome Karle	developing direct methods for the determination of crystal structures"
1986	**Dudley R. Herschbach**	"for their contributions concerning the dynamics of chemical elementary processes"
	Yuan T. Lee	
	John C. Polanyi	
1987	**Donald J. Cram**	"for their development and use of molecules with structure-specific interactions of high selectivity"
	Jean-Marie Lehn	
	Charles J. Pedersen	
1988	**Johann Deisenhofer**	"for their determination of the three-dimensional structure of a photosynthetic reaction centre"
	Robert Huber	
	Hartmut Michel	
1989	**Sidney Altman**	"for their discovery of catalytic properties of RNA"
	Thomas Cech	
1990	**Elias James Corey**	"for his development of the theory and methodology of organic synthesis"
1991	**Richard R. Ernst**	"for his contributions to the development of the

		methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy"
1992	**Rudolph A. Marcus**	"for his contributions to the theory of electron transfer reactions in chemical systems"
1993	**Kary B. Mullis**	"for contributions to the developments of methods within DNA-based chemistry [...] for his invention of the polymerase chain reaction (PCR) method"
	Michael Smith	"for contributions to the developments of methods within DNA-based chemistry [...] for his fundamental contributions to the establishment of oligonucleotide-based, site-directed mutagenesis and its development for protein studies"
1994	**George A. Olah**	"for his contribution to carbocation chemistry"
1995	**Paul J. Crutzen**	"for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone"
	Mario J. Molina	
	F. Sherwood Rowland	
1996	**Robert F. Curl Jr.**	"for their discovery of fullerenes"
	Sir Harold W. Kroto	
	Richard E. Smalley	

1997	**Paul D. Boyer**	"for their elucidation of the enzymatic mechanism underlying the synthesis of adenosine triphosphate (ATP)"
	John E. Walker	
	Jens C. Skou	"for the first discovery of an ion-transporting enzyme, Na^+, K^+ -ATPase"
1998	**Walter Kohn**	"for his development of the density-functional theory"
	John A. Pople	"for his development of computational methods in quantum chemistry"
1999	**Ahmed Zewail**	"for his studies of the transition states of chemical reactions using femtosecond spectroscopy"
2000	**Alan J. Heeger**	"for their discovery and development of conductive polymers"
	Alan G. MacDiarmid	
	Hideki Shirakawa	
2001	**William S. Knowles**	"for their work on chirally catalysed hydrogenation reactions"
	Ryōji Noyori	
	K. Barry Sharpless	"for his work on chirally catalysed oxidation reactions"

2002	**John B. Fenn**	"for the development of methods for identification and structure analyses of biological macromolecules [...] for their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules"
	Koichi Tanaka	
	Kurt Wüthrich	"for the development of methods for identification and structure analyses of biological macromolecules [...] for his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution"
2003	**Peter Agre**	"for discoveries concerning channels in cell membranes [...] for the discovery of water channels"
	Roderick MacKinnon	"for discoveries concerning channels in cell membranes [...] for structural and mechanistic studies of ion channels"
2004	**Aaron Ciechanover**	"for the discovery of ubiquitin-mediated protein degradation"
	Avram Hershko	
	Irwin Rose	
2005	**Yves Chauvin**	"for the development of the metathesis method in

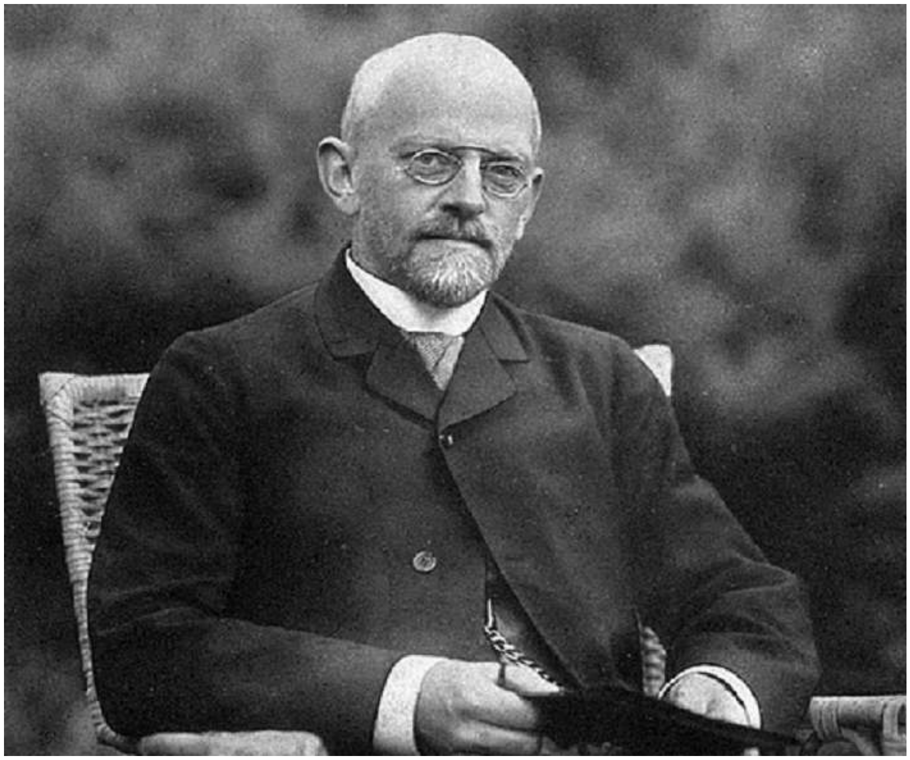
	Robert H. Grubbs	organic synthesis"
	Richard R. Schrock	
2006	**Roger D. Kornberg**	"for his studies of the molecular basis of eukaryotic transcription"
2007	**Gerhard Ertl**	"for his studies of chemical processes on solid surfaces"
2008	**Osamu Shimomura**	"for the discovery and development of the green fluorescent protein, GFP"
	Martin Chalfie	
	Roger Y. Tsien	
2009	**Venkatraman Ramakrishnan**	"for studies of the structure and function of the ribosome"
	Thomas A. Steitz	
	Ada E. Yonath	
2010	**Richard F. Heck**	"for palladium-catalyzed cross couplings in organic synthesis"
	Ei-ichi Negishi	
	Akira Suzuki	

2011	**Dan Shechtman**	"for the discovery of quasicrystals"
2012	**Robert Lefkowitz**	"for studies of G-protein-coupled receptors"
	Brian Kobilka	
2013	**Martin Karplus**	"for the development of multiscale models for complex chemical systems"
	Michael Levitt	
	Arieh Warshel	
2014	**Eric Betzig**	"for the development of super-resolved fluorescence microscopy"
	Stefan W. Hell	
	William E. Moerner	
2015	**Tomas Lindahl**	"for mechanistic studies of DNA repair"
	Paul L. Modrich	
	Aziz Sancar	
2016	**Jean-Pierre Sauvage**	"for the design and synthesis of molecular machines"
	Fraser Stoddart	

	Ben Feringa	
2017	**Jacques Dubochet**	"for developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution"
	Joachim Frank	
	Richard Henderson	
2018	**Frances Arnold**	"for the directed evolution of enzymes"
	George Smith	"for the phage display of peptides and antibodies"
	Sir Gregory Winter	
2019	**John B. Goodenough**	"for the development of lithium ion batteries"
	M. Stanley Whittingham	
	Akira Yoshino	
2020	**Emmanuelle Charpentier**	"for the development of a method for genome editing"
	Jennifer Doudna	

Light would take 0.13 seconds to travel around the Earth.

To escape the **Earth's gravity** a rocket need to travel at 7 miles a second.



No one shall expel us from the paradise which Cantor has created for us.

{Expressing the importance of Georg Cantor's set theory in the development of mathematics.}

— David Hilbert

The largest dinosaur ever discovered was Seismosaurus which was over 100 feet long and weighed up to 80 tones.

The risk of being struck by a falling meteorite for a human is one occurrence every 9,300 years.

List of Nobel laureates in Physiology or Medicine

1901	**Emil Adolf von Behring**	"for his work on serum therapy, especially its application against diphtheria, by which he has opened a new road in the domain of medical science and thereby placed in the hands of the physician a victorious weapon against illness and deaths"
1902	**Sir Ronald Ross**	"for his work on malaria, by which he has shown how it enters the organism and thereby has laid the foundation for successful research on this disease and methods of combating it"
1903	**Niels Ryberg Finsen**	"[for] his contribution to the treatment of diseases, especially lupus vulgaris, with concentrated light radiation, whereby he has opened a new avenue for medical science"
1904	**Ivan Petrovich Pavlov**	"in recognition of his work on the physiology of digestion, through which knowledge on vital aspects of the subject has been transformed and enlarged"
1905	**Robert Koch**	"for his investigations and discoveries in relation to tuberculosis"
1906	**Camillo Golgi**	"in recognition of their work on the structure of the nervous system"
	Santiago Ramón y Cajal	
1907	**Charles Louis Alphonse**	"in recognition of his work on the role played

	Laveran	by protozoa in causing diseases"
1908	**Ilya Ilyich Mechnikov**	"in recognition of their work on immunity"
	Paul Ehrlich	
1909	**Emil Theodor Kocher**	"for his work on the physiology, pathology and surgery of the thyroid gland"
1910	**Albrecht Kossel**	"in recognition of the contributions to our knowledge of cell chemistry made through his work on proteins, including the nucleic substances"
1911	**Allvar Gullstrand**	"for his work on the dioptrics of the eye"
1912	**Alexis Carrel**	"[for] his work on vascular suture and the transplantation of blood vessels and organs"
1913	**Charles Richet**	"[for] his work on anaphylaxis"
1914	**Robert Bárány**	"for his work on the physiology and pathology of the vestibular apparatus"
1915	**Not awarded**	
1916		
1917		
1918		

1919	**Jules Bordet**	"for his discoveries relating to immunity"
1920	**Schack August Steenberg Krogh**	"for his discovery of the capillary motor regulating mechanism"
1921	**Not awarded**	
1922	**Archibald Vivian Hill**	"for his discovery relating to the production of heat in the muscle"
	Otto Fritz Meyerhof	"for his discovery of the fixed relationship between the consumption of oxygen and the metabolism of lactic acid in the muscle"
1923	**Sir Frederick Grant Banting**	"for the discovery of insulin"
	John James Rickard Macleod	
1924	**Willem Einthoven**	"for the discovery of the mechanism of the electrocardiogram"
1925	**Not awarded**	
1926	**Johannes Andreas Grib Fibiger**	"for his discovery of the Spiroptera carcinoma"
1927	**Julius Wagner-Jauregg**	"for his discovery of the therapeutic value of malaria inoculation in the treatment of dementia paralytica"

1928	**Charles Jules Henri Nicolle**	"for his work on typhus"
1929	**Christiaan Eijkman**	"for his discovery of the antineuritic vitamin"
	Sir Frederick Gowland Hopkins	"for his discovery of the growth-stimulating vitamins"
1930	**Karl Landsteiner**	"for his discovery of human blood groups"
1931	**Otto Heinrich Warburg**	"for his discovery of the nature and mode of action of the respiratory enzyme"
1932	**Sir Charles Scott Sherrington**	"for their discoveries regarding the functions of neurons"
	Edgar Douglas Adrian	
1933	**Thomas Hunt Morgan**	"for his discoveries concerning the role played by the chromosome in heredity"
1934	**George Hoyt Whipple**	"for their discoveries concerning liver therapy in cases of anaemia"
	George Richards Minot	
	William Parry Murphy	
1935	**Hans Spemann**	"for his discovery of the organizer effect in embryonic development"

1936	**Sir Henry Hallett Dale**	"for their discoveries relating to chemical transmission of nerve impulses"
	Otto Loewi	
1937	**Albert Szent-Györgyi von Nagyrapolt**	"for his discoveries in connection with the biological combustion processes, with special reference to vitamin C and the catalysis of fumaric acid"
1938	**Corneille Jean François Heymans**	"for the discovery of the role played by the sinus and aortic mechanisms in the regulation of respiration"
1939	**Gerhard Domagk**	"for the discovery of the antibacterial effects of prontosil"
1940	**Not awarded**	
1941		
1942		
1943	**Carl Peter Henrik Dam**	"for his discovery of vitamin K"
	Edward Adelbert Doisy	"for his discovery of the chemical nature of vitamin K"
1944	**Joseph Erlanger**	"for their discoveries relating to the highly differentiated functions of single nerve fibres"
	Herbert Spencer Gasser	
1945	**Sir Alexander Fleming**	"for the discovery of penicillin and its curative effect in

	Sir Ernst Boris Chain	various infectious diseases"
	Howard Walter Florey	
1946	**Hermann Joseph Muller**	"for the discovery of the production of mutations by means of X-ray irradiation"
1947	**Carl Ferdinand Cori**	"for their discovery of the course of the catalytic conversion of glycogen"
	Gerty Theresa Cori, née Radnitz	
	Bernardo Alberto Houssay	"for his discovery of the part played by the hormone of the anterior pituitary lobe in the metabolism of sugar"
1948	**Paul Hermann Müller**	"for his discovery of the high efficiency of DDT as a contact poison against several arthropods"
1949	**Walter Rudolf Hess**	"for his discovery of the functional organization of the interbrain as a coordinator of the activities of the internal organs"
	António Caetano Egas Moniz	"for his discovery of the therapeutic value of leucotomy (lobotomy) in certain psychoses"
1950	**Philip Showalter Hench**	"for their discoveries relating to the hormones of the adrenal cortex, their structure and biological effects"
	Edward Calvin Kendall	
	Tadeusz Reichstein	

1951	**Max Theiler**	"for his discoveries concerning yellow fever and how to combat it"
1952	**Selman Abraham Waksman**	"for his discovery of streptomycin, the first antibiotic effective against tuberculosis"
1953	**Sir Hans Adolf Krebs**	"for his discovery of the citric acid cycle"
	Fritz Albert Lipmann	"for his discovery of co-enzyme A and its importance for intermediary metabolism"
1954	**John Franklin Enders**	"for their discovery of the ability of poliomyelitis viruses to grow in cultures of various types of tissue"
	Frederick Chapman Robbins	
	Thomas Huckle Weller	
1955	**Axel Hugo Theodor Theorell**	"for his discoveries concerning the nature and mode of action of oxidation enzymes"
1956	**André Frédéric Cournand**	"for their discoveries concerning heart catheterization and pathological changes in the circulatory system"
	Werner Forssmann	
	Dickinson W. Richards	
1957	**Daniel Bovet**	"for his discoveries relating to synthetic compounds that inhibit the action of certain body substances, and

		especially their action on the vascular system and the skeletal muscles"
1958	**George Wells Beadle**	"for their discovery that genes act by regulating definite chemical events"
	Edward Lawrie Tatum	
	Joshua Lederberg	"for his discoveries concerning genetic recombination and the organization of the genetic material of bacteria"
1959	**Arthur Kornberg**	"for their discovery of the mechanisms in the biological synthesis of ribonucleic acid and deoxyribonucleic acid"
	Severo Ochoa	
1960	**Sir Frank Macfarlane Burnet**	"for discovery of acquired immunological tolerance"
	Sir Peter Brian Medawar	
1961	**Georg von Békésy**	"for his discoveries of the physical mechanism of stimulation within the cochlea"
1962	**Francis Harry Compton Crick**	"for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material"
	James Dewey Watson	
	Maurice Hugh Frederick Wilkins	

1963	**Sir John Carew Eccles**	"for their discoveries concerning the ionic mechanisms involved in excitation and inhibition in the peripheral and central portions of the nerve cell membrane"
	Sir Alan Lloyd Hodgkin	
	Sir Andrew Fielding Huxley	
1964	**Konrad Bloch**	"for their discoveries concerning the mechanism and regulation of the cholesterol and fatty acid metabolism"
	Feodor Lynen	
1965	**François Jacob**	"for their discoveries concerning genetic control of enzyme and virus synthesis"
	André Lwoff	
	Jacques Monod	
1966	**Peyton Rous**	"for his discovery of tumour-inducing viruses"
	Charles Brenton Huggins	"for his discoveries concerning hormonal treatment of prostatic cancer"
1967	**Ragnar Granit**	"for their discoveries concerning the primary physiological and chemical visual processes in the eye"
	Haldan Keffer Hartline	
	George Wald	
1968	**Robert W. Holley**	"for their interpretation of the genetic code and its

	Har Gobind Khorana	function in protein synthesis"
	Marshall W. Nirenberg	
1969	**Max Delbrück**	"for their discoveries concerning the replication mechanism and the genetic structure of viruses"
	Alfred D. Hershey	
	Salvador E. Luria	
1970	**Julius Axelrod**	"for their discoveries concerning the humoral transmittors in the nerve terminals and the mechanism for their storage, release and inactivation"
	Ulf von Euler	
	Sir Bernard Katz	
1971	**Earl W. Sutherland, Jr.**	"for his discoveries concerning the mechanisms of the action of hormones"
1972	**Gerald M. Edelman**	"for their discoveries concerning the chemical structure of antibodies"
	Rodney R. Porter	
1973	**Karl von Frisch**	"for their discoveries concerning organization and elicitation of individual and social behavior patterns"
	Konrad Lorenz	
	Nikolaas Tinbergen	

1974	**Albert Claude**	"for their discoveries concerning the structural and functional organization of the cell"
	Christian de Duve	
	George E. Palade	
1975	**David Baltimore**	"for their discoveries concerning the interaction between tumour viruses and the genetic material of the cell"
	Renato Dulbecco	
	Howard Martin Temin	
1976	**Baruch S. Blumberg**	"for their discoveries concerning new mechanisms for the origin and dissemination of infectious diseases"
	D. Carleton Gajdusek	
1977	**Roger Guillemin**	"for their discoveries concerning the peptide hormone production of the brain"
	Andrew V. Schally	
	Rosalyn Yalow	"for the development of radioimmunoassays of peptide hormones"
1978	**Werner Arber**	"for the discovery of restriction enzymes and their application to problems of molecular genetics"
	Daniel Nathans	
	Hamilton O. Smith	

1979	**Allan M. Cormack**	"for the development of computer assisted tomography"
	Sir Godfrey N. Hounsfield	
1980	**Baruj Benacerraf**	"for their discoveries concerning genetically determined structures on the cell surface that regulate immunological reactions"
	Jean Dausset	
	George D. Snell	
1981	**Roger W. Sperry**	"for his discoveries concerning the functional specialization of the cerebral hemispheres"
	David H. Hubel	"for their discoveries concerning information processing in the visual system"
	Torsten N. Wiesel	
1982	**Sune K. Bergström**	"for their discoveries concerning prostaglandins and related biologically active substances"
	Bengt I. Samuelsson	
	Sir John R. Vane	
1983	**Barbara McClintock**	"for her discovery of mobile genetic elements"
1984	**Niels K. Jerne**	"for theories concerning the specificity in development and control of the immune system and the discovery of the principle for production of monoclonal antibodies"
	Georges J.F. Köhler	

	César Milstein	
1985	**Michael S. Brown**	"for their discoveries concerning the regulation of cholesterol metabolism"
	Joseph L. Goldstein	
1986	**Stanley Cohen**	"for their discoveries of growth factors"
	Rita Levi-Montalcini	
1987	**Susumu Tonegawa**	"for his discovery of the genetic principle for generation of antibody diversity"
1988	**Sir James W. Black**	"for their discoveries of important principles for drug treatment"
	Gertrude B. Elion	
	George H. Hitchings	
1989	**J. Michael Bishop**	"for their discovery of the cellular origin of retroviral oncogenes"
	Harold E. Varmus	
1990	**Joseph E. Murray**	"for their discoveries concerning organ and cell transplantation in the treatment of human disease"
	E. Donnall Thomas	
1991	**Erwin Neher**	"for their discoveries concerning the function of

	Bert Sakmann	single ion channels in cells"
1992	**Edmond H. Fischer**	"for their discoveries concerning reversible protein phosphorylation as a biological regulatory mechanism"
	Edwin G. Krebs	
1993	**Sir Richard J. Roberts**	"for their discoveries of split genes"
	Phillip A. Sharp	
1994	**Alfred G. Gilman**	"for their discovery of G-proteins and the role of these proteins in signal transduction in cells"
	Martin Rodbell	
1995	**Edward B. Lewis**	"for their discoveries concerning the genetic control of early embryonic development"
	Christiane Nüsslein-Volhard	
	Eric F. Wieschaus	
1996	**Peter C. Doherty**	"for their discoveries concerning the specificity of the cell mediated immune defence"
	Rolf M. Zinkernagel	
1997	**Stanley B. Prusiner**	"for his discovery of Prions - a new biological principle of infection"
1998	**Robert F. Furchgott**	"for their discoveries concerning nitric oxide as a

	Louis J. Ignarro	signaling molecule in the cardiovascular system"
	Ferid Murad	
1999	**Günter Blobel**	"for the discovery that proteins have intrinsic signals that govern their transport and localization in the cell"
2000	**Arvid Carlsson**	"for their discoveries concerning signal transduction in the nervous system"
	Paul Greengard	
	Eric R. Kandel	
2001	**Leland H. Hartwell**	"for their discoveries of key regulators of the cell cycle"
	Sir Tim Hunt	
	Sir Paul M. Nurse	
2002	**Sydney Brenner**	"for their discoveries concerning 'genetic regulation of organ development and programmed cell death'"
	H. Robert Horvitz	
	Sir John E. Sulston	
2003	**Paul Lauterbur**	"for their discoveries concerning magnetic resonance imaging"
	Sir Peter Mansfield	

2004	**Richard Axel**	"for their discoveries of odorant receptors and the organization of the olfactory system"
	Linda B. Buck	
2005	**Barry J. Marshall**	"for their discovery of the bacterium Helicobacter pylori and its role in gastritis and peptic ulcer disease"
	J. Robin Warren	
2006	**Andrew Z. Fire**	"for their discovery of RNA interference - gene silencing by double-stranded RNA"
	Craig C. Mello	
2007	**Mario R. Capecchi**	"for their discoveries of principles for introducing specific gene modifications in mice by the use of embryonic stem cells."
	Sir Martin J. Evans	
	Oliver Smithies	
2008	**Harald zur Hausen**	"for his discovery of human papilloma viruses causing cervical cancer"
	Françoise Barré-Sinoussi	"for their discovery of human immunodeficiency virus"
	Luc Montagnier	
2009	**Elizabeth H. Blackburn**	"for the discovery of how chromosomes are protected by telomeres and the enzyme telomerase"
	Carol W. Greider	

	Jack W. Szostak	
2010	**Sir Robert G. Edwards**	"for the development of in vitro fertilization"
2011	**Bruce A. Beutler**	"for their discoveries concerning the activation of innate immunity"
	Jules A. Hoffmann	
	Ralph M. Steinman	"for his discovery of the dendritic cell and its role in adaptive immunity"
2012	**Sir John B. Gurdon**	"for the discovery that mature cells can be reprogrammed to become pluripotent"
	Shinya Yamanaka	
2013	**James E. Rothman**	"for their discoveries of machinery regulating vesicle traffic, a major transport system in our cells"
	Randy W. Schekman	
	Thomas C. Südhof	
2014	**John O'Keefe**	"for their discoveries of cells that constitute a positioning system in the brain"
	May-Britt Moser	
	Edvard I. Moser	
2015	**William C. Campbell**	"for their discoveries concerning a novel

	Satoshi Ōmura	therapy against infections caused by roundworm parasites"
	Tu Youyou	"for her discoveries concerning a novel therapy against malaria"
2016	**Yoshinori Ohsumi**	"for his discoveries of mechanisms for autophagy"
2017	**Jeffrey C. Hall**	"for their discoveries of molecular mechanisms controlling the circadian rhythm"
	Michael Rosbash	
	Michael W. Young	
2018	**James P. Allison**	"for their discovery of cancer therapy by inhibition of negative immune regulation"
	Tasuku Honjo	
2019	**William Kaelin Jr.**	"for their discoveries of how cells sense and adapt to oxygen availability"
	Peter J. Ratcliffe	
	Gregg L. Semenza	
2020	**Harvey J. Alter**	"for the discovery of Hepatitis C virus"
	Michael Houghton	
	Charles M. Rice	

In Mathematics the art of proposing a question must be held of higher value than solving it.

— Georg Cantor

A mathematical proof should resemble a simple and clear-cut constellation, not a scattered cluster in the Milky Way.

— G.H. Hardy

"{**Replying to G. H. Hardy's suggestion that the number of a taxi (1729) was 'dull', showing off his spontaneous mathematical genius**}

No, it is a very interesting number; it is the smallest number expressible as a sum of two cubes in two different ways, the two ways being 13 + 123 and 93 + 103."

— **Srinivasa Ramanujan**

Source of Information:

- https://www.wikipedia.org