Microscopic world I

- Isotopes: Atoms with the **same number of protons and electrons**, but with a **different number of neutrons.**
- Physical properties: *How a substance behaves on its own (e.g. melting point)*
- Chemical properties: *How a substance reacts with other substances **chemically** to create new compounds/elements.*
- Significance of a "group" on the periodic table:
  - A group has elements which all have the **same** number of **outermost shell electrons** → **similar chemical properties**
  - Properties of elements on the same group have a trend down the group
    - E.g. Group I metals are more reactive down the group.
    - The boiling point of *halogens* increases down the group.

Giant metallic structure	Giant Ionic Structure	Simple molecular structure	Giant covalent structure
Metallic bond between metal ion and 'sea' of delocalized electrons	Ionic bonding between positively and negatively charged ions	*Intermolecular forces* between molecules	Covalent bonds between **atoms**
Strength: 3rd Typical boiling point: ~800K	Strength: 2nd Typical boiling point: ~1000K	Strength: 4th Typical boiling point: ~200K	Strength: 1st Typical boiling point: ~3000K
Malleable Ductile	Brittle	???	Hard
Can conduct electricity	Can conduct electricity **only in molten or aqueous state**	Cannot conduct electricity	Cannot conduct electricity (except graphite)
Metals (e.g. Al)	Compounds between metal and non metal elements/compound ions (e.g. Na_2CO_3)	Non-metallic compounds (e.g. H_2O)	Diamond (C) Graphite (C) Quartz (SiO_2)

- Electrical conductivity:
  - A substance can conduct electricity as long as it has sufficient **delocalized electrons or mobile ions**
  - If it has neither, it cannot conduct electricity.

Example:

a) Magnesium and calcium are Group II elements.

i) What is the name of Group II elements? (1 mark)

Alkaline Earth Metals

ii) Explain, in terms of electronic arrangements of their atoms, why magnesium and calcium have similar chemical properties. (1 mark)

They have the same number of outermost shell electrons.

iii) Predict, with ONE reason, whether magnesium or calcium is more reactive. (1 mark)

Calcium is more reactive. Calcium has one more electron shell than magnesium, the attraction force between calcium and its outmost shell electron is weaker than that in magnesium. Calcium loses its outmost electron more readily than magnesium, hence it is more reactive.
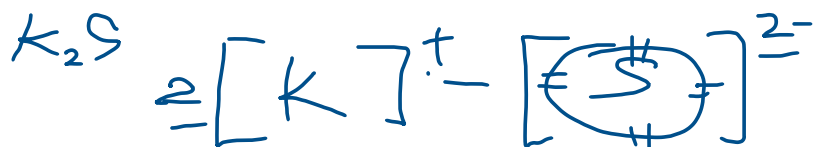
// Calcium, reactivity of group II metals increases down the group.

b) Potassium combines with sulphur to form compound X.

i) State the type of bonding involved in compound X. (1 mark)

Ionic bonding

ii) Draw an electron diagram of compound X, showing electrons in outermost shells only. (1 mark)

iii) Name compound X. (1 mark)

Potassium Sulphide

iv) What is the formula mass of compound X? (1 mark)
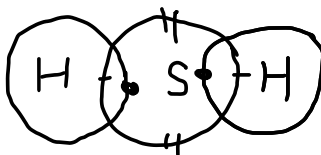(Relative atomic mass: K = 39.1, S = 32.1)

110.3

c) Hydrogen combines with sulphur to form compound Y.

i) State the type of bonding involved in compound Y. (1 mark)

Van der waal's force

ii) Draw an electron diagram of compound Y, showing electrons in outermost shells only. (1 mark)

iii) Name compound Y. (1 mark)

Hydrogen Sulphide

d) State with explanation, which compound (X or Y) has a higher melting point. (2 marks)

K2S has a giant ionic structure while H2S has simple molecular structure

Ionic bonds between K+ and S2- in K2S are stronger than the van der waal's forces between H2S

Molecules. Hence, K2S has a higher melting point.

a) i) Alkaline earth metals (1)

ii) Their atoms have the same number of outermost shell electrons. (1)

iii) Calcium is more reactive than magnesium.

The reactivity of Group II elements increases down the group. / The electron in the outermost shell (valence electron) of Ca is weakly bounded by the nucleus as compared with that of Mg. / Ca atom loses its outermost shell electron more easily than Mg atom. / Ca atom loses its electron more easily than Mg atom because Ca has more electron shells than Mg / the size of Ca atom is larger than that of Mg / the atomic radius of Ca is larger than that of Mg. / Both Ca and Mg are Group II metal, and the size of Ca atom is larger than that of Mg. (1)

b) i) Ionic bonding (1)

iii) Potassium sulphide (1)

iv) $2 \times 39.1 + 32.1$

$= 110.3$ (1) **NO UNIT**

c) i) Covalent bonding (1)

iii) Hydrogen sulphide (1)

d) The electrostatic attraction between $K+$ and $S2–$ in $K2S$/compound X is ionic bond while intermolecular attraction between $H2S$/Y molecules are van der Waals' forces. / Compound X is an ionic compound while compound Y has a simple molecular structure. (1)

As ionic bond between ions is much stronger than van der Waals' forces / intermolecular forces between compound Y molecules, compound X would have a higher melting point than compound Y. (1)

Metals
Extraction

Heating in air alone	Heating in air with carbon	Electrolysis of **molten ore**
Suitable for: • Silver (Ag) • Non reactive metals	Suitable for: • Up to Zn	Suitable for: • Literally everything • Reactive metals

Reactivity of metals

Reactivity: The tendency for a metal atom to form positive ions (and react with other species)

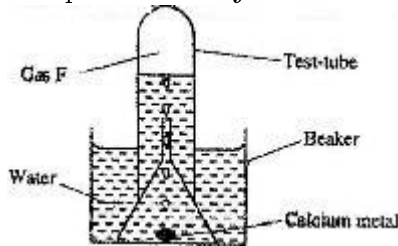Reactivity series (most to least reactive):

K Na Ca Mg Al Zn Fe Pb Cu Ag Au

Typical reactions

Reaction with oxygen (burning in air):

Metals applicable	Observation	Products
Everything more reactive than Cu (Cu included)	• Respective flame colour • White (oxide) layer formed on metal	Metal Oxide (e.g. Fe_2O_3)

Reaction with water: Na K Ca:

Metals applicable	Observation	Products
Na K Ca Setup for **Ca only** Gas F —Test-tube —Beaker Water —Calcium metal **Reaction with steam:** **Fe and above**	• Colourless Gas bubbles formed • Hissing sound • Respective flame colour (except Ca)	Metal Hydroxide (NaOH) H_2 Hydrogen gas Reaction with steam: Metal Oxide Hydrogen gas

Reaction with acid

Metals applicable	Observation	Products
Everything more reactive than Cu (Cu **NOT** included)	• Colourless Gas bubbles formed • Colour solution (if metal ion has colour) • Metal dissolves in the solution	Metal Salt (e.g. $ZnSO_4$) H_2 Hydrogen gas

Displacement reaction

| Metals applicable	Observation	Products
Metal ion in aqueous solution is LESS REACTIVE than the metal in solid state (e.g. Mg(s) in $FeSO_4$(aq))	• Metal deposits form on the solid metal strip • Change in colour of solution (for coloured metal ions)	Less reactive metal as solid More reactive metal as metal ion

Example: Extraction of Zinc

16 Zinc blende mainly consists of zinc sulphide. Zinc can be extracted from its ore by two steps.

Step 1: zinc sulphide + oxygen → zinc oxide + sulphur dioxide

Step 2: zinc oxide + carbon → zinc + carbon dioxide

a) Write chemical equations for the two processes involved. (2 marks)

Step 1: $2ZnS_s + 3O_{2\ g} \rightarrow 2ZnO_s + 2SO_{2\ g}$

Step 2: $2ZnO_s + C_s \rightarrow 2Zn_s + CO_{2\ g}$
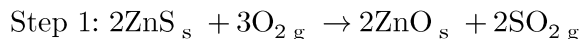
b) In the reaction, 86.0 g of zinc sulphide are used to extract the zinc.

i) Calculate the percentage by mass of zinc in zinc sulphide. (2 marks)

(Relative atomic masses: S = 32.1, Zn = 65.4)

67.1%

ii) Assuming that the percentage yield of the reaction is 80.0%. Calculate the mass of zinc obtained. (3 marks)

86.0 * 67.1% (mass of Zn theoretically)

= 57.7g

57.7 * 0.8 (* percentage yield)
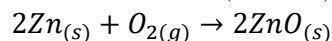
=46.1g

d) Zinc forms zinc oxide when burnt in air.

i) State ONE expected observation. (1 mark)

White layer formed on the metal

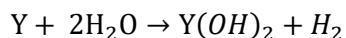ii) Write a chemical equation for the reaction involved. (1 mark)

$$2Zn_{(s)} + O_{2(g)} \rightarrow 2ZnO_{(s)}$$

17 The results of experiments of three metals X, Y and Z are summarized in the following table.

| Metal	React with cold water	React with dilute hydrochloric acid	React with copper(II) sulphate solution
X	no observable change	no observable change	no observable change
Y	gas bubbles formed steadily	gas bubbles formed vigorously	a reaction occurs
Z	no observable change	gas bubbles formed slowly	a reaction occurs

a) It is known that Y is an alkaline earth metal and sinks in water.

i) Draw a labeled diagram of the set-up for carrying out the reaction between Y and cold water, with the collection of the gaseous product. (2 marks)

ii) Write a chemical equation for the reaction between Y and water. (1 mark)
$$Y + 2H_2O \rightarrow Y(OH)_2 + H_2$$

b) Z can form stable Z^{2+} ions.

i) Write a chemical equation for the reaction between Z and dilute hydrochloric acid. (1 mark)
$$Z_{(s)} + 2HCl_{(aq)} \rightarrow ZCl_{2\,(aq)} + H_{2(g)}$$
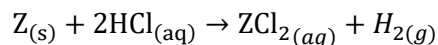
ii) Suggest an observable change when Z reacts with copper(II) sulphate solution. Write an ionic equation for the reaction involved. (2 marks)

Reddish brown solids form on the surface of Z
$$Z + Cu^{2+} \rightarrow Z^{2+} + Cu$$
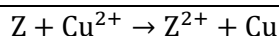
c) Arrange the four metals (X, Y, Z and copper) in descending order of reactivity. Explain your answer. (4 marks)

Y > Z > Cu > X

Y is the most reactive since ONLY Y can react with cold water

X is least reactive since only X cannot displace Cu from CuSO4

Z is more reactive than Cu since it can displace Cu from CuSO4

Mole calculations

There is no better way to get good at moles other than to just do a lot of it. But remember a few principles:

- Mole is a unit for a number i.e. 1 mole = 6.02 * 10^23, it acts just like how a dozen represents 12.
- Mass is conserved → Mass and amount of the same element on both sides of the equation MUST BE THE SAME (assuming no loss of products)
- Relative atomic mass * number of mole = actual mass of the substance on hand (g)

- When seeing a formula, find the limiting reactant. Then the amount of the product can be calculated by multiplying the appropriate mole ratio
- This is important for titration and analytical chemistry. Though I suggest practicing before attempting those questions.

Example:

MO is an oxide of metal M. Upon heating, MO decomposes to give M and oxygen only.

In an experiment, 26.0 g of MO completely decompose to give 24.1 g of M. Calculate the relative atomic mass of M.
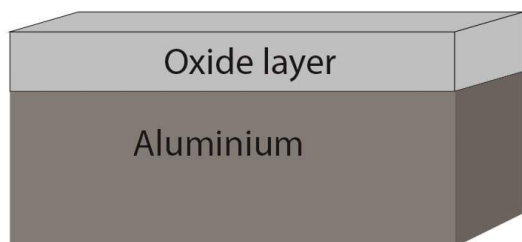
Rusting

Rust is $Fe_2O_3 \bullet nH_2O$ *(hydrated Iron(III) oxide)*

Ways to prevent rust:

Galvanizing (Zn Plating)	Electroplating	Painting
Cathodic protection	Sacrificial protection	Tin plating
Alloying	greasing	

Aluminum:

More reactive than Fe, but much more corrosion resistant, why???

Oxide layer
Aluminium

- Al has an oxide layer on it **which is impermeable to water and oxygen in air;** in comparison, Fe's oxide layer is **permeable** to water and oxygen in air.
- The oxide layer prevents contact between Al metal underneath and oxygen and water in air → no further corrosion.
- The oxide layer can be thickened by *anodization*
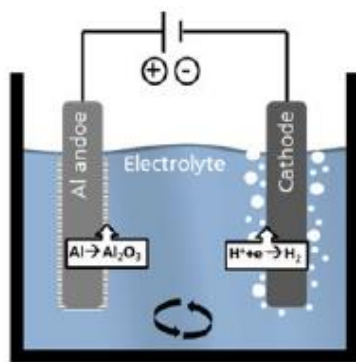
Perks of **anodization**

- Enhanced corrosion resistance
- Allows Al to be easily dyed → improve appearance

Example: DSE 2019-Q9

Iron cans used to store food products are commonly coated with a thin layer of tin.

(a) The thin layer of tin prevents iron cans from corrosion.

(i) Briefly describe the principle for this kind of corrosion prevention. (1 mark)

Tin layer can prevent Fe from contact and reacting with water and oxygen in air

(ii) Explain whether these iron cans would corrode more readily once their surfaces are damaged by scratching. (1 mark)

Yes, tin is less reactive than iron, so iron would lose electrons to tin, thus causing iron to form iron(II)

Ions more readily than before.

(iii) Suggest why galvanisation is not suitable to prevent corrosion in iron cans that are used to store food products. (1 mark)

Zinc ions are poisonous

(b) There is an increasing trend for manufacturers to use cans made entirely of aluminium for storing food products.

(i) Explain why aluminium is more resistant to corrosion than iron, although it occupies a higher position than iron in the reactivity series. (1 mark)

Al has an oxide which is impermeable to oxygen and water in air, so it can prevent Al underneath

From contacting and reacting with air and oxygen and further corrode.

(ii) Name the process that increases the corrosion resistance of aluminium cans. (1 mark)

Anodization

(iii) Other than corrosion resistance, suggest one advantage of using aluminium to make cans. (1 mark)

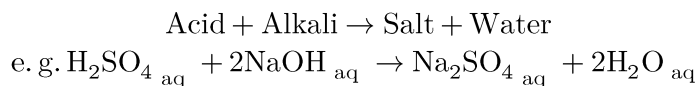Allow Al to be easily dyed to improve appearance.

Acid and alkalis

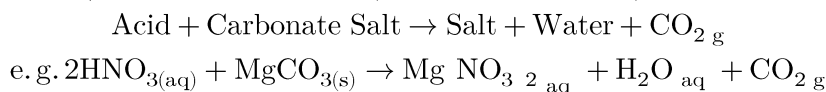| Acid	Alkali
Species responsible: $H^+_{(aq)}$	Species Responsible: $OH^-_{(aq)}$
Corrosive, sour	Corrosive, bitter and slippery
Basicity: The maximum $H^+_{(aq)}$ ions (or OH^-) formed per molecule of the substance when it is dissolved in water	
No special definition	<mark>Base: A substance which reacts with acids to give **salt and water as its only products**</mark>
Strong: HCl, Weak: CH₃COO**H**	Strong: NaOH, KOH Weak:

Reactions of acids

Reaction with alkalis (neutralization)

The reaction between acid and base/alkali to form water and salt only

$$\text{Acid} + \text{Alkali} \rightarrow \text{Salt} + \text{Water}$$
$$\text{e. g.} \ H_2SO_4 \ _{aq} + 2NaOH \ _{aq} \rightarrow Na_2SO_4 \ _{aq} + 2H_2O \ _{aq}$$
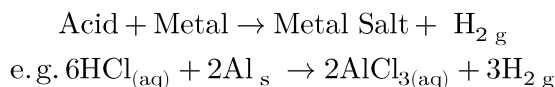
- Exothermic (Temperature increases)
- If the base is not soluble (solid form) then the base is observed to dissolve in the solution.

Reactions with carbonates/hydrogencarbonates (NOT neutralization)

$$\text{Acid} + \text{Carbonate Salt} \rightarrow \text{Salt} + \text{Water} + CO_2 \ _g$$
$$\text{e. g.} \ 2HNO_{3(aq)} + MgCO_{3(s)} \rightarrow Mg \ NO_3 \ _{2 \ aq} + H_2O \ _{aq} + CO_2 \ _g$$

- Colourless gas bubbles are given out
- Insoluble carbonate salts dissolve in the reaction mixture

Reactions with metals

$$\text{Acid} + \text{Metal} \rightarrow \text{Metal Salt} + \ H_2 \ _g$$
$$\text{e. g.} \ 6HCl_{(aq)} + 2Al \ _s \rightarrow 2AlCl_{3(aq)} + 3H_2 \ _g$$
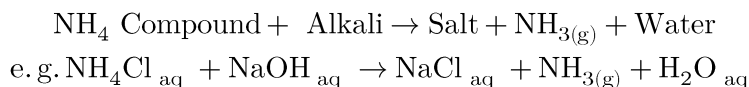
- See Metals - [Typical reactions](#)

Reactions of alkalis

Neutralization, see above.

Reaction with ammonium compounds under heating

$$NH_4 \ \text{Compound} + \ \text{Alkali} \rightarrow \text{Salt} + NH_{3(g)} + \text{Water}$$
$$\text{e. g.} \ NH_4Cl \ _{aq} + NaOH \ _{aq} \rightarrow NaCl \ _{aq} + NH_{3(g)} + H_2O \ _{aq}$$

- Pungent gas is formed
- Place a **moist** red litmus paper at the mouth of the test tube ➔ colour of the red litmus paper turns from red to blue (why?)

Reaction with metal ions

Metal ion	Reaction with $NaOH_{(aq)}$	Reaction with $NH_{3(aq)}$
Ca^{2+}	White precipitate is formed.	White precipitate is formed.
Mg^{2+}	White precipitate is formed.	White precipitate is formed.
Al^{3+}	White precipitate is formed. **Redissolves in excess alkali to form colourless solution**	White precipitate is formed.
Zn^{2+}	White precipitate is formed. **Redissolves in excess alkali to form colourless solution**	White precipitate is formed. **Redissolves in excess alkali to form colourless solution**
Fe^{2+}	Dirty green precipitate is formed.	Dirty green precipitate is formed.
Fe^{3+}	Dirty brown precipitate is formed.	Dirty brown precipitate is formed.
Cu^{2+}	Blue precipitate is formed	Blue precipitate is formed **Redissolves in excess alkali to form deep blue solution**
Pb^{2+}	White precipitate is formed. **Redissolves in excess alkali to form colourless solution**	White precipitate is formed.
Ag^+	Dirty brown precipitate is formed.	Dirty brown precipitate is formed. **Redissolves in excess alkali to form brown solution**

General ionic equation (for precipitate)

$$M^{n+}_{(aq)} + nOH^-_{(aq)} \rightarrow M(OH)_{n\ s}$$
$$e.g.\ \ Fe^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Fe(OH)_{2\ s}$$
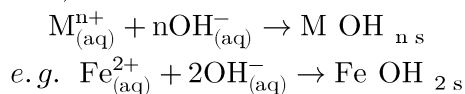
Concentration

Describes how concentrated (or how much) a substance is inside the volume.

$$concentration = \frac{amount(mol)}{volume}$$

This is *occasionally* useful in chemistry since a lot of experiments are conducted with aqueous solutions.

pH and indicators

Litmus (useless)

<6.5	6.5-8	>8

Methyl Orange

<3	3-4.4	>4.4

Phenolphthalein

<9	~9-10	>10

Indicators will become important for titration as their colour change indicates the *end point* of the reaction.

pH: a scale for the concentration of $H^+_{(aq)}$ within the solution

$$pH = -\log[H^+_{(aq)}]$$

$$\text{Also, } [H^+_{aq}] = 10^{-pH}$$

pH scale:

0-2	3-7	7	8-12	12-14
Strongly acidic	Weakly acidic	Neutral	Weakly alkaline	Strongly alkaline

Useful to know: Distilled water contains $[H^+_{aq}] = 10^{-7} \text{mol dm}^{-3}$

Example: Dilute sulphuric acid

Dilute sulphuric acid is a commonly used acid in the laboratory. It is a strong acid.
a) Explain the term 'strong acid'. (1 mark)
Strong acid completely ionizes in water to give out $H^+_{(aq)}$

b) Describe how to dilute concentrated sulphuric acid. (1 mark)
Prepare a large beaker of water, and slowly pour concentrated sulphuric acid into the water.

If water is poured into conc. Sulphuric acid, the resulting ionization reaction is highly exothermic, resulting in the conc. Acid splashing out.

c) Assume that sulphuric acid completely ionises in water, calculate the pH of 0.050 mol dm^{-3} sulphuric acid. (2 marks)
[H+(aq)] = 0.050 * 2 = 0.1M

pH = -log(0.1) = 1

e) What would be observed when a piece of magnesium ribbon is added to dilute sulphuric acid? Write an ionic equation for the reaction involved. (2 marks)
$Mg_{(s)} + 2H^+ \rightarrow Mg^{2+}_{(aq)} + H_{2(g)}$
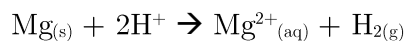
Colourless gas bubbles evolve.

f) What would be observed when a piece of calcium carbonate is added to dilute sulphuric acid? Explain your answer. (2 marks)
$CaCO_{3(s)} + H_2SO_{4(aq)} \rightarrow CaSO_{4(s)} + H_2O_{(l)} + CO_{2(g)}$
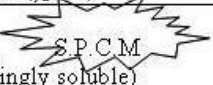
Colourless gas bubble evolves but stops quickly and a white solid is left at the bottom of the solution.

$CaCO_3$ reacts with H_2SO_4 to form insoluble $CaSO_4$ and form a coating on the $CaCO_3$, preventing the $CaCO_3$ underneath from further reacting with H_2SO_4, so the reaction stops quickly.

Salts and preparing salts

Soluble or insoluble? Refer to following chart:

Solubility of Common Salts

Soluble Salts	Insoluble Salts
All Sodium All Potassium S.P.A.N All Ammonium All Nitrates	
All Chlorides (as well as other Halides - Bromides & Iodides)	Lead (II) Chloride Silver Chloride
All Sulphates	Barium Sulphate Calcium Sulphate (sparingly soluble) Lead (II) Sulphate
Sodium Carbonate Potassium Carbonate S.P.A Ammonium Carbonate	All Carbonates
Group I Metal Phosphates e.g. Na_3PO_4 Ammonium Phosphate $(NH_4)_3PO_4$	All Phosphates
Sodium Hydroxide Potassium Hydroxide S.P.C.M Calcium Hydroxide (sparingly soluble) Magnesium Hydroxide (very sparingly soluble)	All Hydroxides

But here's a better way:
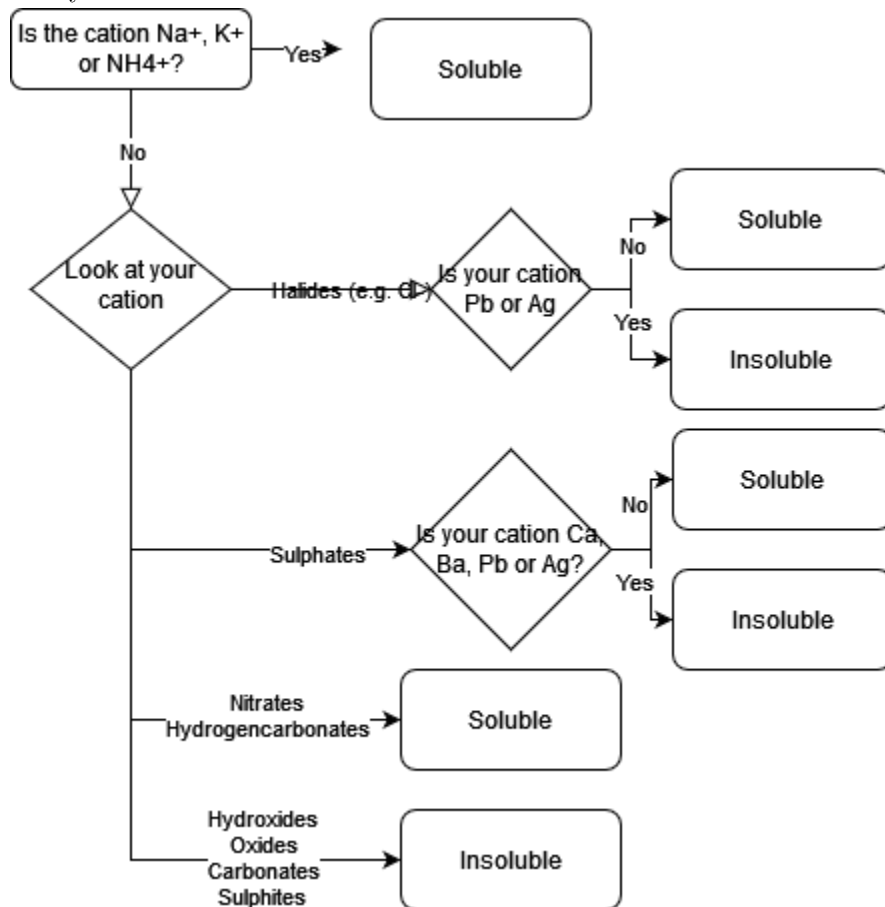
Note: Calcium hydroxide is slightly soluble

Steps to prepare salts:

1. Identify the solubilities of your reactant and products

Soluble → Soluble

1. **Dissolve in distilled water to make an aqueous solution**
2. React with sodium hydroxide → precipitation
3. Filter and obtain residue
4. React with suitable acid (with the residue salt in EXCESS)
5. Dry in oven
6. Wash if needed

Soluble → Insoluble

1. **Dissolve in distilled water to make an aqueous solution**
2. React with sodium solution of the desired anion (e.g. Na_2CO_3)
3. Filter and obtain residue
4. Wash with cold water if needed

Insoluble → Soluble

1. React with suitable acid, with the insoluble reactant in excess
2. Dry the resulting solution in an oven
3. Wash the solid if needed

Insoluble → Insoluble

1. React with suitable acid, with the insoluble reactant in excess
2. Filter and obtain the filtrate (i.e. the liquid)
3. React with sodium solution of the desired anion (e.g. Na_2CO_3)
4. Filter and obtain residue
5. Wash with cold water if needed

Special one: *Crystallization*

1. Obtain whatever salt you want as usual, but leave it in an aqueous solution form
2. Heat the solution until a saturated solution is formed.
3. Let the solution slowly cool down in room temperature
4. Filter the solution and obtain the residue
5. **Wash the crystals with a small amount of cold distilled water** (why?)
6. **Dry with filter paper**
   DO NOT HEAT IN OVEN

Super Special Never seen in DSE one: Na/K/NH$_4$ salt → Na/K/NH$_4$ salt
You need to carry out titration by mixing suitable amounts of acid and alkali to get a pure (enough) solution of Na/K/NH$_4$ salt in its aqueous form and then dry in an oven.

Titration

Standard solution: A solution with a *precisely known* concentration

What salts can be used to create standard solution??

- Chemically stable
- Does not absorb water/carbon dioxide from air
- Ideally large formula mass

Preparing standard solutions:

- Weigh suitable amount of the salt
- Dissolve it in **distilled water** in a beaker
- Transfer solution to 250cm³ (or other volume depending on the question) **volumetric flask**
- Wash the beaker with **distilled water**, pour the washing water in the volumetric flask
- Add water until the **bottom of the meniscus reaches the graduation flask**
- Shake and mix the solution thoroughly

The steps to solve a titration problem:

1. Write down the chemical equation involved
2. Get a reasonable average (usually ditch any outlying values and then take average)
   Outlying values: More than ±0.20 of the other data
3. Identify the endpoint of the reaction to find the **limiting reactant**
4. Mole calculation to find desired product/reactant amount
5. Find whatever you want (mass/concentration) from that mole
6. Profit

Examples for titration: *best way to understand it*

Example 1:

In order to find out the percentage of citric acid in a drug powder, 5.00 g of the powder were dissolved in distilled water and made up to 250.0 cm³ solution. Four 25.0 cm³ portions of the solution were titrated against 0.206 mol dm–3 sodium hydroxide solution. The table lists the titration results obtained:

	Trial 1	Trial 2	Trial 3	Trial 4
Final	31.00	29.65	29.90	29.85
Initial	0.50	0.00	0.30	0.20

a) Citric is a tribasic acid. What is the meaning of 'tribasic acid'? (1 mark)

b) Describe how to prepare 250.0 cm³ of solution from the powder. (3 marks)

c) Calculate the reasonable average for the volume of sodium hydroxide solution required to neutralize 25.0 cm³ of the solution. (1 mark)

_____

_____

_____

d) Calculate the molarity of the solution. (3 marks)

_____

_____

_____

e) Determine the percentage by mass of citric acid in the powder. (2 marks)
(Molar mass of citric acid = 192.0 g mol⁻¹)

_____

_____

_____

Example 2: Determining Solubility

A student used titration to find the solubility of calcium hydroxide with the use of dilute hydrochloric acid. 0.2 M of hydrochloric acid is used to titrate against 25.0 cm3 of calcium hydroxide solution. The following results were obtained.

	Trial 1	Trial 2	Trial 3
Final Reading	19.20	28.05	37.10
Initial Reading	10.00	19.20	28.15

(a) Describe how to prepare the calcium hydroxide solution from calcium hydroxide powder so that its solubility could be found.

_____

_____

_____

(b) Name the apparatus used to transfer 25.0 cm3 of calcium hydroxide solution. Describe how it should be washed before the transfer of solution.

_____

_____

(c) Sketch the titration curve with labelled axes.

(d) (i) Calculate the reasonable average volume of hydrochloric acid used.

_____

_____

(ii) Write the chemical equation involved.

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(iii) Calculate the solubility of calcium hydroxide (in g dm^{-3})

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Example 3: Hard(er) Back titration
2020 DSE Q9
Eggshells mainly contain calcium carbonate and a small amount of organic substances. The percentage by mass of calcium carbonate in a sample of eggshell was determined by the following steps :
Step (1) : The sample was ground into powder.
Step (2): 0.204 g of the powder was put into a conical flask. After that, 25.00 cm^3 of 0.200 M HCl(aq) and 5 cm^3 of ethanol were added.
Step (3): The mixture was heated for 15 minutes.
Step (4): After cooling down, the mixture was titrated with 0.102 M NaOH(aq) using an indicator **X**.
(a) Explain why the sample was ground into powder in Step (1). (1 mark)

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(b) Suggest why ethanol was added in Step (2). (1 mark)

_____

(c) Suggest why the mixture was heated for 15 minutes in Step (3). (1 mark)

_____

(d) The mixture turned from colourless to pale pink at the end point of titration in Step (4). Name indicator **X**.

(e) 16.85 cm₃ of NaOH(aq) was needed to reach the end point of titration in Step (4). Calculate the percentage by mass of calcium carbonate in the sample. (3 marks)
(Relative atomic masses: C = 12.0, 0 = 16.0, Ca = 40.1)

Ex1:
    (a) Each citric acid molecule can ionise in water to give out 3 hydrogen ions at most.
    (b) preparation of the standard solution:
        i.   Dissolve powder in a beaker of distilled water
        ii.   Pour the solution into a 250cm³ volumetric flask
        iii. Wash the beaker with distilled water and pour the washing water into the volumetric flask
        iv. Add water to the volumetric flask until the bottom of the meniscus reaches the graduation mark
        v.   Shake and mix the solution thoroughly
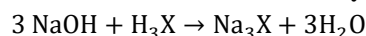   (c) Reasonable average:

	Trial 1	Trial 2	Trial 3	Trial 4
Final	31.00	29.65	29.90	29.85
Initial	0.50	0.00	0.30	0.20
Delta	30.50	29.65	29.60	29.65

$$\bar{v} = \frac{1}{3}(29.65 + 29.60 + 29.65)$$
$$\bar{v} = 29.63 \text{ cm}^3 \text{ (2 d.p is REQUIRED)}$$

    (d) Molarity:
Since Citric acid has a basicity of 3, let CA be represented by H_3X
$3\,NaOH + H_3X \rightarrow Na_3X + 3H_2O$
Mol ratio NaOH : CA = 3:1

Mol CA in 25cm³ solution $= \frac{1}{3}(0.206 \cdot 0.02963) = 2.03 \cdot 10^{-3}$ mol

$$[CA] = \frac{2.03 \cdot 10^{-3}}{0.025} = 0.0814 \text{ M}$$

    (e) % by mass:
Mol CA in 250 cm³ solution (i.e. 5g powder) = $0.25 \cdot 0.0814 = 0.0203$ mol
Mass of CA in 5g powder:
$m_{CA} = 0.0203 \cdot 192 = 3.906$g
Percentage by mass:
$$\frac{m_{CA}}{m} = \frac{3.906}{5} = 78.1\%$$

Ex2:

(a) Dissolve an excess amount of $Ca(OH)_2$ powder in distilled water such that excess $Ca(OH)_{2(s)}$ can be seen inside the solution. Then filter the solution and collect the filtrate, which is a saturated solution of $Ca(OH)_{2(aq)}$

(b) Pipette

It should be first washed with distilled water and then with the saturated solution of $Ca(OH)_2$ before use.

(c) Titration curve:
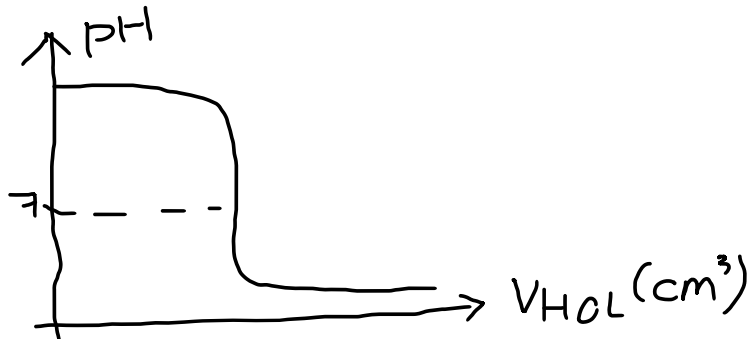
(d) Reasonable average

    i. $\bar{v} = \frac{1}{2}(8.85 + 8.95) = 8.90 \text{cm}^3$

    ii.   Chemical Equation:
$$Ca(OH)_{2(aq)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)}$$

    iii.   Mole ratio of $Ca(OH)_2 : HCl = 1 : 2$

Mol $Ca(OH)_2$ in 25 cm³ solution $= \frac{1}{2}(0.2)(0.00890)$

Mol $Ca(OH)_2$ in 25 cm³ solution $= 8.90 \cdot 10^{-4}$ mol

Mass of $Ca(OH)_2$ in 25 cm³ of solution:

$m_c = 8.90 \cdot 10^{-4}(74.1) = 0.0659$g

Solubility $= \frac{0.0659}{0.025} = 2.64 \text{ g dm}^{-3}$

Ex3:

a. To increase the surface area to volume ratio of the powder so as to increase the rate of reaction

b. To dissolve the organic impurities on the eggshell

c. Speed up the reaction between the calcium carbonate in the sample with HCl(aq). / Shorten the time needed for the reaction. / To make sure that the reaction is complete

d. Phenolphthalein

e. $NaOH + HCl \rightarrow NaCl + H_2O$

Mol ratio NaOH : HCl = 1:1

Mol of HCl remaining = 0.102 * 0.01685 = 1.72 * 10^-3 mol

Mol of HCl reacted with $CaCO_3$ = Original Mol of HCl – Mol HCl remaining

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$
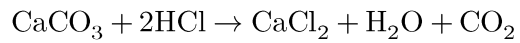
Mol of HCl reacted with $CaCO_3$ = 0.025 * 0.2 - 1.72 * 10^-3 / 2 = 1.64 * 10^-3 mol

Mass of $CaCO_3$ in sample = 1.64 * 10^-3 * 100.1 = 0.164g

% by mass = 0.164/0.204 * 100% = 80.5%