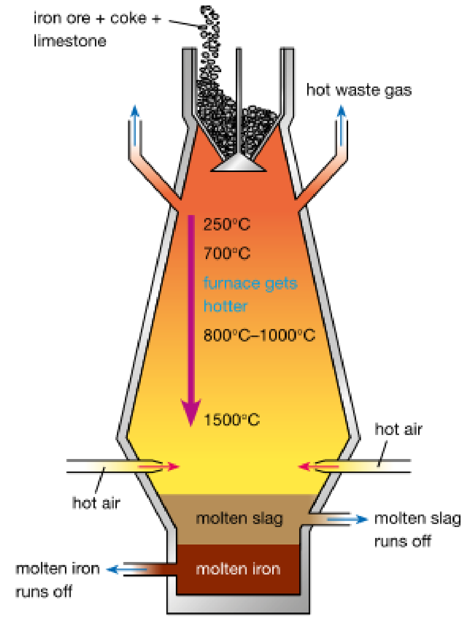
Intensive notes (Topic 3: Metals)

Uses of metals

Metal	Uses	Reason
Iron	Construction, Car / ship bodies	Hard, strong, malleable, cheap
	Magnet	Magnetic
Copper	Electric wire	Good electrical conductor, ductile
	Water pipe	Corrosion resistant, non-toxic
	Cooking utensil	Good heat conductor, non-toxic, corrosion resistant
Aluminium	Overhead power cable	Good electrical conductor, ductile
	Aircraft bodies	Strong, corrosion resistant, low density
	Kitchen foil	Non-toxic, corrosion resistant, malleable
	Soft drink can	Non-toxic, corrosion resistant
	Window frame	Strong, corrosion resistant
Titanium	Supersonic aircraft bodies	Low density, strong, high melting point
	Metal implants in human body	Low density, corrosion resistant, biocompatible
Gold	Jewellery	Corrosion resistant, attractive appearance
Mercury	Thermometer	Expand on heating, liquid at room conditions
Silver	Jewellery	Corrosion resistant, attractive appearance
	Electronic component	Best electrical conductor, ductile, corrosion resistant

Extraction of iron

Step 1	Hot air is blasted near the bottom of the furnace. Coke (carbon) will react with oxygen in air Carbon + Oxygen ➔ Carbon dioxide $C + O_2 \rightarrow CO_2$
Step 2	Coke will further react with the carbon dioxide produced in step 1 to form carbon monoxide Carbon + Carbon dioxide ➔ Carbon monoxide $C + CO_2 \rightarrow 2CO$
Step 3	Carbon monoxide will react with haematite (Fe_2O_3). Iron metal can be obtained in this step. Fe_2O_3 is reduced to Fe in this step. The **reducing agent** used is carbon monoxide. Carbon monoxide + Iron(III) oxide ➔ Carbon dioxide + Iron $3CO + Fe_2O_3 \rightarrow 3CO_2 + 2Fe$



- Limestone is also added to the blast furnace. It is decomposed upon heating to form calcium oxide and carbon dioxide. Calcium oxide can react with the impurities such as silicon dioxide to form slag and it is further removed.
  - Calcium carbonate ➔ Calcium oxide + Carbon dioxide

    $$CaCO_3 \rightarrow CaO + CO_2$$

  - Calcium oxide + Silicon dioxide ➔ Calcium silicate

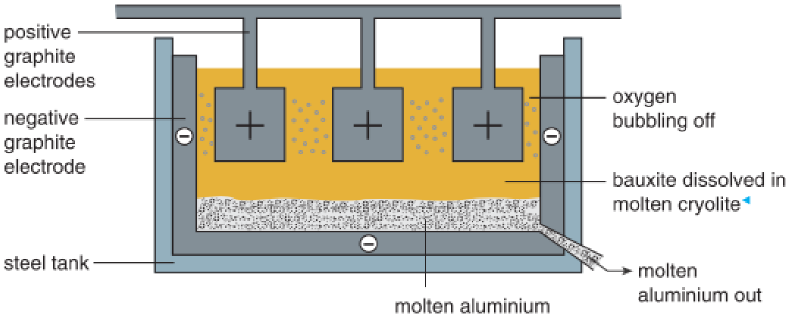
    $$CaO + SiO_2 \rightarrow CaSiO_3$$

Intensive notes (Topic 3: Metals)

Extraction of aluminium

Raw materials required:

1. Bauxite (Source of aluminium ore, Al_2O_3)
2. Cryolite (To reduce the melting point of aluminium ore)



- At negative electrode: Aluminum ion + electrons ➔ Aluminum

$$Al^{3+} + 3e^- \rightarrow Al$$

At positive electrode: Oxide ion ➔ Oxygen + electrons

$$2O^{2-} \rightarrow O_2 + 4e^-$$

- Aluminium oxide must be in molten form. The melting point of bauxite is very high (2000 °C). Therefore the bauxite is dissolved in molten cyolite (a less common aluminum ore) so that the melting point of the mixture of aluminium ore will be reduced to below 2000 °C.

Relation between metal reactivity series and the extraction method

- Reactive metals (element) form stable ore (compound)

➔ Lower the position of the metal in the reactivity series, the more easily it can be extracted from ore.

Q: Explain why iron was discovered and used much earlier than aluminium

A: Iron is less reactive than aluminium. Ore of irons are less stable. Therefore iron can be extracted more easily.

Factors affecting availability of metals

1. Abundance of the metal in Earth's crust
2. Ease and cost of mining the ore
3. Ease and cost of extracting the metal from its ore

In general, the more easily a metal can be extracted, the earlier it was discovered in history.

Ways of conserving metals

1. Reusing metal articles
2. Reducing the use of metals
3. Recycling used metals

Intensive notes (Topic 3: Metals)

Extractions of metals

1. Heating metal ore alone

A. Metal oxide ➔ Metal + Oxygen — Ag, Hg

$$2Ag_2O(s) \rightarrow 4Ag(s) + O_2(g)$$

B. Metal sulphide + Oxygen ➔ Metal + Sulphur dioxide — Ag, Hg, Cu

$$Cu_2S(s) + O_2(g) \rightarrow 2Cu(s) + SO_2(g)$$

2. Heating metal oxide with reducing agent (e.g. Carbon / carbon monoxide / hydrogen)

A. Metal oxide + Carbon ➔ Metal + Carbon dioxide — Cu, Pb, Fe, Zn

$$2PbO(s) + C(s) \rightarrow 2Pb(s) + CO_2(g)$$

B. Metal oxide + Carbon monoxide ➔ Metal + Carbon dioxide — Cu, Pb, Fe, Zn

$$Fe_3O_4(s) + 4CO(g) \rightarrow 3Fe(s) + 4CO_2(g)$$

C. Metal oxide + Hydrogen ➔ Metal + Water — Cu, Pb, Fe, Zn

$$CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(l)$$

*The ores of some metals are in sulphide form. These metal sulphides can be converted to oxide by heating in air

Metal sulphide + Oxygen ➔ Metal oxide + Sulphur dioxide

$$2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$$

3. Electrolysis of molten ore

$$2Al_2O_3(l) \rightarrow 4Al(l) + 3O_2(g)$$ — Al, Mg, Ca, Na, K

*Due to high temperature, aluminium metal will be produced in liquid state

Reactions of metals

1. Reaction of metal with oxygen

Metal + Oxygen ➔ Metal oxide — K, Na, Ca, Mg, Al, Zn, Fe, Pb, Cu, Hg

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

2. Reaction of metal with water / steam

Metal + Water ➔ Metal hydroxide + Hydrogen — K, Na, Ca

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

Metal + Steam ➔ Metal oxide + Hydrogen — K, Na, Ca, Mg, Al, Zn, Fe

$$Zn(s) + H_2O(g) \rightarrow ZnO(s) + H_2(g)$$

3. Reaction of metal with acid

Metal + Dilute hydrochloric acid ➔ Metal chloride + Hydrogen — K, Na, Ca, Mg, Al, Zn, Fe, Pb

$$Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$$

Metal + Dilute sulphuric acid ➔ Metal sulphate + Hydrogen — K, Na, Ca, Mg, Al, Zn, Fe, Pb,

$$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$$

4. Displacement reaction

Metal A + Metal B ion ➔ Metal B + Metal A ion — A should be more reactive than B.

$$Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$$

Intensive notes (Topic 3: Metals)

Metal reactivity series

Most reactive metal | Least reactive metal

(Easy to react to form compounds) | (Difficult to react to form compounds)

K	Na	Ca	Mg	Al	Zn	Fe	Pb	Cu	Hg	Ag	Pt	Au

Forming most stable ore | Forming least stable ore

(Difficult to extract) | (Easy to extract)

Reaction of metals with oxygen in air

Metal	Observation	Word equation
Potassium	On gentle heating, it burns with **lilac** flame and give a **white powder**	Potassium + Oxygen → Potassium oxide
Sodium	On gentle heating, it burns with **golden yellow** flame and give a **white powder**	Sodium + Oxygen → Sodium oxide
Calcium	On strong heating, it burns with **brick-red** flame and give a **white powder**	Calcium + Oxygen → Calcium oxide
Magnesium	On strong heating, it burns with **bright white** flame and give a **white powder**	Magnesium + Oxygen → Magnesium oxide
Aluminium	On strong heating, it burns to give out heat and a **white powder**	Aluminium + Oxygen → Aluminium oxide
Zinc	On strong heating, it burns to give out heat and a powder **(Hot: Yellow; Cold: white)**	Zinc + Oxygen → Zinc oxide
Iron	On strong heating, it burns with **yellow spark** and give a **black powder** (Note: Iron(III) oxide is brown in color)	Iron + Oxygen → Iron(II, III) oxide
Lead	On strong heating, it melts and gives a powder **(Hot: Orange; Cold: yellow)**	Lead + Oxygen → Lead(II) oxide
Copper	On very strong heating, it gives a **black** powder	Copper + Oxygen → Copper(II) oxide
Mercury	On very strong heating, it gives a **red** powder	Mercury + Oxygen → Mercury(II) oxide
Silver	No reaction with oxygen (Note: Silver oxide is black in color)	---
Platinum	No reaction with oxygen	---
Gold	No reaction with oxygen	---

Note: Potassium and sodium should be store under **paraffin oil**

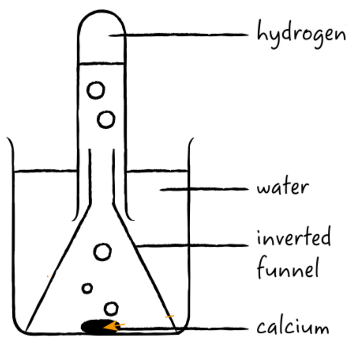
(Shiny surface of reactive metals turns dull when exposed in air)

Calcium should be store in an **airtight container**

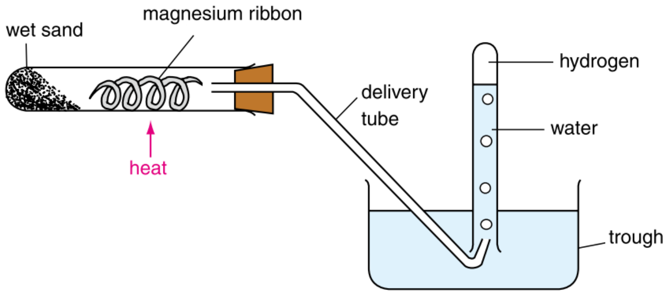
Unit Education

Reaction of metals with water / steam

Metal	Observation	Word equation
Potassium	Reacts with **cold water**: - Melts to form a silvery ball - Moves on water surface with a hissing sound - Burns with lilac flame - Dissolves in water to give an alkaline solution	Potassium + Water ➔ Potassium hydroxide + Hydrogen
Sodium	Reacts with **cold water**: - Melts to form a silvery ball - Moves on water surface with a hissing sound - Burns with golden yellow flame - Dissolves in water to give an alkaline solution	Sodium + Water ➔ Sodium hydroxide + Hydrogen
Calcium	Reacts with **cold water**: - Sinks to the bottom - Reacts readily to give colorless gas bubbles - Forms a milky suspension (calcium hydroxide)	Calcium + Water ➔ Calcium hydroxide + Hydrogen
Magnesium	Reacts with **hot water slowly**. Reacts with **steam vigorously**: - Give an intense white light to form a white solid	Magnesium + **Water** ➔ Magnesium **hydroxide** + Hydrogen Magnesium + **Steam** ➔ Magnesium **oxide** + Hydrogen
Aluminium	Aluminium usually covered by a thin layer of **aluminium oxide** which prevents the reaction between aluminium and steam.	Aluminium + Steam ➔ Aluminium oxide + Hydrogen
Zinc	Reacts with **steam** to give a powder **(Hot: Yellow; Cold: White)**	Zinc + Steam ➔ Zinc oxide + Hydrogen
Iron	Reacts with **steam** to give a **black powder**	Iron + Steam ➔ Iron(II, III) oxide + Hydrogen
Lead, Copper, Mercury, Silver, Platinum, Gold	No reaction with water or steam	---



Calcium + Water set-up



Magnesium + Water set-up

Intensive notes (Topic 3: Metals)

Reaction of metals with dilute sulphuric acid and dilute hydrochloric acid

Metal	Observation	Word equation
Potassium	React **explosively** because **flammable hydrogen gas** is given off and the reaction **produced a lot of heat**	Metal + Dilute hydrochloric acid ➔ Metal chloride + Hydrogen Metal + Dilute sulphuric acid ➔ Metal sulphate + Hydrogen
Sodium	React **explosively** because **flammable hydrogen gas** is given off and the reaction **produced a lot of heat**	
Calcium	Reacts **readily** to give **colorless gas** *Insoluble calcium sulphate forms. When the metal surface is fully covered by calcium sulphate, the reaction stops as the metal is no longer in contact with the acid.	
Magnesium	Reacts **readily** to give **colorless gas**	
Aluminium	Reacts **readily** to give **colorless gas**	
Zinc	Reacts **readily** to give **colorless gas**	
Iron	Reacts **readily** to give **colorless gas**	
Lead	Reacts **very slowly** to give **colorless gas** *Insoluble lead(II) sulphate / lead(II) chloride forms. When the metal surface is fully covered by lead(II) sulphate / lead(II) chloride, the reaction stops as the metal is no longer in contact with the acid.	
Copper	No reaction with both acids	---
Mercury	No reaction with both acids	---
Silver	No reaction with both acids	---
Platinum	No reaction with both acids	---
Gold	No reaction with both acids	---

Displacement reaction

- A metal will displace a less reactive metal from solution of the compound of the less reactive metal, but not vice versa.

  Example 1: **Zinc + Copper(II) sulphate ➔ Copper + Zinc sulphate**

  Zinc is more reactive than copper. Zinc displaces copper metal from the copper(II) sulphate solution.

  Example 2: **Silver + Zinc sulphate ➔ No reaction**

  Silver is less reactive than zinc. There is no reaction between silver and zinc sulphate solution

Note: When **potassium / sodium / calcium** is added to the solution of a metal compound, **colorless gas** will also be given out because these metals can **react with water in the solution** directly.

Appearance of metals

Copper: Reddish brown solid

Gold: Yellow solid

Mercury: Silvery grey liquid

Others: Silvery grey solid

Steps for writing an ionic equation

1. Write down the FULL chemical equation

$$3\ H_2SO_4(aq) + 2\ Al(OH)_3(s) \rightarrow Al_2(SO_4)_3(aq) + 6\ H_2O(l)$$

Note: This is the reaction between acid and a base, producing salt and water

2. Split the compounds that are soluble in water (aqueous state) into individual ions

$$6\ H^+(aq) + 3\ SO_4^{2-}(aq) + 2\ Al(OH)_3(s) \rightarrow 2\ Al^{3+}(aq) + 3\ SO_4^{2-}(aq) + 6\ H_2O(l)$$

Note: Pay attention to the coefficient of H^+. Do not write $3H_2$. It is an acid not hydrogen gas.
$Al(OH)_3$ is insoluble in water. Do NOT split it into Al^{3+} and $3OH^-$

3. Cancel out the ions that appear in both sides. Simplify the equation if needed.

$$6\ H^+(aq) + \boxed{3\ SO_4^{2-}(aq)} + 2\ Al(OH)_3(s) \rightarrow 2\ Al^{3+}(aq) + \boxed{3\ SO_4^{2-}(aq)} + 6\ H_2O(l)$$

$$\boxed{6}\ H^+(aq) + \boxed{2}\ Al(OH)_3(s) \rightarrow \boxed{2}\ Al^{3+}(aq) + \boxed{6}\ H_2O(l)$$

Ionic equation: $$3\ H^+(aq) + Al(OH)_3(s) \rightarrow Al^{3+}(aq) + 3\ H_2O(l)$$

Note: Since SO_4^{2-} does not participate in the reaction, we call them '<u>spectator ion</u>'.

4. If ALL ions are cancelled out, there is NO REACTION between 2 compounds

$$NaCl(aq) + KBr(aq) \rightarrow NaBr(aq) + KCl(aq)$$

$$\boxed{Na^+(aq)} + \boxed{Cl^-(aq)} + \boxed{K^+(aq)} + \boxed{Br^-(aq)} \rightarrow \boxed{Na^+(aq)} + \boxed{Br^-(aq)} + \boxed{K^+(aq)} + \boxed{Cl^-(aq)}$$

States of common chemicals

A. Gas (g)

- He, Ne, Ar, F_2, Cl_2, O_2, N_2, H_2, CO_2, CO, NO_2, NO, SO_3, SO_2, CH_4, NH_3, H_2S, PH_3

B. Liquid (l)

- Br_2, Hg, H_2O, CH_3OH

C. Solid (s)

- All Insoluble salts
- All metals (except Hg)
- C, P_4, S_8, SiO_2, I_2, B, Si

D. Aqueous state (aq)

- Substances that are soluble in water (soluble salts, acids, alkalis etc)

  Note: $Cl_2(g)$, $Br_2(l)$, and $I_2(s)$ can exist as $Cl_2(aq)$, $Br_2(aq)$ and $I_2(aq)$

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Mole calculation

$\text{Mole} = \dfrac{\text{Mass}}{\text{Molar mass}}$	$(\text{Mole}) \times (\text{Avogadro's constant}) = \text{No. of formula unit}$

1. Calculate the number of oxygen atoms in 60.1 g of quartz. (Relative atomic masses: O = 16.0, Si = 28.1)

   Answer: Mole of SiO_2 = (mass) / (molar mass) = 60.1 / (28.1 + 16x2) = 1

   Number of formula unit (i.e. amount of SiO_2) = (mole) x (Avogadro's constant)

   = 1 x 6.02 x 10^{23} = 6.02 x 10^{23}

   Since 1 SiO_2 contains 2 O atoms, number of atoms = 6.02 x 10^{23} x 2 = 1.204 x 10^{24}

2. Calculate the number of atoms in 14.0 g of nitrogen gas. (Relative atomic mass of N = 14.0)

   Answer: Mole of nitrogen (N_2) = mass / molar mass = 14 / 14x2 = 0.5

   Number of formula unit (i.e. amount of N_2 molecules) = (mole) x (Avogadro's constant)

   = 0.5 x (6.02 x 10^{23}) = 3.01 x 10^{23}

   Since 1 N_2 molecules contains 2 N atoms, number of atoms = 3.01 x 10^{23} x 2 = 6.02 x 10^{23}

3. Calculate the number of ions in 1 mol of iron(III) sulphate

   Answer: Number of formula unit (i.e. amount of $Fe_2(SO_4)_3$) = (mole) x (Avogadro's constant)

   = 1 x (6.02 x 10^{23}) = 6.02 x 10^{23}

   Since 1 $Fe_2(SO_4)_3$ contains 2 Fe^{3+} ions and 3 SO_4^{2-} ions, number of ions = 6.02 x 10^{23} x (2+3) = 3.01 x 10^{24} ions

4. Calculate the mass of 30624700 C atoms (Relative atomic mass of C = 12.0)

   Answer: Number of moles of 30624700 C atoms = (no. of formula unit) / (Avogadro's constant)

   = 30624700 / 6.02 x 10^{23} = 5.087 x 10^{-17}

   Mass of 30624700 C atoms = (mole) x (Molar mass) = 5.087 x 10^{-17} x 12.0 = 6.10 x 10^{-16} g.

5. Calculate the mass of 534202 oxygen molecules. (Relative atomic mass of O = 16.0)

   Answer: Number of moles of 534202 oxygen molecules (O_2) = (no. of formula unit) / (Avogadro's constant)

   = 534202 / 6.02 x 10^{23} = 8.87 x 10^{-19}

   Mass of 534202 oxygen molecules = (mole) x (Molar mass) = 8.87 x 10^{-19} x (16.0 x 2) = 2.84 x 10^{-17} g.

Deduce the empirical formula of a compound

- 2.21 g of an oxide of platinum is heated strongly until no further reaction. The mass of the solid remaining is 1.97 g. What is the chemical formula of this oxide? (Relative atomic masses: O = 16.0, Pt = 197.0)

	Pt	**O**
Mass	1.97	2.21 – 1.97 = 0.24
Mole	1.97 / 197 = 0.01	0.24 / 16 = 0.015
Simplest ratio	0.01 / 0.01 = 1	0.015 / 0.01 = 1.5

The formula is Pt_2O_3

Deduce the molecular formula of a compound from empirical formula

- Compound W contains carbon, hydrogen and oxygen only. The relative molecular mass of W is 88. Complete combustion of 1.32 g of W gives 2.64 g of carbon dioxide and 1.08 g of water. (Relative atomic masses: H = 1.0, C = 12.0, O = 16.0)

	C	**H**	**O**
Mass	2.64 x [12 / (12 + 16x2)] = 0.72	1.08 x [1x2 / (1x2 + 16) = 0.12	1.32 – 0.72 – 0.12 = 0.48
Mole	0.72 / 12 = 0.06	0.12 / 1 = 0.12	0.48 / 16 = 0.03
Simplest ratio	0.06 / 0.03 = 2	0.12 / 0.03 = 4	0.03 / 0.03 = 1

The empirical formula is C_2H_4O. Let the molecular formula be $(C_2H_4O)_n$

n (12x2 + 1x4 + 16) = 88

n = 2 (The molecular formula is $C_4H_8O_2$)

Mole calculation and percentage yield

1. In an experiment, 17 g of NH_3 and excess O_2 are allowed to react. The equation for the reaction is shown below:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

(Relative atomic masses: H = 1.0, N = 14.0, O = 16.0)

(a) Calculate the theoretical yield of H_2O.

Answer: Mole of NH_3 used = 17 / (14 + 1x3) = 1

Theoretical mole of H_2O obtained = 1 x 6/4 = 1.5

Theoretical mass of H_2O obtained = 1.5 x (1x2 + 16) = 27 g

(b) If the mass of H_2O obtained is 5.4 g, calculate the percentage yield of H_2O

Answer: Percentage yield = Actual mass / theoretical mass x 100% = 5.4/27 x 100% = 20%

(c) Suggest a reason why the percentage yield cannot reach 100%.

Answer: Incomplete reaction

2. Under certain conditions, 1.0 g of SiO_2 is allowed to react with 1.0 g of Mg. The equation for the reaction is shown below:

$$SiO_2 + 2Mg \rightarrow 2MgO + Si$$

(Relative atomic masses: O = 16.0. Mg = 24.3, Si = 28.1)

(a) Determine the limiting reactant in this reaction.

Answer: Mole of SiO_2 used = 1 / (28.1 + 16x2) = 0.0166

0.0166 mol of SiO_2 requires 0.0166 x 2 = 0.0333 mol of Mg for complete reaction

Mole of Mg used = 1 / 24.3 = 0.0411 > 0.0333 (SiO_2 is limiting and Mg is in excess)

(b) Calculate the theoretical mass of Si that can be formed.

Answer: Theoretical mole of Si obtained = 0.0166 x 1 = 0.0166

Theoretical mass of Si obtained = 0.0166 x 28.1 = 0.468 g

Corrosion

- Corrosion of metal refers to the gradual deterioration of a metal, resulting from the reaction of the metal with air, water or other substances in the environment.

In general, the more reactive a metal, the more rapidly it corrodes.

Note: Rusting refers to the corrosion of **iron** only, but not other metals

Chemistry of rusting

Essential conditions of rusting: Water and oxygen

Step 1: Iron ➔ Iron(II) ion ($Fe \rightarrow Fe^{2+} + 2e^-$)

Water + Oxygen ➔ Hydroxide ion ($O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$)

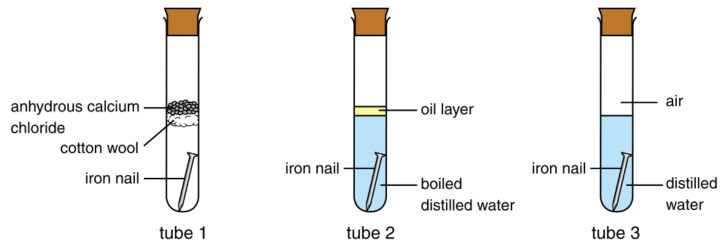
Step 2: Iron(II) ion + Hydroxide ion ➔ Iron(II) hydroxide ($Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$)

Step 3: Iron(II) hydroxide + Water + Oxygen ➔ Iron(III) hydroxide ($4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3$)

Step 4: Iron(III) hydroxide ➔ **Hydrated iron(III) oxide (Rust, reddish brown solid)**

Overall equation: $4Fe(s) + 3O_2(g) + 2nH_2O(l) \rightarrow 2Fe_2O_3 \cdot nH_2O$

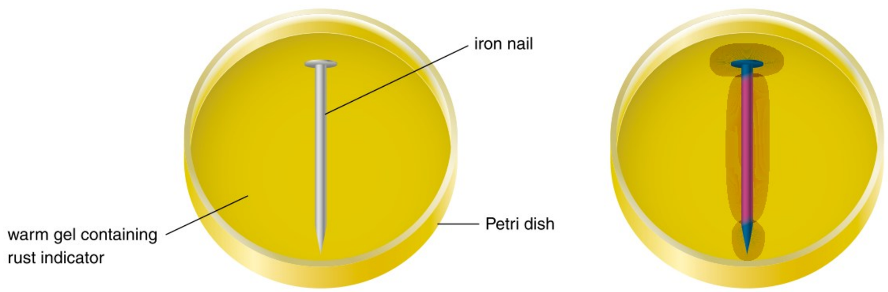
Experiments related to rusting



Tube 1: No rusting will occur. Anhydrous calcium chloride is a drying agent. It removes water from the air. Therefore the iron nail in tube 1 has no contact with water.

Tube 2: No rusting will occur. Boiled distilled water removes dissolved oxygen in water. The oil layer prevents oxygen from dissolving in water again. Therefore the iron nail in tube 2 has no contact with oxygen.

Tube 3: Rusting will occur. It is because iron nail in tube 3 has contact with water and oxygen. Note that normal distilled water still contains dissolved oxygen.



Blue area: When iron rusts, iron(II) ion (Fe^{2+}) will be formed. It turns **potassium hexacyanoferrate(III) ($K_3Fe(CN)_6$) blue**.

Pink area: Hydroxide ion (OH^-) forms during rusting. It turns **phenolphthalein pink**.

Note 1: Uneven, scratched, bent or sharp area of an iron object will rust more readily.

Note 2: Gel can slow down the diffusion of the color patches for easier observation

Intensive notes (Topic 3: Metals)

<table>
<tr><th>Method of rust prevention</th><th>Chemistry</th><th>Advantage</th><th>Disadvantage</th><th>Example</th></tr>
<tr><td>Painting</td><td rowspan="6">Added layer prevents the iron object from contact with aid and water</td><td>- Cheap</td><td>- Scratched off</td><td>1. Bridges
2. Ships
3. Fences
4. Car bodies</td></tr>
<tr><td>Coating with plastic</td><td>- Lasts long
- Looks good</td><td>- More expensive than painting</td><td>1. Coat hangers
2. Paper clips</td></tr>
<tr><td>Greasing</td><td>- Does not fall off
- Lubricating effect</td><td>- Not once and for all
- Dirt would stick to grease</td><td>1. Moving parts of machine
2. Woodworking tools</td></tr>
<tr><td>Galvanizing (zinc-plating)</td><td>- In case the zinc is scratched, the iron is still protected</td><td>- Zinc ions are toxic</td><td>1. Construction
2. Buckets</td></tr>
<tr><td>Tin-plating</td><td>- Tin is corrosion resistant
- Tin is not toxic</td><td>- When tin is scratched, iron rusts more quickly as tin is less reactive than iron</td><td>1. Tin food cans</td></tr>
<tr><td>Electroplating</td><td>- Beautiful appearance</td><td>- Expensive</td><td>1. Water taps
2. Car bumpers</td></tr>
<tr><td>Cathodic protection</td><td>Iron object is connected to the negative terminal of an electric source. It supplies electrons to prevent iron from losing electrons</td><td>- Convenient</td><td>- Not applicable to many objects</td><td>1. Car bodies
2. Underground water pipes
3. Storage tanks
4. Steel pier legs</td></tr>
<tr><td>Sacrificial protection</td><td>Iron object is connected to a more reactive metal. It loses electrons more readily than iron.</td><td>- Effective</td><td>- Sacrificed metal needs replacement</td><td>1. Galvanized iron
2. Pipelines connected to Mg</td></tr>
<tr><td>Alloying</td><td>Iron object is mixed uniformly with other elements such as C, Cr, Mn. (Cr_2O_3 layer which is impermeable to O_2 and H_2O)</td><td>- Beautiful appearance
- Effective</td><td>- Expensive</td><td>1. Cookware
2. Cutlery</td></tr>
</table>

Factors that speed up rusting

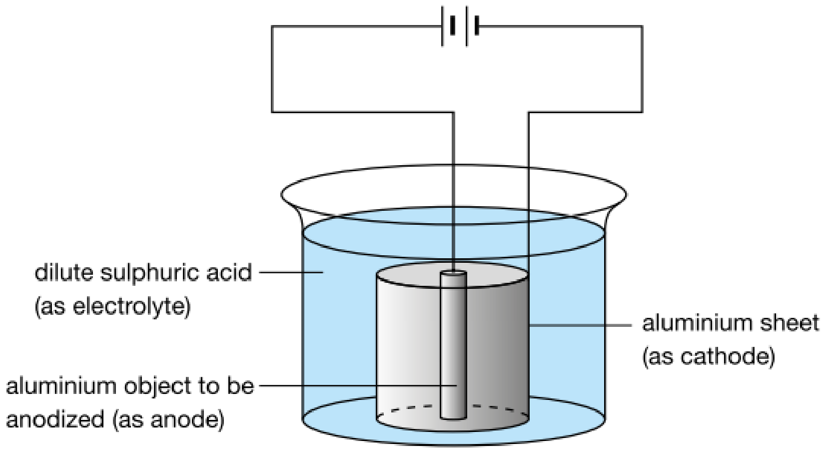
1. Presence of salt (Salt increases the electrical conductivity)
2. Presence of acid (Acid increases the electrical conductivity and promotes iron(II) ion formation)
3. High temperature (Higher temperature, higher reaction rate)
4. Attachment of less reactive metal (e.g. tin, lead, copper, silver) to iron

Corrosion resistance of aluminium

Aluminium has a thin layer of aluminium oxide which is impermeable to water and oxygen.

Anodization: A process to thicken the aluminium oxide layer on the surface of aluminium.

In anodization, the aluminium object is connected to a **positive terminal** of the battery



Anodized aluminium object has a **higher corrosion resistance** and can be **dyed more easily**.