5072 CHEMISTRY (NEW PAPERS WITH SPA)
TOPIC 7: ACIDS, BASES AND SALTS

5067 CHEMISTRY (NEW PAPERS WITH PRACTICAL EXAM)
TOPIC 7: ACIDS, BASES AND SALTS

SUB-TOPIC 7.2
SALTS

LEARNING OUTCOMES
a) Describe the techniques used in the preparation, separation and purification of salts as examples of some of the techniques specified in Section **1.2**(a) (methods for preparation should include precipitation and titration together with reactions of acids with metals, insoluble bases and insoluble carbonates) b) Describe the general rules of solubility for common salts to include nitrates, chlorides (including silver and lead), sulphates (including barium, calcium and lead), carbonates, hydroxides, Group I cations and ammonium salts c) Suggest a method of preparing a given salt from suitable starting materials, given appropriate information

A Introduction to Salts

- A salt is a substance formed when the Hydrogen of an acid is replaced by a metal wholly (forming a normal salt) or partially (forming an acid salt)
- They are made whenever:
  - Acids neutralise Bases or Alkalis
  - Acids reacts with Metals
  - Acids reacts with Metal Carbonates
- Different acids form different salts and each acid can have its Hydrogen replaced by different metals.
- The number of Hydrogen atoms in an acid which are replaceable by a metal is called its basicity.
  - Sulphuric Acid and Carbonic Acid have two replaceable Hydrogen atoms and are therefore dibasic.
  - Phosphoric Acid has three replaceable Hydrogen atoms and is therefore tribasic.
- Some examples of salts from different acids:

Basicity	**1**		**2**		**3**
Acid	Hydrochloric Acid HCl	Nitric Acid HNO_3	Sulphuric Acid H_2SO_4	Carbonic Acid H_2CO_3	Phosphoric Acid H_3PO_4
Salt	Calcium Chloride $CaCl_2$	Magnesium Nitrate $Mg(NO_3)_2$	Copper (II) Sulphate $CuSO_4$	Zinc Carbonate $ZnCO_3$	Sodium Phosphate Na_3PO_4
	Sodium Chloride NaCl	Potassium Nitrate KNO_3	Lead (II) Sulphate $PbSO_4$	Iron (II) Carbonate $FeCO_3$	Calcium Phosphate $Ca_3(PO_4)_2$
Acid Salt			Sodium Hydrogen Sulphate $NaHSO_4$	Calcium Hydrogen Carbonate $Ca(HCO_3)_2$	Sodium Dihydrogen Phosphate, NaH_2PO_4
					Disodium Hydrogen Phosphate, Na_2HPO_4

- From the above table, it can be seen that Sulphuric, Carbonic and Phosphoric Acids have more than one Hydrogen atom, which can be replaced by a metal.
- Accordingly, they can form acid salts where only part of the Hydrogen present in the acid is replaced by a metal.

B Water of Crystallisation

- Many salts, called hydrated salts, have water molecules inside their crystal structures.
- This is essential for their shape and often their colour.
- It is called water of crystallisation.
- The number of water molecules present in the salt is called its degree of hydration, but not all salts have any degree of hydration.
- Common salt is chemically Sodium Chloride and has no water of crystallisation.

Hydrated Salt	Calcium Sulphate	Copper (II) Sulphate	Cobalt (II) Chloride	Magnesium Sulphate	Iron (II) Sulphate	Sodium Carbonate

Chemical Formula	$CaSO_4.2H_2O$	$CuSO_4.5H_2O$	$CoCl_2.6H_2O$	$MgSO_4.7H_2O$	$FeSO_4.7H_2O$	$Na_2CO_3.10H_2O$
Degree of Hydration	2	5	6	7	7	10

- When hydrated salts are heated, their water of crystallisation is lost as steam and the crystal loses its shape and becomes powder.
- Copper (II) Sulphate crystals are blue, but on heating, they turn white as the Water of Crystallisation is lost.
  $CuSO_4.5H_2O$ (s) → $CuSO_4$ (s) + $5H_2O$ (g)
- We call a crystal which has lost its water of crystallisation anhydrous.
- The white anhydrous Copper (II) Sulphate which is formed is a useful chemical as it can be used to test for the presence of water.
- If any water is present, it changes from white to blue as it becomes a hydrated crystal again.

C Solubility Rules

Types	Formula	Soluble	Insoluble
Group I salts	Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	All	-
Ammonium salts	NH_4^+	All	-
Sulphates	SO_4^{2-}	All	Except $BaSO_4$, $CaSO_4$, $PbSO_4$
Chlorides	Cl^-	All	Except AgCl, $PbCl_2$*
Bromides	Br^-	All	Except AgBr, $PbBr_2$*
Iodides	I^-	All	Except AgI, PbI_2*
Carbonates	CO_3^{2-}	Except Group I & Ammonium salts	All
Hydroxides	OH^-	Except Group I & Ammonium salts	All
Oxides	O^{2-}	Except Group I & Ammonium salts	All
Sulphides	S^{2-}	Except Group I & Ammonium salts	All
Sulphites	SO_3^{2-}	Except Group I & Ammonium salts	All

* - $PbCl_2$, $PbBr_2$ and PbI_2 are soluble in hot water, but insoluble in cold water

D Preparation of Salts

- The procedure used in preparing salts is such that the salts obtained are of a high degree of purity.
- E.g. A + B → Salt X + D
- The method used in preparing Salt X must be such that Salt X obtained is free of excess reagent A and B and by-product D.
- The method used depends on whether the salts are soluble or insoluble in water.
- In the cases of normal salts:
  - Salts of strong acids and strong bases are neutral.
  - Salts of strong acids and weak bases are acidic.
  - Salts of weak acids and strong bases are alkaline.

Salt	***Soluble Salt***		***Insoluble Salt***
	Group I & Ammonium Salts	***All others***	
Method of Preparation	Titration (Acid + Alkali → Salt + Water)	Addition of excess Oxide or Carbonate to appropriate acids (For more reactive metals, reaction of acid + metal may also be used)	Precipitation/ Double-Decomposition Method (Soluble + Soluble → Insoluble + Water)
Example	Potassium Chloride	Copper (II) Sulphate Crystals	Lead (II) Sulphate
Reagents	Potassium Hydroxide, Hydrochloric Acid	Copper (II) Oxide, Sulphuric Acid	Lead (II) Nitrate, Sodium Sulphate
Equation	$KOH\ (aq) + HCl\ (aq) \rightarrow KCl\ (aq) + H_2O\ (l)$	$CuO\ (s) + H_2SO_4\ (aq) \rightarrow CuSO_4\ (aq) + H_2O\ (l)$	$Pb(NO_3)_2\ (aq) + Na_2SO_4\ (aq) \rightarrow PbSO_4\ (s) + 2NaNO_3\ (aq)$
Procedure	1. Pipette 20cm^3 of Potassium Hydroxide (Alkali) into a flask. 2. Add a known indicator to the flask. 3. Use a burette to add Hydrochloric Acid (Acid) into the flask. 4. Note the volume added when indicator changes colour. 5. Repeat the procedure without adding indicator. 6. Evaporate the solution obtained till it is saturated. 7. Allow the solution to cool and crystals of Potassium Chloride will form. 8. Filter off the crystals and dry them between two pieces of filter paper.	1. Add Copper (II) Oxide (Oxide/ Carbonate) to warm dilute Sulphuric Acid (Acid) until the Copper (II) Oxide no longer dissolves (i.e. it is in excess). 2. Filter the mixture to remove the excess Copper (II) Oxide. 3. Heat the filtrate (which contains the Copper (II) Sulphate solution) until it is saturated. 4. Allow the solution to cool and crystals of Copper (II) Sulphate will form 5. Filter the crystals and dry them between two pieces of filter paper.	1. Mix aqueous solutions of Lead (II) Nitrate (soluble) and Sodium Sulphate (soluble) together. 2. A precipitate of Lead (II) Sulphate forms. This is obtained by filtering the mixture. 3. The Lead (II) Sulphate obtained is washed twice with distilled water to remove any excess reagent. 4. The salt is then dried by pressing it between two pieces of filter paper.

E Flowchart for Preparation of Salts