

# Acids, Bases and Salts

## Summary

### Acids

#### *Electrical conductivity*

Any solution's ability to conduct electricity is defined by its charged ions in it. As a result, a strong acid will produce more charged ions than a weak one, and so its solution will be a better electrical conductor than a weak acid. The same goes for strong/weak bases.

#### *Acids in daily life*

- Ethanoic acid – found in vinegar and tomato juice
- Citric acid – found in citrus foods like lemons, oranges and grapefruit
- Lactic acid – found in sour milk and yoghurt, and in muscle respiration
- Tartaric acid – found in grapes
- Tannic acid – found in tea and ant's body
- Formic acid – found in bee stings
- Hydrochloric acid – found in stomach juices

#### *Common laboratory acids*

- Hydrochloric acid (HCl)
- Sulphuric acid (H<sub>2</sub>SO<sub>4</sub>)
- Nitric acid (HNO<sub>3</sub>)

**Dilute acid:** solution containing small amount of acid dissolved in water

**Concentrated acids:** solution containing large amount of acid dissolved in water

#### *Properties of acids*

- sour taste
- hazardous - irritants to skin, causing skin to redden and blister
- change the color of indicators - turn blue litmus red
- react with metals to produce hydrogen gas - gas is tested with a burning splint which burns with a 'pop' sound
- react with carbonates and hydrogencarbonates to produce carbon dioxide - to test this, the gas produced is bubbled into limewater which forms a white precipitate
- react with metal oxides and hydroxides - react slowly with warm dilute acid to form salt and water

#### *Storage of acids*

- Acids are stored in claypots, glass or plastic containers as sand, glass and plastic do not react with acids.
- If it is stored in metal container, metal would react with acids

## Uses of acids

- Sulphuric Acid
  - Used in car batteries
  - Manufacture of ammonium sulphate for fertilisers
  - Manufacture of detergents, paints, dyes, artificial fibres & plastics
- Hydrochloric acid
  - can remove rust (iron(III) oxide) which dissolves in acids
- Acids are used in preservation of foods (e.g. ethanoic acid)

## Acids and hydrogen ions

- Acids are covalent compounds and do not behave as acids in the absence of water as water reacts with acids to produce  $H^+$  ions, responsible for its acidic properties
  - e.g. Citric acid crystals doesn't react with metals and doesn't change colours of indicators; citric acid in water reacts with metals and change turns litmus red.
- Hydrogen gas is formed by acids as  $H^+(aq)$  ions are present in acid solutions. This means when a solid/gas acid dissolved in water, they produce  $H^+$  ions in it
  - Chemical equation:  $HCl(s) \xrightarrow{\text{water}} HCl(aq)$
  - Ionic Equation:  $HCl(s) \xrightarrow{\text{water}} H^+(aq) + Cl^-(aq)$
- However when dissolved in organic solutions, they don't show acidic properties. When metals react with acids, only the hydrogen ions react with metals, e.g.:
  - Chemical equation:  $2Na(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2(g)$
  - Ionic equation:  $2Na(s) + 2H^+(aq) \rightarrow 2Na^+(aq) + H_2(g)$
- **Basicity** of an acid is maximum number of  $H^+$  ions produced by a molecule of acid
  - dibasic: can replace two hydrogen atoms
  - tribasic: can replace three hydrogen atoms

| Acids             | Reaction with water                                       | Basicity  |
|-------------------|---|-----------|
| Hydrochloric acid | $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$                  | monobasic |
| Nitric acid       | $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$              | monobasic |
| Ethanoic acid     | $CH_3COOH(aq) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$ | monobasic |
| Sulphuric acid    | $H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$        | dibasic   |

## Fizzy drinks

- Soft drink tablets contains solid acid (e.g. citric acid,  $C_6H_8O_7$ ) & sodium bicarbonate
- When tablet is added to water, citric acid ionises and the  $H^+$  produced reacts with sodium bicarbonate to produce carbon dioxide gas, making them fizz

## Strong and weak acids

- **Strong Acids** - acid that **completely ionises** in water.
  - Their reactions are irreversible.
  - E.g.  $H_2SO_4$ ,  $HNO_3$ ,  $HCl$
  - $H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$ 
    - In above  $H_2SO_4$  has completely been ionized in water, forming 3 kinds of particles:

- H<sup>+</sup> ions
- SO<sub>4</sub><sup>2-</sup> ions
- H<sub>2</sub>O molecules

- Strong acids react more vigorously with metals than weak acids – hydrogen gas bubbles are produced rapidly

- **Weak acids** - acids that **partially ionise** in water.

- The remaining molecules remain unchanged as acids.
- Their reactions are reversible.
- E.g. CH<sub>3</sub>COOH, H<sub>2</sub>CO<sub>3</sub>, H<sub>3</sub>PO<sub>4</sub>
- H<sub>3</sub>PO<sub>4</sub> (aq) ⇌ 3H<sup>+</sup> (aq) + PO<sub>4</sub><sup>2-</sup> (aq)
- Weak acids react slowly with metals than strong acids – hydrogen gas bubbles are produced slowly.

## ***Concentration vs Strength***

| CONCENTRATION  | STRENGTH   |
|--|--|
| Is the amount of solute (acids or alkalis) dissolved in 1 dm <sup>3</sup> of a solution              | Is how much ions can be disassociated into from acid or alkali |
| It can be diluted by adding more water to solution or concentrated by adding more solute to solution | The strength cannot be changed                                 |

- Comparing 10 mol/dm<sup>3</sup> and 0.1 mol/dm<sup>3</sup> of hydrochloric acids and 10 mol/dm<sup>3</sup> and 0.1 mol/dm<sup>3</sup> of ethanoic acids
  - 10 mol/dm<sup>3</sup> of ethanoic acid solution is a **concentrated solution of weak acid**
  - 0.1 mol/dm<sup>3</sup> of ethanoic acid solution is a **dilute solution of weak acid**
  - 10 mol/dm<sup>3</sup> of hydrochloric acid solution is a **concentrated solution of strong acid**
  - 0.1 mol/dm<sup>3</sup> of hydrochloric acid solution is a **dilute solution of strong acid**

## **Bases and Alkalis**

- Bases are oxides or hydroxides of metals
- Alkalis are bases which are soluble in water
- All alkalis produces hydroxide ions (OH<sup>-</sup>) when dissolved in water.
- Hydroxide ions give the properties of alkalis.
- They don't behave as acids in absence of water.
- Alkalis are therefore substances that produce hydroxide ions, OH<sup>-</sup> (aq), in water.

## ***Laboratory Alkalis***

- Sodium Hydroxide, NaOH
- Aqueous Ammonia, NH<sub>4</sub>OH
- Calcium Hydroxide, Ca(OH)<sub>2</sub>

## ***Properties of Alkalis***

- have a slippery feel
- hazardous
- Dilute alkalis are irritants

- Concentrated alkalis are corrosive and burn skin (caustic(i.e. burning) alkalis)
- change the colour of indicators: turn common indicator litmus – red litmus to blue
- react with acids
  - The reaction is called **neutralisation**
- react with ammonium compounds
  - They react with heated solid ammonium compounds to produce ammonia gas
  - $(\text{NH}_4)_2\text{SO}_4 (\text{s}) + \text{Ca}(\text{OH})_2 (\text{aq}) \rightarrow \text{CaSO}_4 (\text{aq}) + 2\text{NH}_3 (\text{g}) + 2\text{H}_2\text{O} (\text{l})$
- react with solutions of metal ions
  - Barium sulphate,  $\text{BaSO}_4 (\text{aq})$ , contains  $\text{Ba}^{2+} (\text{aq})$  ions
  - $\text{Ca}(\text{OH})_2 (\text{aq}) + \text{BaSO}_4 (\text{aq}) \rightarrow \text{Ba}(\text{OH})_2 (\text{s}) + \text{CaSO}_4 (\text{aq})$
  - The solid formed is precipitate – the reaction is called **precipitate reaction**

### ***Strong and weak alkalis***

- Strong Alkalis:** base that completely ionises in water to form  $\text{OH}^- (\text{aq})$  ions.
  - Their reactions are irreversible.
  - E.g.  $\text{NaOH}$ ,  $\text{KOH}$ ,  $\text{Ca}(\text{OH})_2$
  - $\text{Ca}(\text{OH})_2 (\text{s}) \rightarrow \text{Ca}^{2+} (\text{aq}) + 2\text{OH}^- (\text{aq})$
- Weak Alkalis:** base that partially ionise in water.
  - The remaining molecules remain unchanged as base.
  - Their reactions are reversible.
  - E.g.  $\text{NH}_3$
  - $\text{NH}_3 (\text{g}) + \text{H}_2\text{O} (\text{l}) \rightleftharpoons \text{NH}_4^+ (\text{aq}) + \text{OH}^- (\text{aq})$

### ***Uses of Alkalis***

- Alkalis neutralise acids in teeth (toothpaste) and stomach (indigestion)
- Soap and detergents contain weak alkalis to dissolve grease
- Floor and oven cleaners contain  $\text{NaOH}$  (strong alkalis)
- Ammonia (mild alkalis) is used in liquids to remove dirt and grease from glass

### ***pH and Indicators***

Indicators are substances that has different colours in acidic and alkaline solutions

#### **Common indicators:**

- Litmus
- Methyl orange
- Phenolphthalein

| Indicator              | Colour in acids | colour changes at pH | Colour in alkalis |
|------------------------|-----------------|----------------------|-------------------|
| Phenolphthalein        | Colourless      | 9                    | Pink              |
| Methyl orange          | Red             | 4                    | Yellow            |
| Litmus                 | Red             | 7                    | Blue              |
| Screened methyl orange | Red             | 4                    | Green             |
| Bromothymol blue       | Yellow          | 7                    | Blue              |

## *pH Scale*

A measure of acidity or alkalinity of a solution is known as pH

- pH 7 is neutral – in pure water
- solutions of less than pH 7 are acidic.
  - The solutions contain hydrogen ions.
  - The lower the pH, the more acidic the solution is and more hydrogen ions it contains.
- solutions of more than pH 7 are alkaline.
  - The solution contains hydroxide ions.
  - The higher the pH, the more alkaline the solution and more hydroxide ions it contains.

## *Measuring pH of a Solution*

- **Universal indicators**
  - It can be in paper or solution form.
  - Universal paper can be dipped into a solution then pH found is matched with the colour chart.
  - It gives approximate pH value.
- **pH meter**
  - A hand-held pH probe is dipped into solution and meter will show the pH digitally or by a scale.
  - Measures pH water in lakes, water, and streams accurately
- **pH sensor and computer**
  - A probe is dipped into solution and will be sent to computer through interface used to measure pH of solution.
  - The pH reading is displayed on computer screen.

## *Ionic Equations*

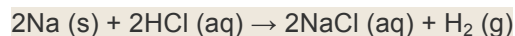
Ionic equation is equation involving ions in aqueous solution, showing formation and changes of ions during the reaction

### **Rule to make ionic equations:**

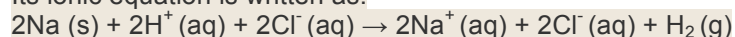
- Only formulae of ions that change is included; ions don't change = omitted
- Only aqueous solutions are written as ions; liquids, solids and gases written in full

## *Reaction between Metals and Acids*

### **Eg. reaction of sodium with hydrochloric acid**



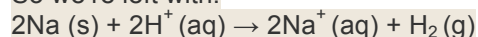
Its ionic equation is written as:



Since 2  $\text{Cl}^- \text{ (aq)}$  ions don't change, they're not involved in reaction.

As ionic equation is used to show changes in reactions, we omit  $\text{Cl}^- \text{ (aq)}$  ions.

So we're left with:

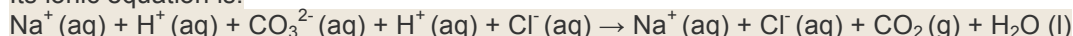


## ***Reaction between soluble ionic compounds and acids***

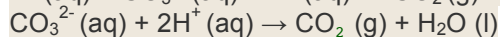
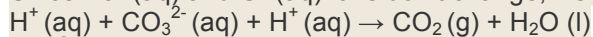
### **e.g. Reaction of sodium hydrogencarbonate with hydrochloric acid**



Its ionic equation is:

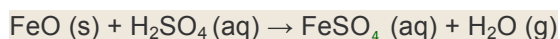


Since  $\text{Na}^+(\text{aq})$  and  $\text{Cl}^-(\text{aq})$  ions don't change, we omit them, leaving:

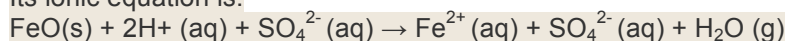


## ***Reaction between insoluble ionic compounds and acids***

### **e.g. Reaction between iron(II) oxide and sulphuric acid**

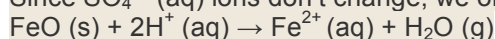


Its ionic equation is:



Note: FeO is written in full as it is solid (although it is an ionic compound)

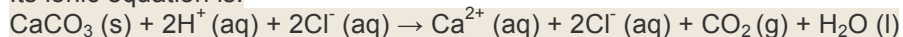
Since  $\text{SO}_4^{2-}(\text{aq})$  ions don't change, we omit  $\text{SO}_4^{2-}$  ions, leaving:



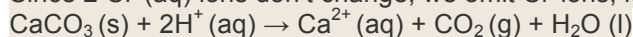
### **E.g. Reaction between calcium carbonate and hydrochloric acid**



Its ionic equation is:

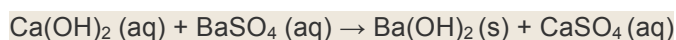


Since 2  $\text{Cl}^-(\text{aq})$  ions don't change, we omit  $\text{Cl}^-$  ions, leaving:

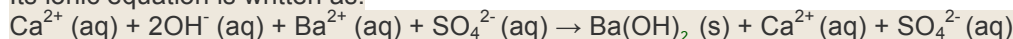


## ***Reaction producing precipitate***

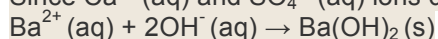
### **E.g. Reaction between calcium hydroxide and barium sulphate**



Its ionic equation is written as:

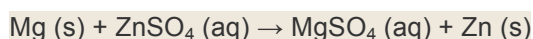


Since  $\text{Ca}^{2+}(\text{aq})$  and  $\text{SO}_4^{2-}(\text{aq})$  ions don't change, we omit them, leaving:

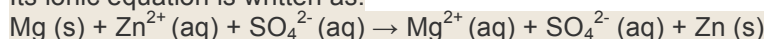


## ***Displacement reactions***

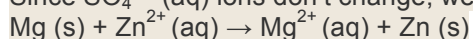
### **E.g. Reactions between magnesium with zinc sulphate**



Its ionic equation is written as:



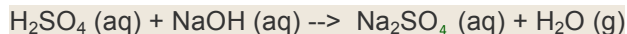
Since  $\text{SO}_4^{2-}(\text{aq})$  ions don't change, we omit them, leaving:



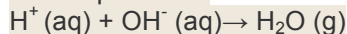
## Neutralization

- Neutralization is the reaction between acid and base to form salt and water only.
- From ionic equation, we know that the reaction only involves  $\text{H}^+$  ions from acids with  $\text{OH}^-$  ions from alkali to form water.

**E.g.  $\text{NaOH} + \text{H}_2\text{SO}_4$  forms  $\text{Na}_2\text{SO}_4 + \text{H}_2\text{O}$**



Ionic equation is:



Plants don't grow well in acidic soil. Quicklime (calcium hydroxide) is added to neutralise the acidity of soil according to equation:

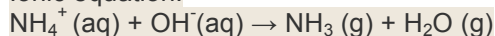


## Reaction between Base and Ammonium Salts

**E.g. Reaction between  $\text{NaOH}$  and  $\text{NH}_4\text{OH}$**



Ionic equation:

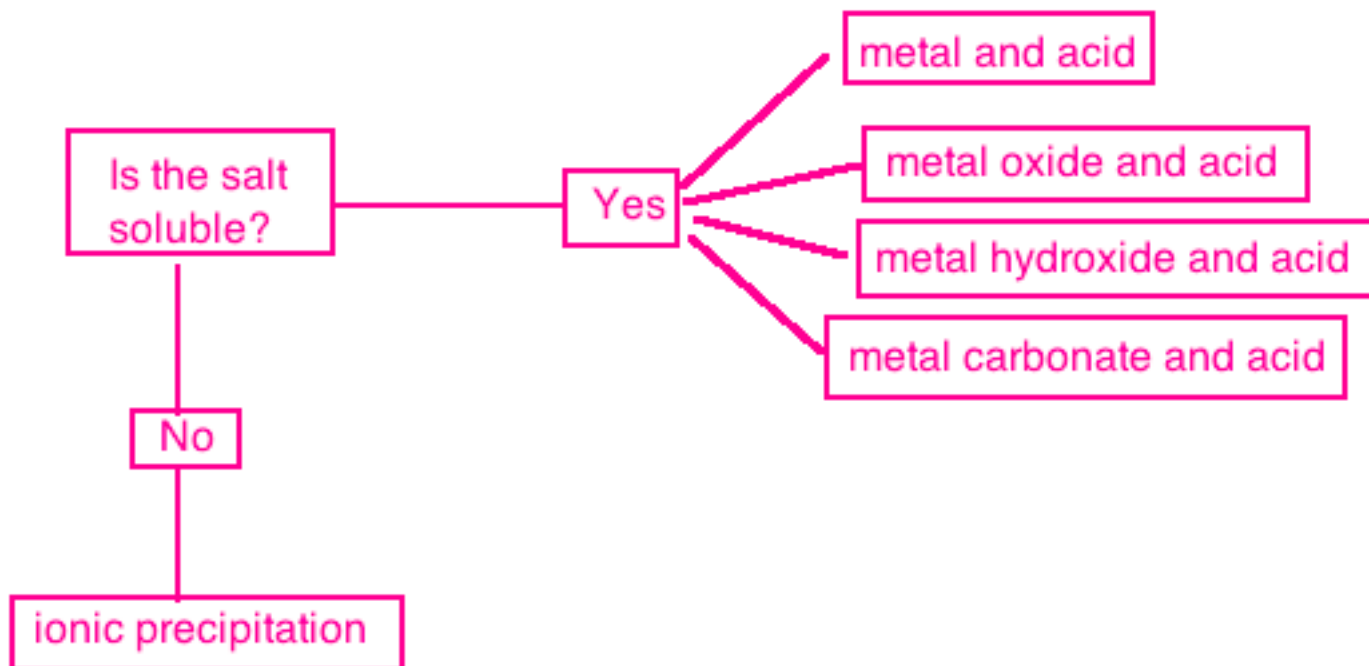


## Oxides

|                         |  |
|-------------------------|--|
| <b>Acidic oxide</b>     | Oxides of non-metals, usually gases which reacts with water to produce acids, e.g. $\text{CO}_2$ , $\text{NO}_3$ , $\text{P}_4\text{O}_{10}$ , $\text{SO}_2$   |
| <b>Basic oxide</b>      | Oxides of metals, usually solid which reacts with water to produce alkalis, e.g. $\text{CaO}$ , $\text{K}_2\text{O}$ , $\text{BaO}$                            |
| <b>Amphoteric oxide</b> | Oxides of transition metals, usually solid, which reacts with acids/alkalis to form salt and water, e.g. $\text{Al}_2\text{O}_3$ , $\text{FeO}$ , $\text{PbO}$ |
| <b>Neutral oxide</b>    | Oxides that don't react with either acids/alkalis, hence do not form salts, e.g. $\text{H}_2\text{O}$ , $\text{CO}$ , $\text{NO}$                              |

## Preparation of Salts

| <b>Soluble</b>  | <b>Insoluble</b>   |
|---|--|
| All Nitrates  | -  |
| All sulphates except -->  | $\text{BaSO}_4$ , $\text{CaSO}_4$ , $\text{PbSO}_4$                        |
| All Chlorides except -->  | $\text{PbCl}_2$ (soluble in hot water),<br>$\text{AgCl}$ , $\text{HgCl}_2$ |
| Potassium, Sodium,<br>Ammonium salts  | -  |
| $\text{K}_2\text{CO}_3$ , $\text{Na}_2\text{CO}_3$ , $(\text{NH}_4)_2\text{CO}_3$ | All other carbonates   |
| $\text{K}_2\text{O}$ , $\text{Na}_2\text{O}$                                      | All other oxides   |



### *Preparation of insoluble salts - ionic precipitation*

- Insoluble salts, e.g.  $\text{BaSO}_4$ ,  $\text{CaSO}_4$ ,  $\text{PbSO}_4$ ,  $\text{PbCl}_2$ ,  $\text{AgCl}$  and most carbonates
- involves mixing a solution that contains its positive ions with another solution that contains its negative ions

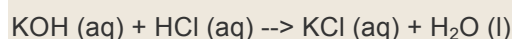
#### **E.g. Preparation of $\text{BaSO}_4$**

- First  $\text{BaCl}_2$ , since it contains wanted barium ion, is reacted with  $\text{H}_2\text{SO}_4$ , since it contains wanted sulphate ion, to produce solid  $\text{BaSO}_4$  & aqueous  $\text{KCl}$ .
- $\text{BaSO}_4$  then separated from  $\text{KCl}$  by filtration, leaving filtrate  $\text{KCl}$  &  $\text{BaSO}_4$  left on filter paper.
- Salt is washed with water to completely remove  $\text{KCl}$  & filter paper is squeezed with another filter paper to dry  $\text{BaSO}_4$ .

### *Preparation of soluble salts*

#### **1. By Metal Hydroxide and Acid**

- This method is suitable for soluble metal hydroxides called alkalis. - **titration**



- $25.0 \text{ cm}^3$  acid, as standard solution, is placed in conical flask using pipette.
- Add a few drops of indicator & titrate with alkali from burette until indicator changes colour, showing all acid has just reacted.
- Volume of alkali added is measured.
- Prepare new  $25.0 \text{ cm}^3$  acid again with pipette & add same volume of alkali as before to prevent excess alkali/acid because both reactant & product are aqueous.
- Next, the product is evaporated to dryness to obtain the salt.



## 2. By reacting metal with acid

- This preparation is suitable for the more reactive metals like Mg, Zn, Fe, Al (but not Na, K and Ca).
- In general, the metal is added to the acid until there is no further reaction. (when no more bubbles of hydrogen gas are produced)
- Excess metal is then filtered out, and the clear filtrate is then evaporated until crystals form.

### E.g. Reacting Zn with H<sub>2</sub>SO<sub>4</sub> to prepare ZnSO<sub>4</sub>

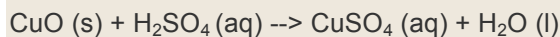


- Zn is added to H<sub>2</sub>SO<sub>4</sub> until in excess to ensure no more H<sub>2</sub>SO<sub>4</sub> is present.
- Then the mixture is filtered off to separate Zn from ZnSO<sub>4</sub>.
- The filtrate (ZnSO<sub>4</sub>) is then placed in evaporating dish to evaporate most of water then it's cooled after ZnSO<sub>4</sub> crystals are formed.
- The crystals then filtered and squeezed between filter papers to dry.

## 3. By reacting metal oxide with acid

- Nearly all the metal oxides react with acids, but most require warming,
- This method is especially suitable for those metals which do not react with dilute acids.
- eg, copper metal has no reaction with dilute acids but copper(II) oxide, if warmed with dilute acids, forms salts

### E.g. Reacting CuO with Acids

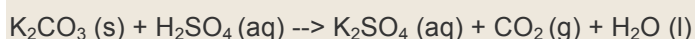


- Add excess copper(II) oxide to the warm sulphuric acid so that all the acid is neutralised. The unreacted oxide is then removed by filtering.
- The filtrate is a blue solution of copper(II) sulphate.
- The crystals are obtained by concentrating the solution by evaporation, and then leaving it to cool.
- The crystals formed can be removed by filtration.
- As copper(II) sulphate crystals contain water of crystallisation, it is important not to evaporate the solution to dryness.

## 4. By Reacting Metal Carbonate with Acid

- Similar to that involving metal oxide and acid, but this time, no heat is required.
- The carbonate fizzes and gives off carbon dioxide gas.
- Excess carbonate must be added to ensure that all the acid is neutralised
- The solution is then filtered to remove unreacted carbonate and evaporate to concentrate the solution for crystallisation

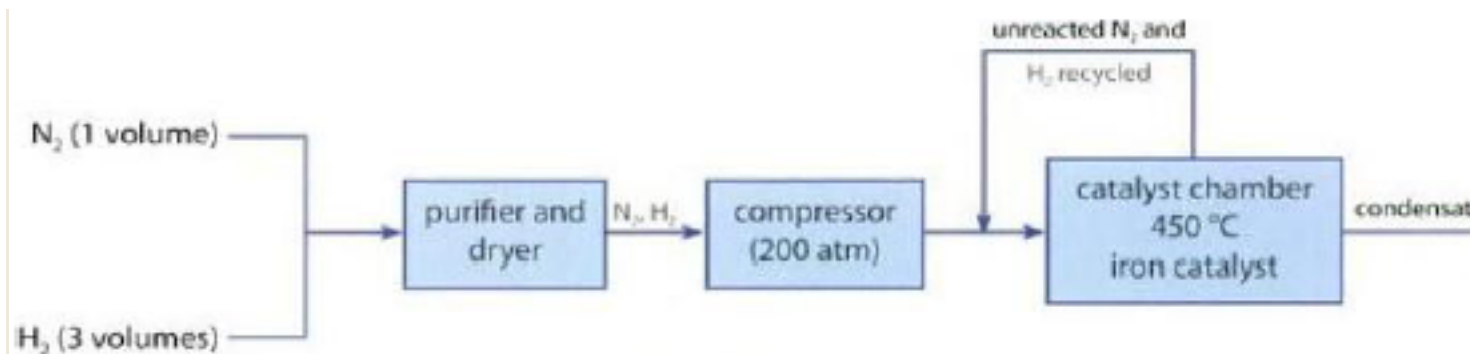
### E.g. Reacting CaCO<sub>3</sub> with Acids



- The same process is used as reaction of acid with metal, just that carbon dioxide is produced.
- Carbon dioxide can be tested by bubbling it into limewater which will turn limewater colourless to milky.

## Properties and uses of Ammonia

- produced from nitrogen reacted with hydrogen
- **For producing:** fertilisers, nitric acid, nylon, dyes, cleaners and dry cell
- **The Manufacture of Ammonia: The Haber Process**
  - The Process: Nitrogen and hydrogen are mixed together in ratio 1:3, where nitrogen is obtained from air and hydrogen is obtained from natural gas, and passed over iron catalyst.
  - Since the reaction is reversible so  $\text{H}_2$  and  $\text{O}_2$ , reproduced from decomposition of produced  $\text{NH}_3$ , are passed over the catalyst again to produce ammonia.



### Conditions for Manufacturing Ammonia

to have high yield of ammonia we should have:

- Higher pressure
- Lower temperature

But in practice, we use lower pressure of 200 atm and higher temperature of 450°C. This is because:

- Using low temperature is too slow to reach equilibrium
- Using high pressure involves safety risk and higher cost

### Ammonia as fertilizers

Plants need nitrogen as one of component for growth and ammonium fertilizers contain nitrogen for that.

#### % content of nitrogen in ammonium fertilizers

E.g. Ammonium sulphate,  $(\text{NH}_4)_2\text{SO}_4$ , and urea,  $(\text{NH}_2)_2\text{CO}$ , are 2 kinds of fertilizers. Deduce, in terms of nitrogen content, which of these fertilizers best for plants.

$$\% \text{ mass} = (\text{total mass of element} / \text{total mass of compound}) \times 100$$

$$(\text{NH}_4)_2\text{SO}_4 = (28 / 132) \times 100 = 21.2\% \text{ of N}$$

$$(\text{NH}_2)_2\text{CO} = (28 / 60) \times 100 = 46.7\% \text{ of N}$$

Therefore,  $(\text{NH}_2)_2\text{CO}$  is a better fertilizer since it contains more nitrogen.

## Problems with Ammonia

- **Eutrophication** is the increase in organic content of water when fertilizers leach into soil and washed into rivers and streams.
- When excess fertilizers washed away by rain, nitrate ions in it gets into rivers and helps aquatic plants like algae to grow swiftly.
- When too much algae, water turns murky and sunlight would not penetrate into water to help their growth which in turn lead to deaths of algae.
- Decay of this organic matter uses up oxygen, hence killing aquatic animals.
- Then even more algae dies and even more animals die
- **Water pollution** results from runoff of fertilizer use, leaching from septic tanks, sewage and erosion of natural deposits.
- ions from nitrogen in soil leaches down the soil into groundwater due to its solubility.
- Since groundwater is our drink source, when humans drink this water, they will get seriously ill and babies may suffer breathlessness to death

## MCQ Questions

1. Which of the following gases cannot be removed from the exhaust gases of a petrol powered car by its catalytic converter?
  - a. carbon dioxide
  - b. carbon monoxide
  - c. hydrocarbons
  - d. nitrogen dioxide
2. An excess of dilute sulphuric acid reacts with both aqueous barium hydroxide and aqueous barium chloride. In what way are the two reactions the same?
  - a. a gas is produced
  - b. an insoluble salt is produced
  - c. the final pH is 7
  - d. water is produced
3. In separate experiments, an excess of aqueous sodium hydroxide or aqueous ammonia was gradually added to a solution X. In both experiments, a precipitate was obtained which dissolved in an excess of the added reagent. What could X contain?
  - a. copper(II) nitrate
  - b. iron(II) nitrate
  - c. iron(III) nitrate
  - d. zinc nitrate
4. Which of the following is a property of ethanoic acid but is not a property of sulphuric acid?
  - a. it reacts with copper(II) oxide
  - b. it reacts with sodium carbonate
  - c. it reacts with magnesium
  - d. it burns in air

5. Which salt could be prepared by a method involving crystallization as the final stage?

- a. barium sulphate
- b. calcium carbonate
- c. silver chloride
- d. sodium nitrate

6. An element X forms a hydroxide which dissolves both in acids and in alkalis. What could X be?

- a. aluminium
- b. calcium
- c. copper
- d. iron

7. Under suitable conditions, hydrochloric acid reacts with each of the following substances. Which reaction gives a colorless solution only?

- a. calcium carbonate
- b. iron(II) hydroxide
- c. potassium hydroxide
- d. silver nitrate

8. After acidification with dilute nitric acid, a colorless solution of X reacts with aqueous silver nitrate to give a white precipitate. What could X be?

- a. calcium iodide
- b. copper(II) chloride
- c. lead(II) chloride
- d. sodium chloride

9. Two tests were carried out on a colorless liquid X. X turned anhydrous copper(II) sulphate from white to blue. X reacted with calcium, giving hydrogen. What could X be?

- 1. dilute hydrochloric acid
- 2. ethanol
- 3. water

- a. 1 only
- b. 1 and 2 only
- c. 1 and 3 only
- d. 1, 2 and 3

10. Which of the following is a characteristic property of alkalis in aqueous solution?

- a. they liberate ammonia from ammonium salts
- b. they liberate carbon dioxide from carbonates
- c. they give hydrogen with any metal
- d. they turn universal indicator red

11. A mineral X dissolves in dilute hydrochloric acid, giving off a gas which turns limewater milky. When aqueous ammonia is added to the colorless solution, a white precipitate is formed. The precipitate dissolves in an excess of aqueous ammonia to give a colorless solution. What is X?

- a. calcium carbonate

- b. copper(II) carbonate
- c. zinc carbonate
- d. zinc sulphide

12. Aqueous sodium hydroxide reacts with a metal ion producing a colored precipitate. This precipitate changes color on standing. What is the ion present?

- a.  $\text{Al}^{3+}$
- b.  $\text{Cu}^{2+}$
- c.  $\text{Fe}^{2+}$
- d.  $\text{Zn}^{2+}$

13. A bee sting is acidic. Which household substance will neutralize a bee sting?

- a. damp bicarbonate of soda pH 8
- b damp common salt pH 7
- c. lemon juice pH 5
- D. vinegar pH 4

14. An excess of sodium hydroxide is added to an aqueous solution of salt X and boiled. Ammonia gas is only given off after aluminium foil is added to the hot solution.

What could be X?

- a. ammonium chloride
- b. ammonium nitrate
- c. sodium chloride
- d. sodium nitrate

15. Which ion reacts with aqueous ammonia to give a precipitate that dissolves in an excess of ammonia?

- a.  $\text{Al}^{3+}$
- b.  $\text{Fe}^{2+}$
- c.  $\text{Fe}^{3+}$
- d.  $\text{Zn}^{2+}$

16. A solid element conducts electricity. The element burns in air to form a white solid. This white solid dissolves in water to give an alkaline solution. What is the element?

- a. aluminium
- b. calcium
- c. carbon
- d. copper

17. Which calcium compound does not increase the pH of acidic soils?

- a. calcium carbonate
- b. calcium hydroxide
- c. calcium oxide
- d. calcium sulphate

18. What is the concentration of hydrogen ions in  $0.05 \text{ mol/dm}^3$  sulphuric acid?

- a.  $0.025 \text{ g/dm}^3$
- b.  $0.05 \text{ g/dm}^3$
- c.  $0.10 \text{ g/dm}^3$

d.  $2.0 \text{ g/dm}^3$

19. A solution X forms a white precipitate with dilute sulphuric acid and also with aqueous silver nitrate. What could solution X contain?

- a. barium chloride
- b. barium nitrate
- c. magnesium chloride
- d. magnesium sulphate

20. Which of the following is a reaction of dilute hydrochloric acid?

- a. ammonium chloride reacts to give ammonia
- b. calcium carbonate reacts to give carbon dioxide
- c. copper reacts to give hydrogen
- d. universal indicator paper turns blue

21. Which compound in solution produces a precipitate with aqueous ammonia that does not dissolve when an excess of ammonia is added?

- a. copper(II) sulphate
- b. iron(II) chloride
- c. potassium hydroxide
- d. zinc chloride

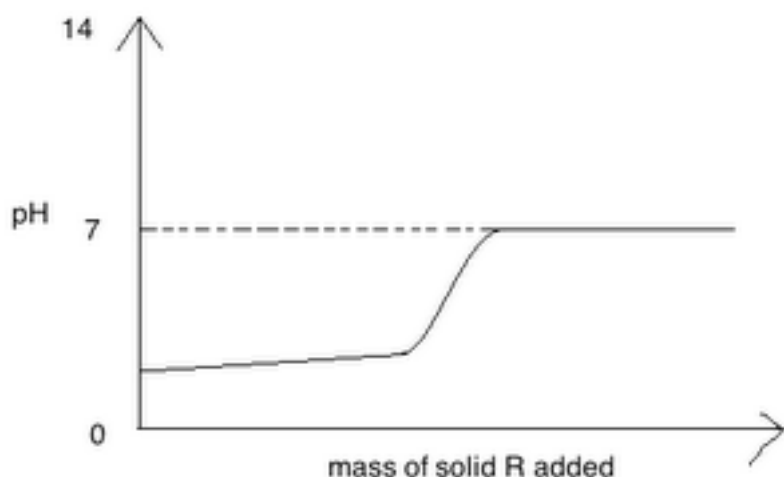
22. A white compound produces a mixture of gases when heated. This mixture turns moist Universal Indicator paper red and relights a glowing splint. What does this mixture contain?

- a. an acidic gas and hydrogen
- b. an acidic gas and oxygen
- c. an alkaline gas and hydrogen
- d. an alkaline gas and oxygen

23. Which of the following describes a step in the preparation of insoluble barium sulphate from aqueous barium chloride and dilute sulphuric acid?

- a. add dilute sulphuric acid until no more gas is produced
- b. add the indicator methyl orange
- c. collect the precipitate of barium sulphate by filtration
- d. evaporate the filtrate until it crystallises

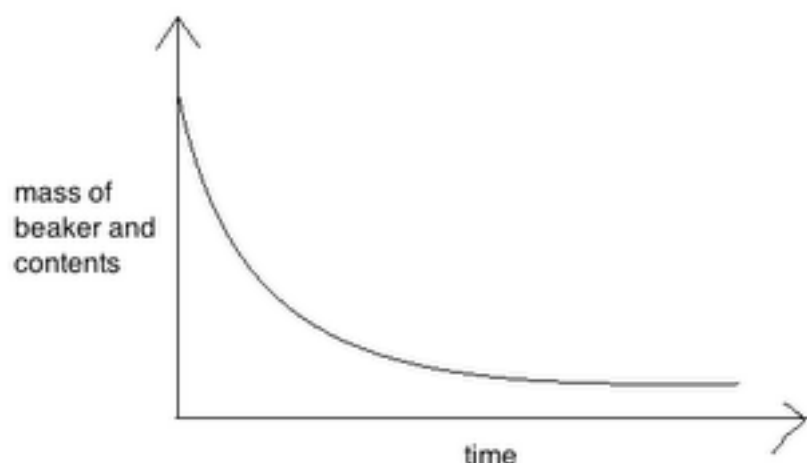
24. Solid R is gradually added to aqueous solution S. The changes in pH are shown in the graph



What are R and S?

|   | R                         | S                 |
|---|---------------------------|-------------------|
| a | insoluble metal oxide     | hydrochloric acid |
| b | insoluble non-metal oxide | sodium hydroxide  |
| c | soluble metal oxide       | hydrochloric acid |
| d | soluble non-metal oxide   | sodium hydroxide  |

25. Two solutions are mixed in a beaker and the mass of the beaker and the contents is then recorded at various times. The graph shows the results.



What could be the two solutions?

- aqueous copper(II) sulphate and aqueous ammonia
- aqueous sodium carbonate and dilute nitric acid
- aqueous sodium hydroxide and aqueous zinc sulphate
- dilute hydrochloric acid and aqueous sodium sulphate

26. Element L burns in air giving a product that dissolves in water producing an alkaline solution. What is element L?

- carbon
- iron
- sodium
- sulfur

27. In an accident at a factory, some nitric acid was spilt. Which substance, when added in excess, neutralises the acid without leaving an alkaline solution?

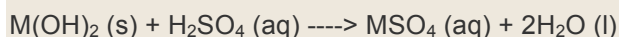
- aqueous ammonia

- b. aqueous sodium hydroxide
- c. calcium carbonate
- d. water

28. Which statement does not describe a property of a weak acid in solution?

- a. it forms a salt with sodium hydroxide
- b. it has a pH of between 8 and 9
- c. it is only partly dissociated into ions
- d. it reacts with sodium carbonate to give off carbon dioxide

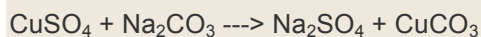
29. An aqueous solution of a sulphate is made from a solid hydroxide, of a metal M, by the reaction:



For which hydroxide would the method not work?

- a. barium hydroxide
- b. copper(II) hydroxide
- c. iron(II) hydroxide
- d. magnesium hydroxide

30. In an experiment, 4.0 cm<sup>3</sup> of 1.0 mol/dm<sup>3</sup> aqueous copper(II) sulphate was mixed with 8cm<sup>3</sup> of 1.0 mol/dm<sup>3</sup> aqueous sodium carbonate.



What did the reaction vessel contain when the reaction was complete?

- a. a colourless solution only
- b. a green precipitate and a blue solution
- c. a green precipitate and a colourless solution
- d. a white precipitate and a blue solution

31. Which of the following compounds dissolves in water to give a solution with a pH greater than 7?

- a. calcium carbonate
- b. copper(II) hydroxide
- c. sodium hydroxide
- d. sulphur dioxide

32. Waste water from a factory was found to have a pH value of 2. Which substance could be used to neutralise the waste water before it is released into a river?

- a. ammonium sulphate
- b. lime
- c. oxygen
- d. sulphur dioxide

33. Which of the following gases will not turn moist blue litmus paper red?

- a. carbon dioxide
- b. chlorine
- c. hydrogen chloride
- d. nitrogen monoxide



34. Which of the following correctly describes the solution formed and the gas evolved when potassium reacts with water?

|    | Solution | Gas     |
|----|----------|---------|
| a. | alkaline | neutral |
| b. | acidic   | neutral |
| c. | alkaline | acidic  |
| d. | neutral  | neutral |

35. Which of the following compounds can be classified as a normal salt?

I.  $K_2SO_4$

II.  $Zn(OH)Cl$

III.  $NaHCO_3$

IV.  $CH_3COONa$

- a. I and II only
- b. II and IV only
- c. I, II, and III
- d. I and IV only

## MCQ Answers

- 1. a
- 2. b (a white precipitate of barium sulphate produced in both cases)
- 3. d
- 4. d (ethanoic acid is an organic compound that contain carbon atoms in its molecule that can burn in air to form carbon dioxide)
- 5. d (sodium nitrate is the only soluble salt. The rest are insoluble and are obtained by filtration)
- 6. a (aluminum oxide is an amphoteric oxide that reacts with both acids and alkalis)
- 7. c
- 8. d (since X is a colorless solution, it does not contain transition metal ions. The white ppt is likely to be  $AgCl$ )
- 9. c
- 10. a
- 11. c
- 12. c
- 13. a
- 14. d (for ammonium nitrate, ammonia gas would also be evolved when it is boiled with sodium hydroxide. Boiling the sample in sodium hydroxide and aluminium foil is a chemical test for identifying nitrate ions)
- 15. d
- 16. c
- 17. d
- 18. c
- 19. a
- 20. b
- 21. b
- 22. b
- 23. c (when 2 solutions are mixed,  $BaSO_4$  precipitate is formed. It may be obtained by filtration)
- 24. a
- 25. b (the graph shows a loss in mass. hence, the reaction is likely to be one that gives out a gas that escapes from the reaction vessel)

26. c  
27. c  
28. b  
29. a (barium hydroxide is soluble in water and reacts with dilute sulphuric acid to form insoluble barium sulphate)  
30. c  
31. c  
32. b  
33. d  
34. a  
35. d

## Structured Questions Worked Solutions

**1a. Hydrogen chloride is a neutral gas and dissolves in water to form an acidic solution**

**i. explain why dry hydrogen chloride gas is neutral**

**ii. explain why aqueous hydrogen chloride is acidic**

**iii. describe how sodium carbonate can be used to confirm that an aqueous solution contains an acid**

**1b. The oxides of elements may be acidic, basic, or amphoteric. Give the name and formula of one example of each of these three types of oxide.**

### Solution

1ai. Hydrogen chloride is covalently bonded, with sharing of electrons. Hence the molecules are not charged since no ionisation occurs.

1aii. When hydrogen chloride dissolves in water the molecules then ionises to form  $\text{H}^+$  and  $\text{Cl}^-$ . Water also ionises to form  $\text{H}^+$  and  $\text{OH}^-$ . The number of hydrogen ions is greater than hydroxide ions so the solution becomes acidic.

1aiii. It reacts with sodium carbonate to liberate carbon dioxide.

1b. sulphur dioxide,  $\text{SO}_2$  - ACIDIC  
potassium hydroxide,  $\text{KOH}$  - BASIC  
zinc oxide,  $\text{ZnO}$  - AMPHOTERIC

**2. The reaction between zinc granules and dilute sulphuric acid at  $25^\circ\text{C}$  can be made to go faster by adding a small amount of copper powder.**

**a. in an experiment, 0.65 g of zinc granules and  $100\text{ cm}^3$  of  $0.2\text{ mol/dm}^3$  sulphuric acid are allowed to react.**

**i. calculate the number of moles of zinc in 0.65 g**

**ii. calculate the number of moles of sulphuric acid in  $100\text{ cm}^3$  of  $0.2\text{ mol/dm}^3$  solution**

**iii. give the equation, including state symbols, for the reaction**

**iv. explain why the reaction stops.**

**b. give one other method of making the reaction between zinc granules and dilute sulphuric acid go faster.**

**Explain in terms of collisions between reacting particles how the method you have described speeds up the reaction.**

### Solution

2ai. no. of moles of Zn = mass/Mr =  $0.65/65 = 0.01$

2aii. no. of moles of sulphuric acid = molarity x volume =  $0.2 \times 0.1 = 0.02$

2aiii.  $\text{Zn (s)} + \text{H}_2\text{SO}_4 \text{ (aq)} \rightarrow \text{ZnSO}_4 \text{ (aq)} + \text{H}_2 \text{ (g)}$

2aiv. All the zinc have reacted with the  $\text{H}_2\text{SO}_4$ . The  $\text{H}_2\text{SO}_4$  acid is in excess.

2b. Use powdered zinc instead of granules. With powdered zinc, more zinc particles are able to move and collide with the acid particles. This increases the number of collision and thus increases the rate of reaction.

### **3. This question is about oxides. Use only the following oxides as answers.**

**carbon dioxide**

**copper(II) oxide**

**sodium oxide**

**carbon monoxide**

**silicon dioxide**

**sulphur dioxide**

**a. which oxide has a macromolecular structure?**

**b. which oxide is used to bleach wood pulp in the manufacture of paper?**

**c. which oxides are basic?**

**d. which oxides are common atmospheric pollutants?**

**e. which oxide is the main constituent of sand?**

**f. which oxide gives a blue solution when heated with dilute sulphuric acid?**

### Solution

3a. silicon dioxide

3b. sulphur dioxide

3c. copper(II) oxide and sodium oxide

3d. carbon monoxide and sulphur dioxide

3e. silicon dioxide

3f. copper(II) oxide

### **4. Describe what is observed in each of the following reactions.**

**a. aqueous sodium hydroxide is added to aqueous iron(III) sulphate**

**b. dilute hydrochloric acid is added to solid sodium carbonate**

**c. aqueous barium chloride is added to dilute sulphuric acid**

**d. aqueous silver nitrate is added to aqueous sodium chloride**

### Solution

4a. orange-brown precipitate is seen

4b. solid dissolved and effervescence seen (a colorless and odourless gas is evolved)

4c. white precipitate seen

4d. white precipitate seen

**5a. Potassium nitrate is a salt which can be prepared by reacting an acid with an alkali, using the titration method.**

**i. name an acid and an alkali which react to make potassium nitrate**

**ii. explain why the titration method is suitable for the preparation of potassium nitrate**

**5b. Lead(II) iodide is a salt which can be prepared by the precipitation method.**

**i. name suitable reagents for the preparation of lead(II) iodide**

**ii. explain why the precipitation method is suitable for the preparation of lead(II) iodide**

### **Solution**

5ai. acid: nitric acid

alkali: potassium hydroxide

5aii. Since the acid, alkali and the salt are soluble in water,  $\text{KNO}_3$  cannot be prepared by other methods (eg. precipitation). The exact quantities of each acid and alkali are determined by titration where the end-point is determined by the use of an indicator.

5bi. lead nitrate and potassium iodide

5bii. Because lead iodide is insoluble in water. Once formed, it precipitates out readily while the salt  $\text{KNO}_3$  remains soluble in water.

**6. Write the name of one example of each of the following.**

**a. a green solid which decomposes on heating to form carbon dioxide**

**b. a gas which turns moist red litmus paper blue**

**c. an acid that forms a white precipitate when mixed with aqueous barium nitrate**

**d. a metal which is extracted by electrolysis**

### **Solution**

6a. copper(II) carbonate

6b. ammonia

6c. sulphuric acid

6d. aluminium

**7a. For each of the following reactions,**

**i. state the observations you would expect to make**

**ii. name the product(s) of the reaction(s)**

**iii. explain the changes which take place**

**1 Aqueous sodium hydroxide is added to aqueous iron(II) sulphate and the mixture is allowed to stand**

**2. Chlorine is bubbled into aqueous potassium iodide. The solid product is collected and then heated.**

**7b. Hydrogen can be manufactured using the reversible reaction between methane and steam. The formation of hydrogen is endothermic.**

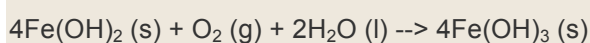
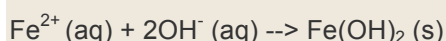
**i. write the equation for this reaction**

**ii. explain why this reaction is best carried out at a high temperature but at a low pressure.**

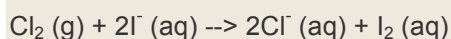
**Solution**

7ai.

1. Dirty green precipitate of iron(II) hydroxide is formed which turns brown (iron(III) hydroxide) on standing. The brown solid is formed as a result of air oxidation of iron(II) to iron(III).

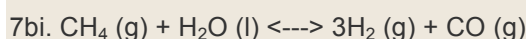
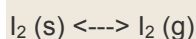


2. The solution turned brown due to formation of iodine. Iodide is oxidised by chlorine to give iodine.



With more iodine formed, it finally precipitates out as a black solid.

Heating this black iodine crystal causes it to sublime to form violet iodine vapour. Black iodine crystals will be seen to form at the cooler surface.



7bii. A high temperature speeds up the rate of reaction. It also helps to push the equilibrium to the right since the forward reaction is endothermic. Since there are greater amount of gaseous products, lowering the pressure would also help shift the reaction to the right. Hence, the yield will be higher.

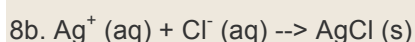
**8a. Name two aqueous solutions which will react to form a precipitate of silver chloride, AgCl**

**8b. Write an ionic equation, including state symbols, for the reaction in a.**

**8c. Describe how you would obtain a pure, dry sample of silver chloride precipitate from the mixture in a.**

**Solution**

8a. sodium chloride and silver nitrate



8c. Mix the two solutions. Filter the resulting mixture. AgCl is obtained as the residue. Wash the residue with water and then dry the solid in an oven.

9. A student adds aqueous sodium hydroxide from a burette into 25.0cm<sup>3</sup> of dilute sulphuric acid. The student measures the pH value of the mixture during the addition of the sodium hydroxide.

a. describe how the pH value changes

b. give an ionic equation to represent the neutralisation reaction between sodium hydroxide and sulphuric acid.

c. sulphuric acid is a strong acid.

i. what is meant by the term acid?

ii. what is the difference between a strong acid and a weak acid?

d. dilute sulphuric acid reacts with magnesium to give hydrogen. Give the ionic equation for this reaction.

### Solution

9a. pH increases from 1 to 14

9b.  $\text{H}^+ (\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow \text{H}_2\text{O} (\text{l})$

9ci. an acid is a compound that produces hydrogen ions,  $\text{H}^+$  when it dissolves in water,

9cii. a strong acid dissociates fully in water whereas a weak acid dissociates partially in water to form hydrogen ions  $\text{H}^+$ .

9d.  $\text{Mg} (\text{s}) + 2\text{H}^+ (\text{aq}) \rightarrow \text{Mg}^{2+} (\text{aq}) + \text{H}_2 (\text{g})$

10a. For each salt, suggest the name of the missing reagent and briefly describe how to obtain the solid product from the reaction mixture.

i. salt to be made: lithium chloride

reagent 1: dilute hydrochloric acid

reagent 2: \_\_\_\_\_

I could obtain solid lithium chloride by: \_\_\_\_\_

ii. salt to be made: barium sulphate

reagent 1: aqueous potassium sulphate

reagent 2: \_\_\_\_\_

I could obtain solid barium sulphate crystals by: \_\_\_\_\_

iii. salt to be made: blue copper(II) sulphate crystals

reagent 1: dilute sulphuric acid

reagent 2: \_\_\_\_\_

I could obtain blue copper(II) sulphate crystals by: \_\_\_\_\_

10b. Ammonium sulphate can be made by reacting aqueous ammonia with dilute sulphuric acid.



Calculate the mass of ammonium sulphate that can be made from 51 g of ammonia.

#### Solution

10ai. reagent 2: aqueous lithium hydroxide

Evaporating the salt solution to dryness to obtain lithium chloride crystals

10aii. reagent 2: aqueous barium chloride

Filtration

10aiii. reagent 2: solid copper(II) oxide

Crystallisation

10b. Mr of  $\text{NH}_3$  = 17

Mr of  $(\text{NH}_4)_2\text{SO}_4$  = 132

no. of moles of  $\text{NH}_3$  =  $51/17 = 3$

no. of moles of  $(\text{NH}_4)_2\text{SO}_4$  = 1.5

Mass of  $(\text{NH}_4)_2\text{SO}_4$  made =  $1.5 \times 132 = 198 \text{ g}$

11. The table shows the soil pH ranges required by different crops for growth.

| crop      | pH range  |
|-----------|-----------|
| peanut    | 5.0 - 6.5 |
| millet    | 6.0 - 6.5 |
| sunflower | 6.0 - 7.5 |
| paprika   | 7.0 - 8.5 |
| mango     | 5.5 - 6.0 |

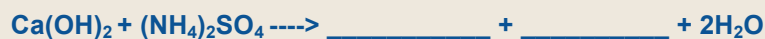
a. A farmer plants peanut and millet crops. Only the peanut crop grows well. Predict the pH of the soil

b. Which other crop is most likely to grow well in the same soil

c. The farmer adds calcium hydroxide,  $\text{Ca}(\text{OH})_2$ , and ammonium sulphate,  $(\text{NH}_4)_2\text{SO}_4$ , to the soil. Explain the purpose of using each compound.

d. A reaction occurs between calcium hydroxide and ammonium sulphate.

i. complete the equation for this reaction.



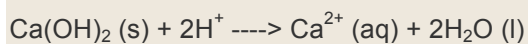
ii. Explain why the farmer should not have added these two compounds to the soil at the same time.

### Solution

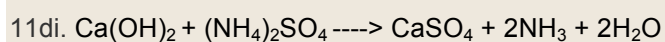
11a. 5.0 - 5.5

11b. Mango crop

11c.  $\text{Ca}(\text{OH})_2$  is a weak alkali so it neutralises the acidic soil by reacting with  $\text{H}^+$  ions in the soil.



$(\text{NH}_4)_2\text{SO}_4$  serves as a nitrogenous fertiliser to increase the nitrogen content of the soil.



11dii. Ammonium compounds that make up fertilisers react with alkali, calcium hydroxide under the heat of the sun to release ammonia gas. The nitrogen content of the soil decreases as nitrogen is lost from the soil into the atmosphere.

