Material World Review – Science and Technology (ST)

This summary provides a quick overview of the Material World concepts that will be assessed during the ST ministry exam.
To explore a concept in more detail, scan its QR code.

Concentration

Concentration is the ratio between the amount of solute and the amount of solution.
Example: 25.0 g of solute is dissolved in 800 mL of solution.
What is the concentration of the solution?

Density (g/L)

$m = 25.0 \text{ g}$

$V = 800 \text{ mL} \times \dfrac{1 \text{ L}}{1\ 000 \text{ mL}} = 0.800 \text{ L}$

$C = \ ? \text{ (g/L)}$

$$C = \frac{m}{V}$$

$$C = \frac{25.0 \text{ g}}{0.800 \text{ L}}$$

$$C \approx 31.3 \text{ g/L}$$

In % (m/V)

$m = 25.0 \text{ g}$

$V = 800 \text{ mL}$

$C = \ ? \ \% \text{ (m/V)}$

$$C = \frac{m}{V} \times 100$$

$$C = \frac{25.0 \text{ g}}{800 \text{ mL}} \times 100$$

$$C \approx 3.13 \ \% \text{ (m/V)}$$

In ppm

$m = 25.0 \text{ g}$

$V = 800 \text{ mL}$

$C = \ ? \ \% \text{ (m/V)}$

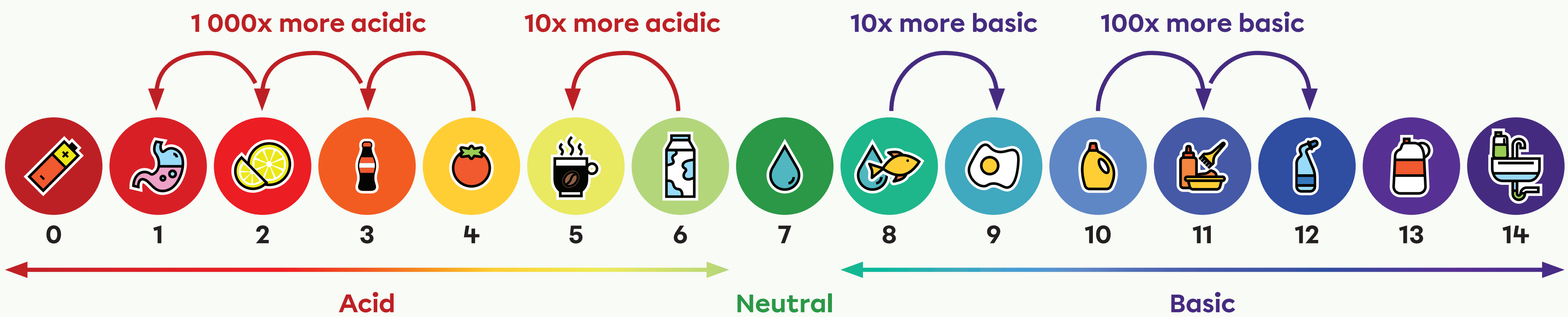
$$C = \frac{m}{V} \times 1\ 000\ 000$$

$$C = \frac{25.0 \text{ g}}{800 \text{ mL}} \times 1\ 000\ 000$$

$$C = 31\ 250 \text{ ppm} \approx 3.13 \times 10^4 \text{ppm}$$

The pH Scale

The **pH scale** is a logarithmic scale used to compare the acidic, neutral, or basic (alkaline) nature of solutions.



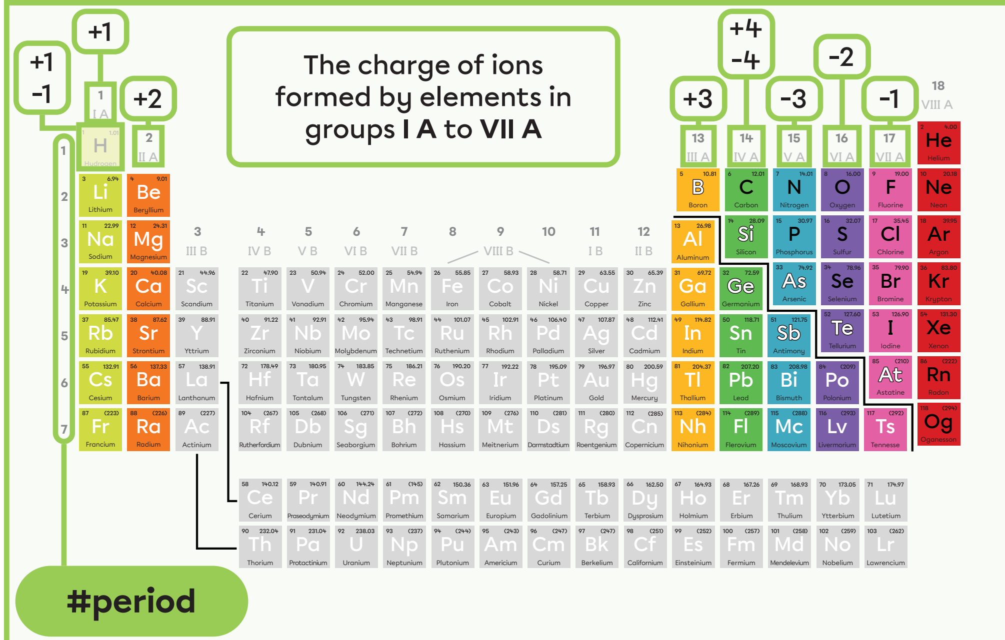
Electrolytic Dissociation

An **electrolyte** is a substance that allows <u>current to flow</u> through an aqueous solution.

Electrolytic dissociation is the separation of an electrolyte into a cation and an anion.

Type of Electrolyte	Acid	Base	Salt
General Chemical Formula	(H) + Non-metal	Metal + (OH)	Metal + Non-metal
Ions in Solution	A proton (H^+) and an anion	A cation and a hydroxide (OH^-)	A cation and an anion
pH in Solution	Below 7	Above 7	Variable
Examples	**HCl, CH_3COOH, H_2SO_4**	Na**OH**, Ca**(OH)**$_2$	$MgCl_2$, KNO_3, NaF

Groups in the Periodic Table of Elements



Group	Characteristics
Alkali Metals	• Soft metals • Very reactive • Good electrical conductors
Alkaline-Earth Metals	• Soft metals • Reactive • Good electrical conductors • Found in the Earth's crust
Halogens	• Very reactive • Disinfectants • React with metals to form salts
Noble Gases	• Non-metals • Very stable • Emit light when an electric current is passed through them

Rutherford-Bohr Atomic Model

- Atomic number = Number of p^+ in the nucleus = Number of e^- to be distributed
- Period number = Number of electron shells
- Group number as a Roman numeral = e^- valence number
- 1st shell: max. 2 e^-
- 2nd and other shells: max. 8 e^-

Example: magnesium atom (Mg)

Ions

An **ion** is an atom that has lost or gained electrons to take on the same electronic configuration as a noble (or inert) gas and become more stable.

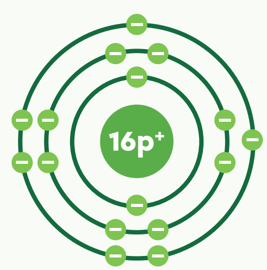
Cation: positively charged ion

Anion: negatively charged ion

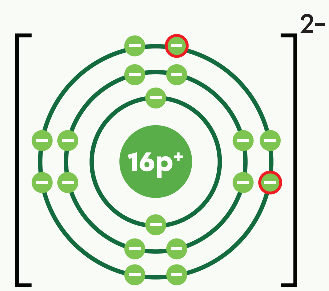
Example: A sulphur atom (S) gains 2 electrons to form a sulphur ion (S^{2-}), obtaining the same electronic configuration as argon (Ar).

Legend: Electron gained

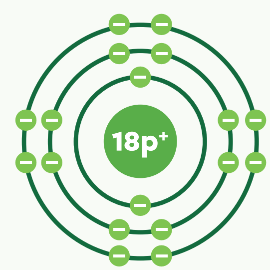
Sulphur atom (S)



Sulphur ion (S^{2-})



Argon ion (Ar)



Chemical Reactions

Oxidation is a reaction in which an element of one of the reactants loses electrons. This can happen in the presence of oxygen.

Example: Formation of iron oxide (rust)
$4\ Fe_{(s)} + 3\ O_{2(g)} \rightarrow 2\ Fe_2O_{3(s)}$

Combustion is an oxidation process that releases energy.

Example: Propane combustion
$C_3H_{8(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(l)}$ + Energy

Cellular respiration is the slow combustion of glucose in animal and plant cells.

$C_6H_{12}O_{6(s)} + 6\ O_{2(g)} \rightarrow 6\ CO_{2(g)} + 6\ H_2O_{(l)}$ + Energy

Photosynthesis is a glucose synthesis reaction that takes place in plant cells.

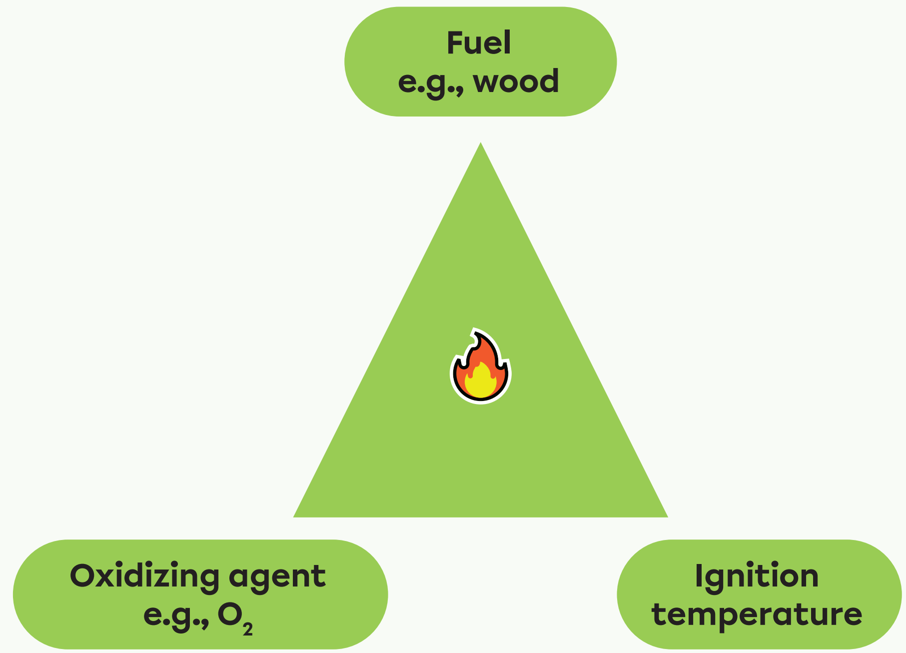
$6\ CO_{2(g)} + 6\ H_2O_{(l)}$ + Energy $\rightarrow C_6H_{12}O_{6(s)} + 6\ O_{2(g)}$

Acid-base neutralization is the reaction of an acid with a base to produce a salt and water.

Example: Neutralization of HCl by NaOH
$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

Fire Triangle

Combustion requires 3 elements.
Without all 3, a fire goes out.



Law of Conservation of Matter

Matter is neither created nor destroyed, but transformed. The mass of the reactants is equal to the mass of the products.

Mass of reactants			=	Mass of products
$C_2H_{4(g)}$	+	$H_{2(g)}$	→	$C_2H_{6(g)}$
28.06 g	+	2.02 g	=	30.08 g
	30.08 g		=	30.08 g ✓

Balancing a Chemical Equation

Balancing a chemical equation means balancing the number of atoms in the reactants and products in keeping with the Law of Conservation of Matter.

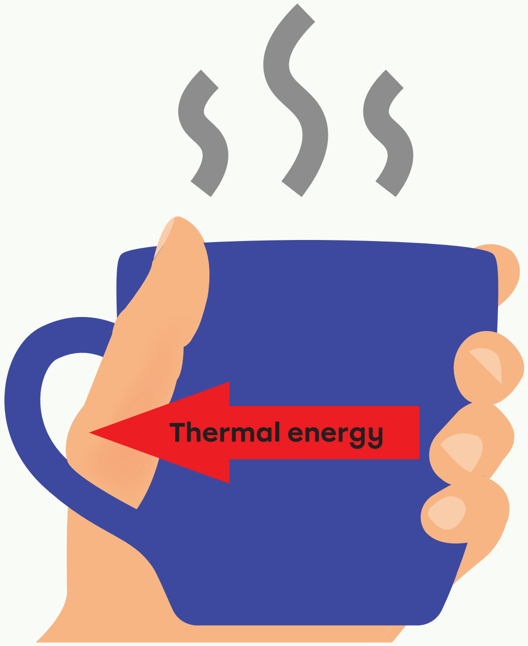
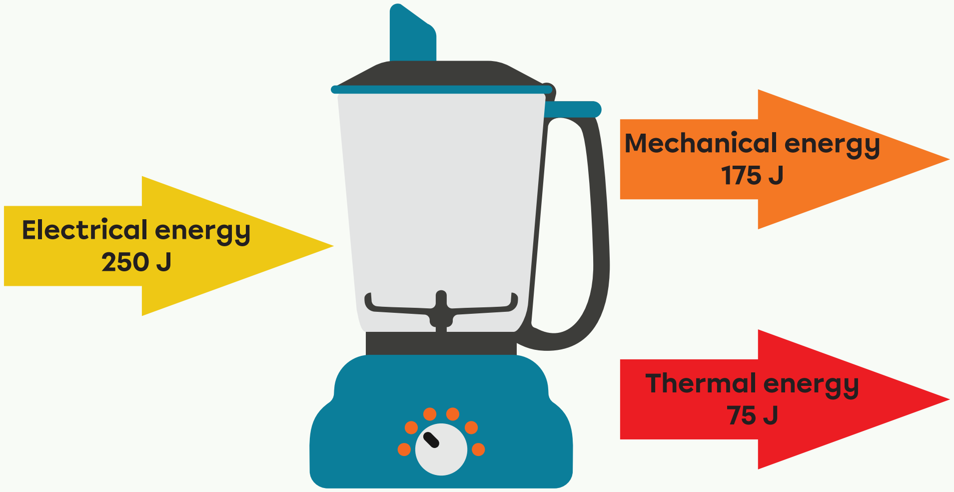
	N_2	+	3 H_2	→	2 NH_3
N	2		0		2 (2 × 1)
H	0		6 (3 × 2)		6 (2 × 3)

Number of N atoms	
Reactants	Products
2	2 ✓

Number of H atoms	
Reactants	Products
6	6 ✓

Law of Conservation of Energy

Energy cannot be created nor destroyed. It can only be **transferred** or **transformed**.

Thermal energy transfer from coffee to hand	Transformation of electrical energy into mechanical and thermal energy
	

$$\text{Energy consumed} = \text{Useful energy} + \text{Dissipated energy}$$
$$250\ \text{J} = 175\ \text{J} + 75\ \text{J}$$
$$250\ \text{J} = 250\ \text{J}$$

Energy Efficiency

Example: A toaster consumes 270 000 J of electrical energy and transforms it into 197 100 J of useful thermal energy.
What is the energy efficiency?

$$\text{Energy efficiency} = \ ?\ \%$$
$$E_{\text{consumed}} = 270\ 000\ \text{J}$$
$$E_{\text{useful}} = 197\ 100\ \text{J}$$

$$\text{Energy efficiency} = \frac{E_{\text{useful}}}{E_{\text{consumed}}} \times 100$$

$$\text{Energy efficiency} = \frac{197\ 100\ \text{J}}{270\ 000\ \text{J}} \times 100$$
$$\text{Energy efficiency} \approx 73\ \%$$

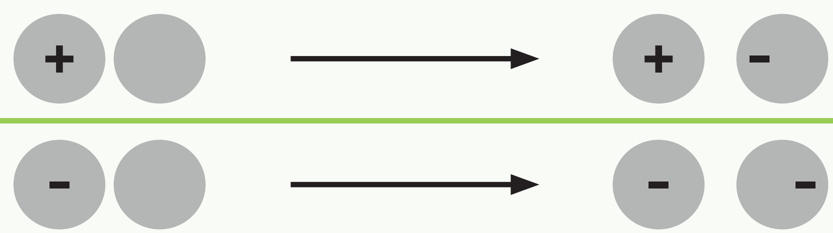
Static Electricity

Law of Electric Charges
+ - = Attraction
++ or - - = Repulsion

Conduction: Contact between a charged and a neutral object.

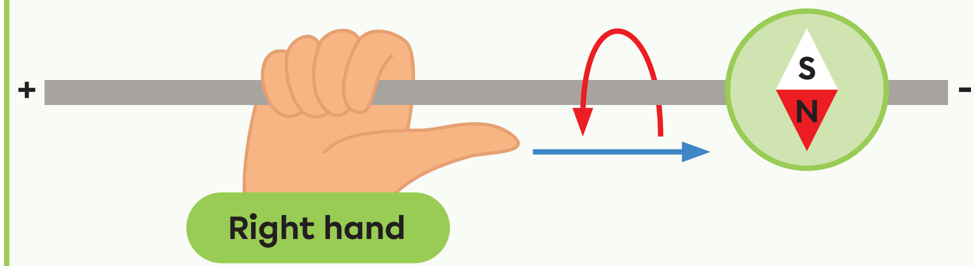
Friction: One object pulls electrons from the other.

Induction: A nearby charge causes electrons to move temporarily.



Magnetic Field Around a Straight Wire

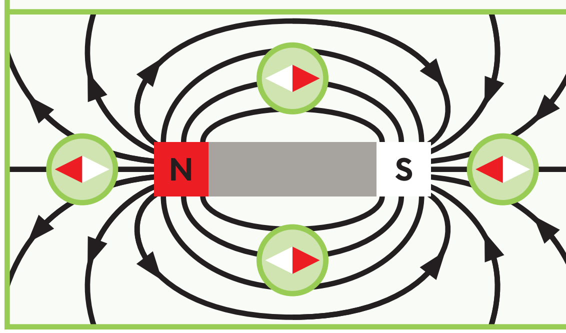
- Thumb: conventional current direction
- Fingers: direction of rotation of the magnetic field

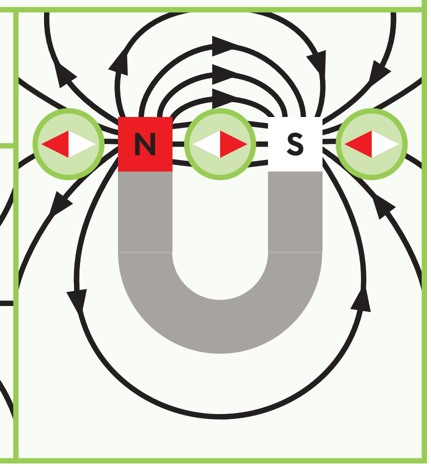


Magnetic Field Around Magnets

Magnetic field lines run from the magnetic north pole to the magnetic south pole.

Law of magnetic poles
N-S = Attraction
N-N or S-S = Repulsion





Ohm's Law (V=RI)

Example: A toaster with a resistance of 12 Ω carries a current of 10 000 mA. What is the potential difference, or voltage, of the toaster's outlets?

$$R = 12\ \Omega$$
$$I = 10\ 000\ \text{mA} \times \frac{1\ \text{A}}{1\ 000\ \text{mA}} = 10\ \text{A}$$
$$V = \ ?\ \text{V}$$

$$V = RI$$

$$V = 12\ \Omega \times 10\ \text{A}$$
$$V = 120\ \text{V}$$

Electrical Power (P=VI)

Example: What is the electrical power of the toaster in the previous example?

$$V = 120\ \text{V}$$
$$I = 10\ \text{A}$$
$$P = \ ?\ \text{W}$$

$$P = VI$$

$$P = 120\ \text{V} \times 10\ \text{A}$$
$$P = 1\ 200\ \text{W}$$

Electrical Energy Consumed (E=P∆t)

Example: The toaster runs for 3 min and 45 sec. How much electrical energy does it consume?

Joules (J)

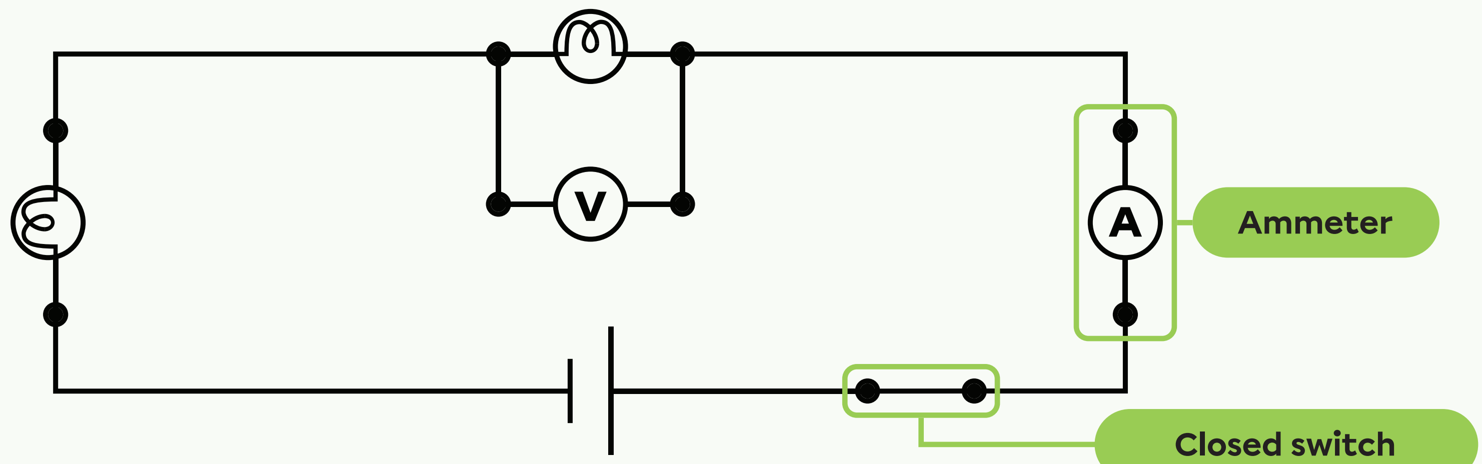
$$P = 1\ 200\ \text{W}$$
$$\Delta t = \left(3\ \text{min} \times \frac{60\ \text{s}}{1\ \text{min}}\right) + 45\ \text{s} = 225\ \text{s}$$
$$E = \ ?\ \text{J}$$
$$E = P\Delta t$$
$$E = 1\ 200\ \text{W} \times 225\ \text{s}$$
$$E = 270\ 000\ \text{J}$$

Kilowatt-hour (kWh)

$$P = 1\ 200\ \text{W} \times \frac{1\ \text{kW}}{1\ 000\ \text{W}} = 1.2\ \text{kW}$$
$$\Delta t = \left(3\ \text{min} \times \frac{1\ \text{h}}{60\ \text{min}}\right) + \left(45\ \text{sec} \times \frac{1\ \text{h}}{3\ 600\ \text{s}}\right) = 0.0625\ \text{h}$$
$$E = \ ?\ \text{kWh}$$
$$E = P\Delta t$$
$$E = 1.2\ \text{kW} \times 0.0625\ \text{h}$$
$$E = 0.075\ \text{kWh}$$

Electrical Circuits

Series circuit



Parallel circuit