CHEMISTRY NOTES

FORM 2

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**INTRODUCTION TO SALTS**

1.(a) A salt is an ionic compound formed when the cation from a base combine with the anion derived from an acid.

A salt is therefore formed when the hydrogen ions in an acid are replaced wholly/fully or partially/partly ,directly or indirectly by a metal or ammonium radical.

(b) The number of ionizable/replaceable hydrogen in an acid is called **basicity** of an acid.

Some acids are therefore:

(i)**mono**basic acids generally denoted **H**X e.g.

**H**Cl, **H**NO3,HCOO**H**,CH3COO**H**.

(ii)**di**basic acids ; generally denoted **H2**X e.g.

**H2**SO4, **H2**SO3, **H2**CO3,**H**OOCOO**H**.

(iii)**tri**basic acids ; generally denoted **H3**X e.g.

**H3**PO4.

(c) Some salts are **normal** salts while other are **acid** salts.

(i)A normal salt is formed when all the ionizable /replaceable hydrogen in an acid is replaced by a metal or metallic /ammonium radical.

(ii)An acid salt is formed when part/portion the ionizable /replaceable hydrogen in an acid is replaced by a metal or metallic /ammonium radical.

Table showing normal and acid salts derived from common acids

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Acid name** | **Chemical formula** | **Basicity** | **Normal salt** | **Acid salt** |
| Hydrochloric acid | HCl | Monobasic | Chloride(Cl-) | None |
| Nitric(V)acid | HNO3 | Monobasic | Nitrate(V)(NO3-) | None |
| Nitric(III)acid | HNO2 | Monobasic | Nitrate(III)(NO2-) | None |
| Sulphuric(VI)acid | H2SO4 | Dibasic | Sulphate(VI) (SO42-) | Hydrogen sulphate(VI)  (HSO4-) |
| Sulphuric(IV)acid | H2SO3 | Dibasic | Sulphate(IV) (SO32-) | Hydrogen sulphate(IV)  (HSO3-) |
| Carbonic(IV)acid | H2CO3 | Dibasic | Carbonate(IV)(CO32-) | Hydrogen carbonate(IV)  (HCO3-) |
| Phosphoric(V)  acid | H3PO4 | Tribasic | Phosphate(V)(PO43-) | Dihydrogen phosphate(V)  (H2PO42-)  Hydrogen diphosphate(V)  (HP2O42-) |

The table below show shows some examples of salts.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Base/alkali | Cation | Acid | Anion | Salt | Chemical name of salts |
| NaOH | Na+ | HCl | Cl- | NaCl | Sodium(I)chloride |
| Mg(OH)2 | Mg2+ | H2SO4 | SO42- | MgSO4  Mg(HSO4)2 | Magnesium sulphate(VI)  Magnesium hydrogen sulphate(VI) |
| Pb(OH)2 | Pb2+ | HNO3 | NO3- | Pb(NO3)2 | Lead(II)nitrate(V) |
| Ba(OH)2 | Ba2+ | HNO3 | NO3- | Ba(NO3)2 | Barium(II)nitrate(V) |
| Ca(OH)2 | Ba2+ | H2SO4 | SO42- | MgSO4 | Calcium sulphate(VI) |
| NH4OH | NH4+ | H3PO4 | PO43- | (NH4 )3PO4  (NH4 )2HPO4  NH4 H2PO4 | Ammonium phosphate(V)  Diammonium phosphate(V)  Ammonium diphosphate(V) |
| KOH | K+ | H3PO4 | PO43- | K3PO4 | Potassium phosphate(V) |
| Al(OH)3 | Al3+ | H2SO4 | SO42- | Al2(SO4)2 | Aluminium(III)sulphate(VI) |
| Fe(OH)2 | Fe2+ | H2SO4 | SO42- | FeSO4 | Iron(II)sulphate(VI) |
| Fe(OH)3 | Fe3+ | H2SO4 | SO42- | Fe2(SO4)2 | Iron(III)sulphate(VI) |

(d) Some salts undergo **hygroscopy**, **deliquescence** and **efflorescence**.

(i) Hygroscopic salts /compounds are those that absorb water from the atmosphere but do not form a solution.

Some salts which are hygroscopic include anhydrous copper(II)sulphate(VI), anhydrous cobalt(II)chloride, potassium nitrate(V) common table salt.

(ii)Deliquescent salts /compounds are those that absorb water from the atmosphere and form a solution.

Some salts which are deliquescent include: Sodium nitrate(V),Calcium chloride, Sodium hydroxide, Iron(II)chloride, Magnesium chloride.

(iii)Efflorescent salts/compounds are those that lose their water of crystallization to the atmosphere.

Some salts which effloresces include: sodium carbonate decahydrate, Iron(II)sulphate(VI)heptahydrate, sodium sulphate (VI)decahydrate.

(e)Some salts contain water of crystallization.They are hydrated.Others do not contain water of crystallization. They are anhydrous.

Table showing some hydrated salts.

|  |  |
| --- | --- |
| Name of hydrated salt | Chemical formula |
| Copper(II)sulphate(VI)pentahydrate | CuSO4.5H2O |
| Aluminium(III)sulphate(VI)hexahydrate | Al2 (SO4) 3.6H2O |
| Zinc(II)sulphate(VI)heptahydrate | ZnSO4.7H2O |
| Iron(II)sulphate(VI)heptahydrate | FeSO4.7H2O |
| Calcium(II)sulphate(VI)heptahydrate | CaSO4.7H2O |
| Magnesium(II)sulphate(VI)heptahydrate | MgSO4.7H2O |
| Sodium sulphate(VI)decahydrate | Na2SO4.10H2O |
| Sodium carbonate(IV)decahydrate | Na2CO3.10H2O |
| Potassium carbonate(IV)decahydrate | K2CO3.10H2O |
| Potassium sulphate(VI)decahydrate | K2SO4.10H2O |

(f)Some salts exist as a simple salt while some as complex salts. Below are some complex salts.

Table of some complex salts

|  |  |  |
| --- | --- | --- |
| Name of complex salt | Chemical formula | Colour of the complex salt |
| Tetraamminecopper(II)sulphate(VI) | Cu(NH3) 4 SO4 H2O | Royal/deep blue solution |
| Tetraamminezinc(II)nitrate(V) | Zn(NH3) 4 (NO3 )2 | Colourless solution |
| Tetraamminecopper(II) nitrate(V) | Cu(NH3) 4 (NO3 )2 | Royal/deep blue solution |
| Tetraamminezinc(II)sulphate(VI) | Zn(NH3) 4 SO4 | Colourless solution |

(g)Some salts exist as two salts in one. They are called **double salts**.

Table of some double salts

|  |  |
| --- | --- |
| Name of double salts | Chemical formula |
| Trona(sodium sesquicarbonate) | Na2CO3 NaHCO3.2H2O |
| Ammonium iron(II)sulphate(VI) | FeSO4(NH4) 2SO4.2H2O |
| Ammonium aluminium(III)sulphate(VI) | Al2(SO4) 3(NH4) 2SO4.H2O |

(h)Some salts dissolve in water to form a **solution**. They are said to be soluble. Others do not dissolve in water. They form a **suspension/precipitate** in water.

Table of solubility of salts

|  |  |
| --- | --- |
| Soluble salts | Insoluble salts |
| All nitrate(V)salts |  |
| All sulphate(VI)/SO42- salts **except** | Barium(II) sulphate(VI)/BaSO4  Calcium(II) sulphate(VI)/CaSO4  Lead(II) sulphate(VI)/PbSO4 |
| All sulphate(IV)/SO32- salts **except** | Barium(II) sulphate(IV)/BaSO3  Calcium(II) sulphate(IV)/CaSO3  Lead(II) sulphate(IV)/PbSO3 |
| All chlorides/Cl- **except** | Silver chloride/AgCl  Lead(II)chloride/PbCl2(dissolves in hot water) |
| All phosphate(V)/PO43- |  |
| All sodium,potassium and ammonium salts |  |
| All hydrogen carbonates/HCO3- |  |
| All hydrogen sulphate(VI)/ HSO4- |  |
| Sodium carbonate/Na2CO3,  potassium carbonate/ K2CO3,  ammonium carbonate (NH4) 2CO3 | **except**  All carbonates |
| All alkalis(KOH,NaOH, NH4OH) | **except** All bases |

13 Salts can be prepared in a school laboratory by a method that uses its solubility in water.

1. Soluble salts may be prepared by using any of the following methods:

**(i)Direct displacement/reaction of a metal with an acid**.

By reacting a metal higher in the reactivity series than hydrogen with a dilute acid,a salt is formed and hydrogen gas is evolved.

Excess of the metal must be used to ensure all the acid has reacted.

When effervescence/bubbling /fizzing has stopped ,excess metal is filtered.

The filtrate is heated to concentrate then allowed to crystallize.

Washing with distilled water then drying between filter papers produces a sample crystal of the salt. i.e.

M(s) + H2X -> MX(aq) + H2(g)

Examples

Mg(s) + H2SO4(aq) -> MgSO4 (aq) + H2(g)

Zn(s) + H2SO4(aq) -> ZnSO4 (aq) + H2(g)

Pb(s) + 2HNO3(aq) -> Pb(NO3) 2(aq) + H2(g)

Ca(s) + 2HNO3(aq) -> Ca(NO3) 2(aq) + H2(g)

Mg(s) + 2HNO3(aq) -> Mg(NO3) 2(aq) + H2(g)

Mg(s) + 2HCl(aq) -> MgCl 2(aq) + H2(g)

Zn(s) + 2HCl(aq) -> ZnCl 2(aq) + H2(g)

**(ii)Reaction of an insoluble base with an acid**

By adding an insoluble base (oxide/hydroxide )to a dilute acid until **no more dissolves**, in the acid,a salt and water are formed. Excess of the base is filtered off. The filtrate is heated to concentrate ,allowed to crystallize then washed with distilled water before drying between filter papers e.g.

PbO(s) + 2HNO3(aq) -> Pb(NO3) 2(aq) + H2O (l)

Pb(OH)2(s) + 2HNO3(aq) -> Pb(NO3) 2(aq) + 2H2O (l)

CaO (s) + 2HNO3(aq) -> Ca(NO3) 2(aq) + H2O (l)

MgO (s) + 2HNO3(aq) -> Mg(NO3) 2(aq) + H2O (l)

MgO (s) + 2HCl(aq) -> MgCl 2(aq) + H2O (l)

ZnO (s) + 2HCl(aq) -> ZnCl 2(aq) + H2O (l)

Zn(OH)2(s) + 2HNO3(aq) -> Zn(NO3) 2(aq) + 2H2O (l)

CuO (s) + 2HCl(aq) -> CuCl 2(aq) + H2O (l)

CuO (s) + H2SO4(aq) -> CuSO4(aq) + H2O (l)

Ag2O(s) + 2HNO3(aq) -> 2AgNO3(aq) + H2O (l)

Na2O(s) + 2HNO3(aq) -> 2NaNO3(aq) + H2O (l)

**(iii)reaction of insoluble /soluble carbonate /hydrogen carbonate with an acid.**

By adding an excess of a soluble /insoluble carbonate or hydrogen carbonate to adilute acid, effervescence /fizzing/bubbling out of carbon(IV)oxide gas shows the reaction is taking place. When effervescence /fizzing/bubbling out of the gas is over, excess of the insoluble carbonate is filtered off. The filtrate is heated to concentrate ,allowed to crystallize then washed with distilled water before drying between filter paper papers e.g.

PbCO3 (s) + 2HNO3(aq) -> Pb(NO3) 2(aq) + H2O (l)+ CO2(g)

ZnCO3 (s) + 2HNO3(aq) -> Zn(NO3) 2(aq) + H2O (l)+ CO2(g)

CaCO3 (s) + 2HNO3(aq) -> Ca(NO3) 2(aq) + H2O (l)+ CO2(g)

MgCO3 (s) + H2SO4(aq) -> MgSO4(aq) + H2O (l)+ CO2(g)

Cu CO3 (s) + H2SO4(aq) -> CuSO4(aq) + H2O (l) + CO2(g)

Ag2CO3 (s) + 2HNO3(aq) -> 2AgNO3(aq) + H2O (l) + CO2(g)

Na2CO3 (s) + 2HNO3(aq) -> 2NaNO3(aq) + H2O (l) + CO2(g)

K2CO3 (s) + 2HCl(aq) -> 2KCl(aq) + H2O (l) + CO2(g)

NaHCO3 (s) + HNO3(aq) -> NaNO3(aq) + H2O (l) + CO2(g)

KHCO3 (s) + HCl(aq) -> KCl(aq) + H2O (l) + CO2(g)

**(iv)neutralization/reaction of soluble base/alkali with dilute acid**

By adding an acid to a burette into a known volume of an alkali with 2-3 drops of an indicator, the colour of the indicator changes when the acid has completely reacted with an alkali at the **end point.** The procedure is then repeated without the indicator .The solution mixture is then heated to concentrate , allowed to crystallize ,washed with distilled water before drying with filter papers. e.g.

NaOH (aq) + HNO3(aq) -> NaNO3(aq) + H2O (l)

KOH (aq) + HNO3(aq) -> KNO3(aq) + H2O (l)

KOH (aq) + HCl(aq) -> KCl(aq) + H2O (l)

2KOH (aq) + H2SO4(aq) -> K2SO4(aq) + 2H2O (l)

2 NH4OH (aq) + H2SO4(aq) -> (NH4)2SO4(aq) + 2H2O (l)

NH4OH (aq) + HNO3(aq) -> NH4NO3(aq) + H2O (l)

**(iv)direct synthesis/combination.**

When a metal **burn** in a gas jar containing a non metal , the two directly combine to form a salt. e.g.

2Na(s) + Cl2(g) -> 2NaCl(s)

2K(s) + Cl2(g) -> 2KCl(s)

Mg(s) + Cl2(g) -> Mg Cl2 (s)

Ca(s) + Cl2(g) -> Ca Cl2 (s)

Some salts once formed undergo **sublimation** and **hydrolysis**. Care should be taken to avoid water/moisture into the reaction flask during their preparation.Such salts include aluminium(III)chloride(AlCl3) and iron (III)chloride(FeCl3)

1. Heated aluminium foil reacts with chlorine to form aluminium(III)chloride that sublimes away from the source of heating then deposited as solid again

2Al(s) + 3Cl2(g) -> 2AlCl3 (**s/g**)

Once formed aluminium(III)chloride hydrolyses/reacts with water vapour / moisture present to form aluminium hydroxide solution and highly acidic fumes of hydrogen chloride gas.

AlCl3(s)+ 3H2 O(g) -> Al(OH)3 (**aq**) + 3HCl(g)

2. Heated iron filings reacts with chlorine to form iron(**III**)chloride that sublimes away from the source of heating then deposited as solid again

2Fe(s) + 3Cl2(g) -> 2FeCl3 (**s/g**)

Once formed , aluminium(III)chloride hydrolyses/reacts with water vapour / moisture present to form aluminium hydroxide solution and highly acidic fumes of hydrogen chloride gas.

FeCl3(s)+ 3H2 O(g) -> Fe(OH)3 (**aq**) + 3HCl(g)

(b)**Insoluble** salts can be prepared by reacting **two** suitable **soluble** salts to form **one soluble** and **one insoluble**. This is called **double decomposition** or **precipitation**. The mixture is filtered and the **residue** is washed with distilled water then dried.

**Cu**SO4(aq) + Na2**CO3** (aq) -> **CuCO3** (**s**) + Na2 SO4(aq)

**Ba**Cl2(aq) + K2**SO4** (aq) -> **BaSO4** (**s**) + 2KCl (aq)

**Pb(**NO3)2(aq) + K2**SO4** (aq) -> **PbSO4** (**s**) + 2KNO3 (aq)

2**Ag**NO3(aq) + Mg**Cl**2 (aq) -> 2**AgCl**(**s**) + Mg(NO3)2 (aq)

**Pb(**NO3)2(aq) + (NH4**)** 2**SO4** (aq) -> **PbSO4** (**s**) + 2NH4NO 3(aq)

**Ba**Cl2(aq) + K2**SO3** (aq) -> **BaSO3** (**s**) + 2KCl (aq)

14. Salts may lose their water of crystallization , decompose ,melt or sublime on heating on a Bunsen burner flame.

The following shows the behavior of some salts on heating gently /or strongly in a laboratory school burner:

**(a)effect of heat on chlorides**

All chlorides have very high melting and boiling points and therefore are not affected by laboratory heating except ammonium chloride. Ammonium chloride **sublimes** on **gentle** heating. It **dissociate** into the constituent **ammonia** and **hydrogen chloride** gases on strong heating.

NH4Cl(s) NH4Cl(g) NH3(g) + HCl(g)

(sublimation) (dissociation)

**(b)effect of heat on nitrate(V)**

(i) Potassium nitrate(V)/KNO3 and sodium nitrate(V)/NaNO3 decompose on heating to form Potassium nitrate(III)/KNO2 and sodium nitrate(III)/NaNO2 and producing Oxygen gas in each case.

2KNO**3** (s) -> 2KNO2(s) + O2(g)

2NaNO**3** (s) -> 2NaNO2(s) + O2(g)

(ii)Heavy metal nitrates(V) salts decompose on heating to form the oxide and a mixture of brown acidic nitrogen(IV)oxide and oxygen gases. e.g.

2Ca(NO3)2 (s) -> 2CaO(s) + 4NO2(g) + O2(g)

2Mg(NO3)2(s) -> 2MgO(s) + 4NO2(g) + O2(g)

2Zn(NO3)2(s) -> 2ZnO(s) + 4NO2(g) + O2(g)

2Pb(NO3)2(s) -> 2PbO(s) + 4NO2(g) + O2(g)

2Cu(NO3)2(s) -> 2CuO(s) + 4NO2(g) + O2(g)

2Fe(NO3)2(s) -> 2FeO(s) + 4NO2(g) + O2(g)

(iii)Silver(I)nitrate(V) and mercury(II) nitrate(V) are lowest in the reactivity series. They decompose on heating to form the **metal**(silver and mercury)and the Nitrogen(IV)oxide and oxygen gas. i.e.

2AgNO3(s) -> 2Ag (s) + 2NO2(g) + O2(g)

2Hg(NO3)2 (s) -> 2Hg (s) + 4NO2(g) + O2(g)

(iv)Ammonium nitrate(V) and Ammonium nitrate(III) decompose on heating to Nitrogen(I)oxide(relights/rekindles glowing splint) and nitrogen gas respectively.Water is also formed.i.e.

NH4NO3(s) -> N2O (g) + H2O(l)

NH4NO2(s) -> N2 (g) + H2O(l)

**(c) effect of heat on nitrate(V)**

Only Iron(II)sulphate(VI), Iron(III)sulphate(VI) and copper(II)sulphate(VI) decompose on heating. They form the **oxide**, and produce highly acidic fumes of acidic **sulphur(IV)oxide** gas.

2FeSO4 (s) -> Fe2O3(s) + SO3(g) + SO2(g)

Fe2(SO4) 3(s) -> Fe2O3(s) + SO3(g)

CuSO4 (s) -> CuO(s) + SO3(g)

**(d) effect of heat on carbonates(IV) and hydrogen carbonate(IV).**

(i)Sodium carbonate(IV)and potassium carbonate(IV)**do not decompose** on heating.

(ii)Heavy metal nitrate(IV)salts decompose on heating to form the **oxide** and produce **carbon(IV)oxide** gas.Carbon (IV)oxide gas forms a white precipitate when bubbled in lime water. The white precipitate dissolves if the gas is in excess. e.g. CuCO3 (s) -> CuO(s) + CO2(g)

CaCO3 (s) -> CaO(s) + CO2(g)

PbCO3 (s) -> PbO(s) + CO2(g)

FeCO3 (s) -> FeO(s) + CO2(g)

ZnCO3 (s) -> ZnO(s) + CO2(g)

(iii)Sodium hydrogen carbonate(IV) and Potassium hydrogen carbonate(IV)decompose on heating to give the corresponding carbonate (IV) and form water and carbon(IV)oxide gas. i.e.

2NaHCO 3(s) -> Na2CO3(s) + CO2(g) + H2O(l)

2KHCO 3(s) -> K2CO3(s) + CO2(g) + H2O(l)

(iii) Calcium hydrogen carbonate (IV) and Magnesium hydrogen carbonate(IV) decompose on heating to give the corresponding carbonate (IV) and form water and carbon(IV)oxide gas. i. e.

Ca(HCO3) 2(**aq**) -> CaCO3(s) + CO2(g) + H2O(l)

Mg(HCO3) 2(**aq**) -> MgCO3(s) + CO2(g) + H2O(l)