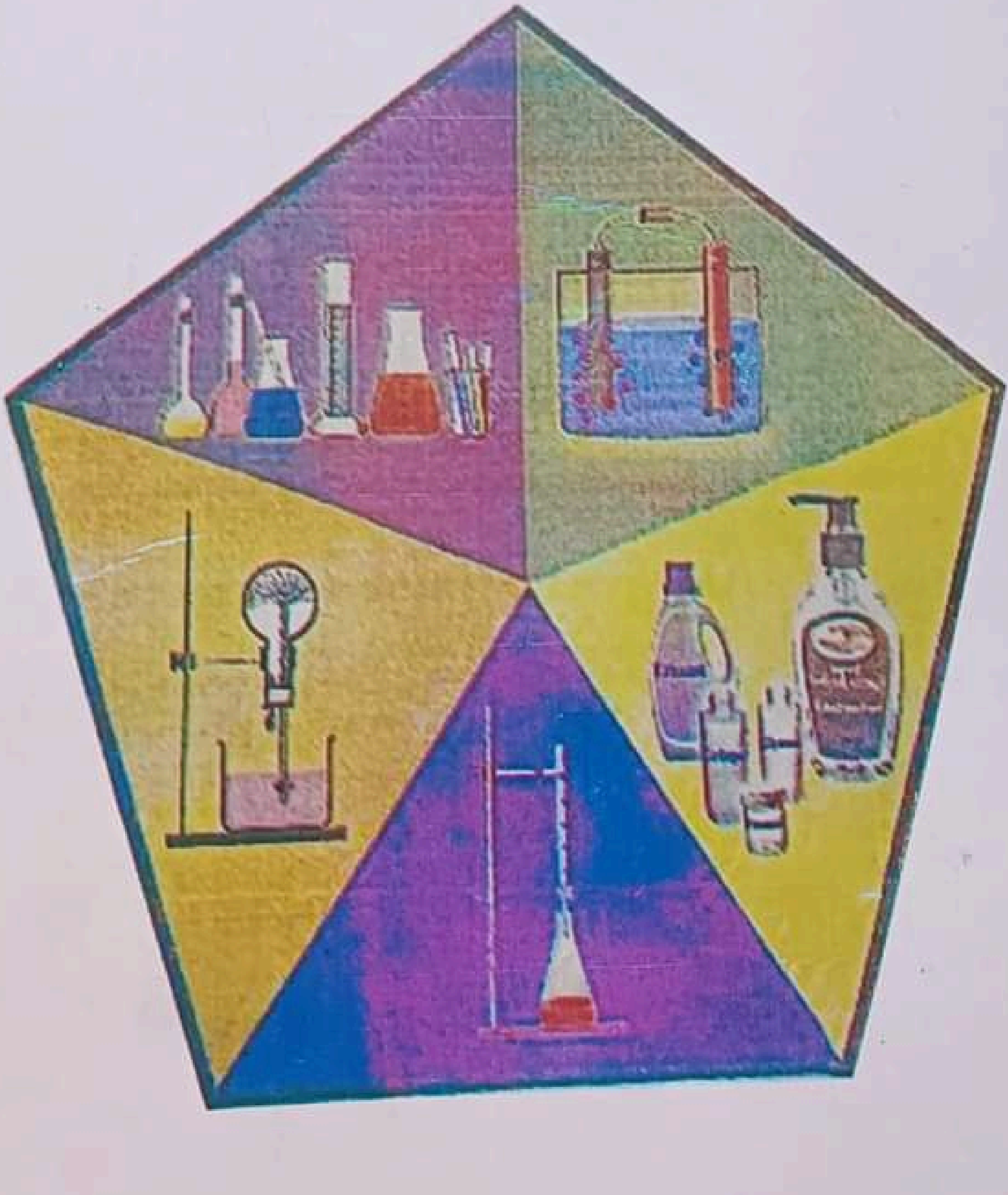
THE GOVERNMENT OF
THE REPUBLIC OF THE UNION OF MYANMAR

MINISTRY OF EDUCATION

EXPERIMENTAL CHEMISTRY

CHEMISTRY
GRADE 11



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EXPERIMENT 1

Common Laboratory Apparatus Used in Chemistry Experiments

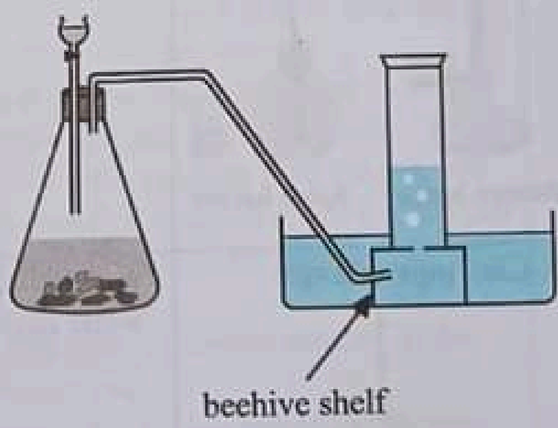
Learning Objectives

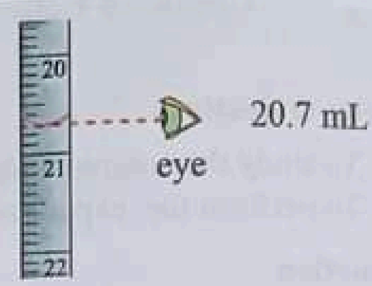
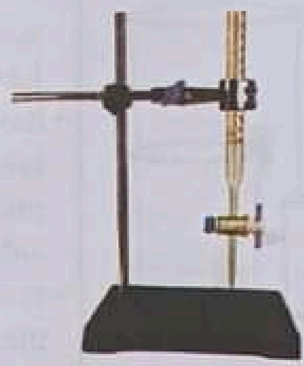
- To study the common laboratory apparatus and the proper handling in the chemistry experiments
- To perform the experiments effectively and safely

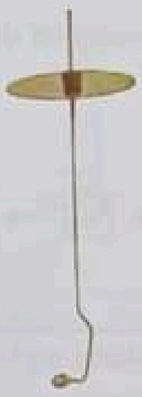
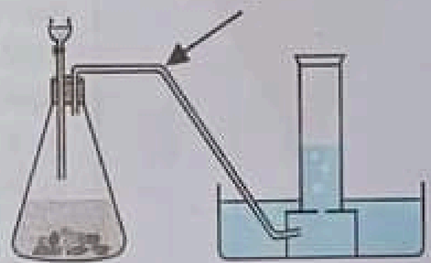
Introduction

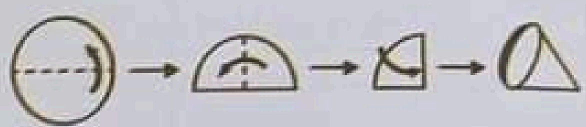
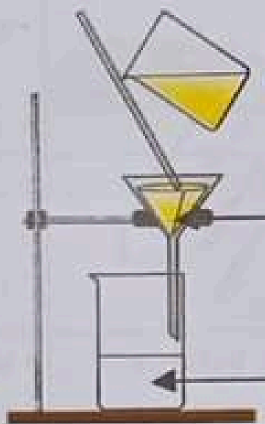
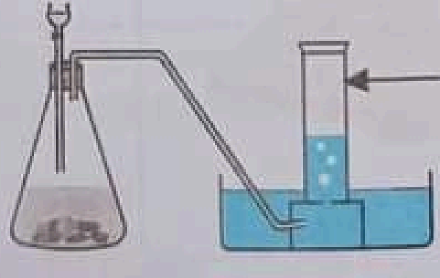
The students have to know the common laboratory apparatus and to understand how to use and handle effectively and safely. The following table shows the common laboratory apparatus and their handling methods.

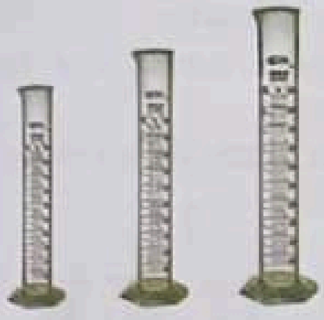
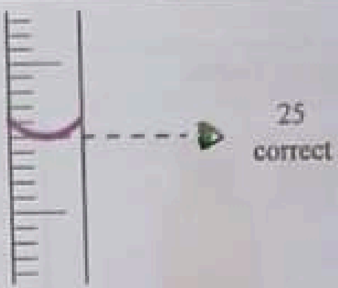
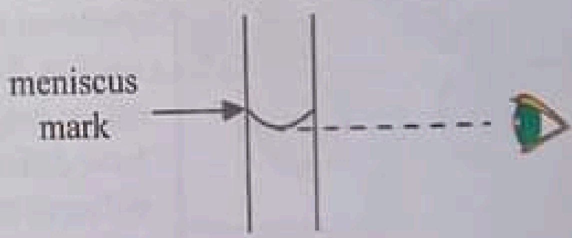
Table Common Laboratory Apparatus and Their Handling Methods

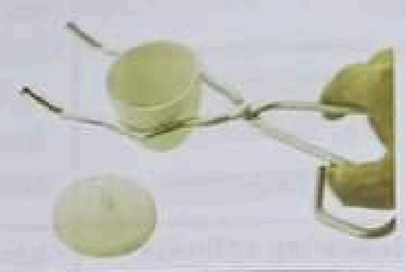
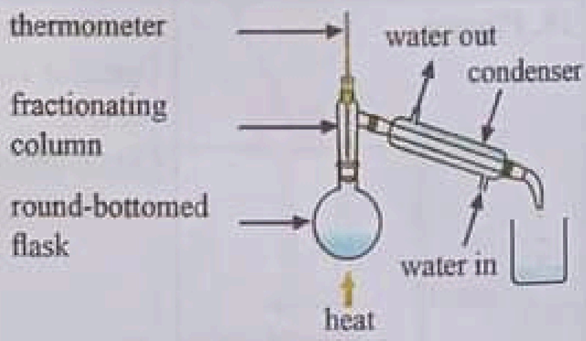
Apparatus	Description/Information	Handling and Reading
1. Beaker 	• used for holding liquids • cannot measure the volume of liquids accurately (but they do have graduations) • have different sizes and labelled with the maximum volume on its side • made of heat resistant glass such as Pyrex	• use the graduation marks on the beaker to measure the approximate volume of liquid • stir the liquid in the beaker with glass rod • fill the beaker not more than one-third of the volume when heating
2. Beehive Shelf 	• used to support a receiving gas jar or tube while a gas is being collected over water with a trough • made of porcelain or glass	• must immerse the beehive shelf in a trough of water 

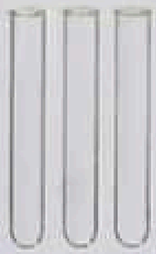
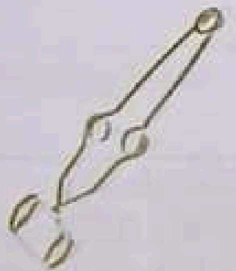
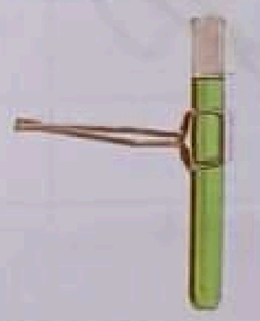
Apparatus	Description/Information	Handling and Reading
3. Burette 	• used to deliver solution in precisely-measured, variable volumes • used primarily for volumetric analysis (titration) • have different capacity and labelled with the graduation marks from top to bottom	 • place the eye horizontally to the meniscus (the curve surface of the liquid) to read the level of a liquid in a burette • not necessary to fill up the liquid level up to the mark of zero • hold the tap of burette with left hand during titration • do not trap the bubbles in the tip
4. Burette stand and clamp 	• used to support burette via burette clamp while titration is performed	• tighten the burette fitted to the clamp 
5. Burner  **Bunsen burner** **Spirit burner**	• used for heating and combustion	• hold straight upward and close it if it is unnecessary
6. Clay pipe triangle 	• used to hold a crucible while heating	• place the clay pipe triangle on the tripod stand and put the burner underneath it 

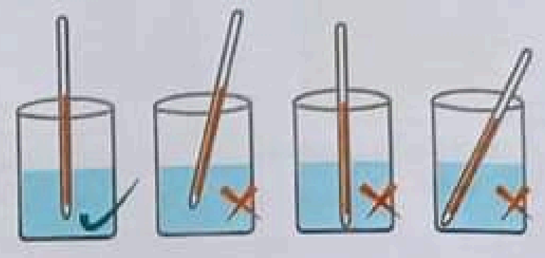
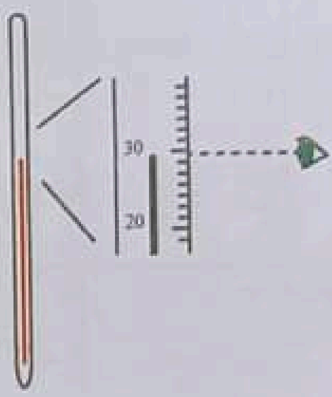
Apparatus	Description/Information	Handling and Reading
7. Conical flask (Erlenmeyer flask) 	• same properties as beaker (different volume sizes) • commonly used in volumetric analysis (titration)	• hold the neck of conical flask with right hand during titration
8. Deflagrating spoon 	• used for heating substances until they burn away • made of stainless steel which is a long-handle spoon with a cover	• position at a particular angle to avoid burning your body • lower into a gas jar filled with a gas to demonstrate deflagration 
9. Delivery tube 	• have different shapes and sizes • made of glass	
10. Electronic balance 	• used for weighing a substance	• place an empty container (a weighing bottle) on the balance pan • set the balance to zero so that it can ignore the mass of the container • remove the container from the pan, add the chemical to it, and return it to the pan • record the mass of the chemical shown on the display • never place a chemical directly on the balance pan • never place the hot and wet substances on the pan

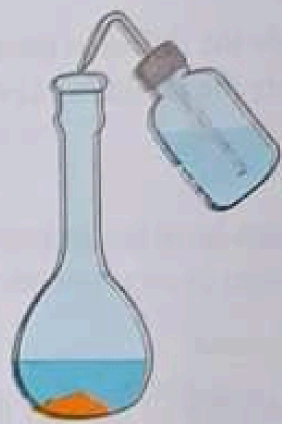
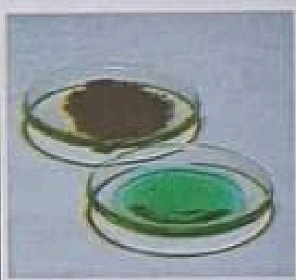
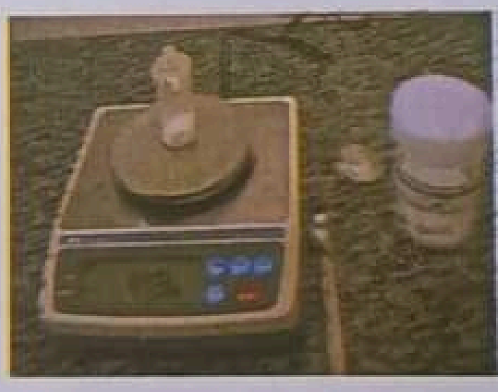
Apparatus	Description/Information	Handling and Reading
11. Evaporating basin 	• used to evaporate excess water (or other solvent) to ensure that a concentrated solution or dissolved substance is left behind • made of ceramic (porcelain), nickel, steel, etc.	• hold it carefully with tongs not to spill the residue left or burnt
12. Filter paper 	• used to separate solids from liquids	• handle the filter paper with dry hands (take care of staining something) • fold to cone shape • put it into a funnel and moisten the cone with a small amount of water 
13. Funnel 	• used for decantation and filtration purposes • used to separate the liquid and solid through a filter paper • used to transfer or fill the liquid to the container such as burette, measuring cylinder, volumetric flask, etc. • made of glass or plastic	• run down the solution along a glass rod into the funnel • do not exceed the liquid level to the top of the filter paper in the funnel 
14. Gas jar 	• used for collecting gases • made of glass	• cover the jar with a lid when it is full of gas 

Apparatus	Description/Information	Handling and Reading
15. Glass rod & Glass tube 	• use the glass rod for stirring purpose • use the glass tube for delivering drops of liquid from one container to another	• always wash the glass rods and the glass tubes with water after testing
16. Measuring cylinder 	• used to measure the volume of a liquid accurately • have different sizes (volumes) • have graduation marks from bottom to top	 • fill with a liquid till the bottom of the meniscus to reach the desired mark • place the eye horizontally to the meniscus to read a measuring cylinder
17. Mortar & Pestle 	• used to grind solids into fine powder • made of ceramic (porcelain)	• do not use force while grinding
18. Pipette 	• used to measure the precise volumes of liquids in mL • have different sizes • made of glass	 • withdraw a liquid until the bottom of the meniscus of liquid level to reach the mark • hold it straight forward to check the mark
19. Pipette bulb 	• used to withdraw the liquid into a pipette • made of rubber	• use the correct size of bulb for the pipette • press the bulb to remove the air before drawing the liquid • release the bulb gradually till the liquid reach the desired mark

Apparatus	Description/Information	Handling and Reading
20. Porcelain crucible 	• used for drying or ashing	• hold the hot crucible using tongs 
21. Reagent bottle 	• intended to store the chemicals in the liquid or powdered form • intended to store the corrosive chemicals in the glass bottles and the light sensitive chemicals in the brown bottles • made of plastic or glass	• label clearly the names of chemicals in both words and formulae • warn as flammable, corrosive or fuming if it is necessary • close the bottle firmly, do not close tightly or loosely 
22. Round-bottomed flask 	• used for heating and/or boiling of liquid, distillation, carrying out chemical reactions • used as distilling flask in rotary evaporators • have different sizes with different necks, e.g., single-neck, two-necked, three-necked round-bottomed flasks • made of glass (Pyrex)	 **distillation set-up**
23. Spatula 	• used to scrap, transfer and apply the paste or powders from one container to another • made of steel or plastic	

Apparatus	Description/Information	Handling and Reading
24. Stopwatch 	• used for measuring a particular period of time	• press a button to start and then stop it • record the experimental time duration
25. Test tube 	• used to hold liquids • made of glass • made of heat resistant glass (Pyrex) for heating	• never point the test tube towards others or look down into the test tube during heating
26. Test tube brush 	• used for cleaning the inner portion of the test tube	
27. Test tube holder 	• used to hold a test tube for a short period of "gentle heating"	
28. Test tube rack 	• used to place test tubes in the upright direction	

Apparatus	Description/Information	Handling and Reading
29. Thermometer 	• used to measure temperature or a temperature gradient • also used to measure the temperature of vapour in the distillation set • thermometer bulb contains mercury or red ethanol • have the scale up to 300 °C	• immerse vertically the thermometer in the liquid, and do not touch sides and the bottom of the container  
30. Tongs 	• used for picking up crucibles, crucible covers or holding apparatus, which are too hot to hold by hand	• hold the tongs firmly
31. Volumetric flask 	• used to prepare standard solutions with exact or precise amount of solute and solvent • have different sizes • made of glass (Pyrex)	• place a solute in the flask through a funnel, and dissolve it in a little amount of solvent used, then add the solvent up to the mark

Apparatus	Description/Information	Handling and Reading
32. Wash bottle 	• used for rinsing solids out of a container when filtering or filling gradually water up to a desired volume	• do not touch the tip of the wash bottle with the inner wall of the container 
33. Watch glass 	• used to cover beakers or to weigh solids on it • used to evaporate a small amount of liquid	 
34. Weighing bottle 	• used for precise weighing of solids • made of glass, ceramic or plastic • have different shapes and sizes	

- Immediately fit a stopper tightly to the cylinder.
- Record the time when the blue litmus paper turns red.
  Why does the blue litmus paper turn red?
- Repeat the demonstration with red litmus paper and a cotton plug dipped in ammonium hydroxide (ammonia solution) (1 cm^3) in the other measuring cylinder. (Place the cylinder horizontally.)
- Record the time when the red litmus paper turns blue.
  Why does the red litmus paper turn blue?
- Record the volume of each gas diffused.
  (Assume that the volumes of HCl and NH_3 gases are the same.)

  How can you estimate the volume of a gas in a cylinder?

  How would the calculated ratio be affected if the cylinders were not identical during the demonstration?

  Which gas required a short travelling time for diffusion?

  What is the relationship between the molar mass of gas and its rate of diffusion?

  Why did the calculated ratio of the rate of diffusion from the data collected in this demonstration differ from the theoretical ratio?
- From these observations, Graham's law of gaseous diffusion can be checked.
  Does the experiment obey the Graham's law of diffusion of gases? Explain.

CAUTION

- The hydrochloric acid and ammonia solutions should be kept in the glass bottles with close-fitting stoppers.
- Never touch the concentrated hydrochloric acid with hands because it is highly corrosive.
- The volume of solutions should be the same.
- Reasonable amounts of cotton plugs should be used.
- Two identical measuring cylinders should be used.

Observations, calculations and results

time (s) of insertion of stopper (starting time) for HCl = (A)

time (s) of appearance of colour change of litmus paper = (B)

time (s) of HCl gas diffused t_{HCl} = (B – A)

volume (cm^3) of HCl gas diffused = V_{HCl}

rate ($cm^3\ s^{-1}$) of diffusion of HCl $r_{HCl} = \dfrac{V_{HCl}}{t_{HCl}}$

time (s) of insertion of stopper (starting time) for NH_3 = (X)

time (s) of appearance of colour change of litmus paper = (Y)

time (s) of NH_3 gas diffused t_{NH_3} = (Y – X) volume (cm^3) of NH_3 gas diffused $= V_{NH_3}$

rate ($cm^3\ s^{-1}$) of diffusion of NH_3 $\quad r_{NH_3} = \frac{V_{NH_3}}{t_{NH_3}}$

the ratio of the experimental diffusion rate $\quad \frac{r_{NH_3}}{r_{HCl}} = ?$

molar mass of NH_3 $\quad M_{NH_3} = 17.0\ g\ mol^{-1}$

molar mass of HCl $\quad M_{HCl} = 36.5\ g\ mol^{-1}$

The theoretical ratio of the diffusion rate $= \frac{r_{NH_3}}{r_{HCl}} = \sqrt{\frac{M_{HCl}}{M_{NH_3}}} = \sqrt{\frac{36.5}{17.0}} = 1.47$

Conclusion

Write a lab report by using the following tabular form.

No.	Data	Results		Inference
		NH_3	HCl	
1	time of diffusion (s)			
2	volume of diffusion (cm^3)			
3	rate of diffusion ($cm^3\ s^{-1}$)			
4	observed ratio of rate of diffusion			
5	theoretical ratio of rate of diffusion			

volume (cm^3) of NH_3 gas diffused $= V_{NH_3}$

rate ($cm^3\ s^{-1}$) of diffusion of NH_3 $r_{NH_3} = \frac{V_{NH_3}}{t_{NH_3}}$

the ratio of the experimental diffusion rate $\frac{r_{NH_3}}{r_{HCl}} = ?$

molar mass of NH_3 $M_{NH_3} = 17.0\ g\ mol^{-1}$

molar mass of HCl $M_{HCl} = 36.5\ g\ mol^{-1}$

The theoretical ratio of the diffusion rate $= \frac{r_{NH_3}}{r_{HCl}} = \sqrt{\frac{M_{HCl}}{M_{NH_3}}} = \sqrt{\frac{36.5}{17.0}} = 1.47$

Conclusion

Write a lab report by using the following tabular form.

No.	Data	Results		Inference
		NH_3	HCl	
1	time of diffusion (s)			
2	volume of diffusion (cm^3)			
3	rate of diffusion ($cm^3\ s^{-1}$)			
4	observed ratio of rate of diffusion			
5	theoretical ratio of rate of diffusion			

EXPERIMENT 3

Colour Change of Different Acid-Base Indicators

Learning Objective

- To observe the colour change of indicators in acid, base and salt solutions

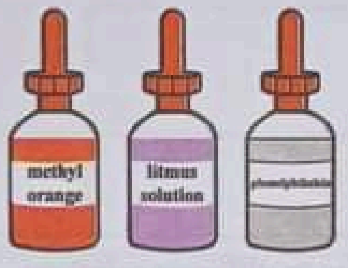
Introduction

Indicators are the chemical compounds used for identifying whether a given substance is acidic or basic in nature. Litmus papers, phenolphthalein and methyl orange are common indicators.

Acids are defined as the substances which produce H^+ ions when dissolve in water whereas bases are substances which produce OH^- ions in aqueous solutions.

An acid reacts with base to form salt and water, and this is called neutralisation reaction.

For example, $HCl\ (aq)\ +\ NaOH\ (aq) \longrightarrow NaCl\ (aq)\ +\ H_2O\ (l)$



In this experiment, the colour change of acid-base indicators in HCl, NaOH and NaCl solutions will be observed.

Apparatus and materials

- measuring cylinder (10 mL), glass rods, glass tubes, test tubes, watch glass
- 0.1 M hydrochloric acid (HCl) solution, 0.1 M sodium hydroxide (NaOH) solution, litmus papers (blue and red), methyl orange indicator, phenolphthalein indicator

Procedure

- Take three test tubes **A**, **B** and **C**.
  - o Fill about 1 mL of HCl in **A** and 1 mL of NaOH solution in **B**.
  - o Fill 2 mL each (**equal amount**) of hydrochloric acid (HCl) and sodium hydroxide (NaOH) in the test tube **C**. Stir the solution with a glass rod to obtain salt solution.

    What is neutralisation reaction?

    What are the reactants and products in the neutralisation reaction?

    Write down the chemical equation for the reaction in test tube C.

    Test each solution with blue and red litmus papers.
  - o Observe the change in colours and record in the table below.
  - o ***What is the pH of NaCl solution? Explain.***

    How would you observe if you did not take the equal amount of acid and base solutions in the neutralisation reaction? Explain.

- Take another three test tubes **D**, **E** and **F**.
  - o Fill about 1 mL each of HCl in **D**, NaOH in **E** and the salt solution (from **C**) in **F**.
  - o Add a few drops of methyl orange indicator in the above test tubes.
  - o Observe the change in colours and record in the table below.
- Take another three test tubes **G**, **H** and **I**.
  - o Fill about 1 mL each of HCl in **G**, NaOH in **H** and the salt solution (from **C**) in **I**.
  - o Add a few drops of phenolphthalein indicator in the above test tubes.
  - o Observe the change in colours and record in the table below.

    How do you identify whether a solution is acidic or basic?

    What is an indicator?

    What is the change in colour of indicators in acid, base and salt solutions?

CAUTION

- A reasonable amount of acid, base, salt and indicator must be taken.
- Be careful not to spill the acid and base.
- Chemicals must not be touched with hand.
- Reaction must be observed carefully.

Observation and results

Test tube	Colour change of indicators in different solutions			
	blue litmus paper	red litmus paper	methyl orange	phenolphthalein
A				
B				
C				
D				
E				
F				
G				
H				
I				

Conclusion

Write a lab report by using the following tabular form.

Table The Colour Changes of Indicators in Acidic, Basic and Neutral Solutions

Indicator	**Colour of indicators in different solutions**		
	Acidic solution	**Basic solution**	**Neutral solution**

EXPERIMENT 4

Preparation of Chemical Reagents for Volumetric Analysis

Learning Objective

- To develop skills for preparing the required chemical reagents

Introduction

The volumetric analysis is the quantitative chemical analysis measured by volume in which the unknown concentration of a substance is determined by the known concentration of a substance. Since this experiment is concerned with the concentration of the solutions, students have to know how to prepare solutions of chemical reagents.

To prepare a solution that contains a specific concentration of a substance, it is necessary to dissolve the desired number of moles of solute in enough solvent to give the desired final volume of solution. The most common unit for the concentration of solution is molarity. The molarity of a solution is defined as the number of moles of solute in 1 dm^3 of the solution. To prepare a solution in the laboratory, usually a given volume and molarity are required. To determine the molarity, the number of moles and molar mass of the solute are needed.

In this experiment, standard sodium carbonate solution, hydrochloric acid solution and some indicator solutions will be prepared.

Apparatus and materials

- balance, funnel, measuring cylinder (100 mL), volumetric flasks (100 mL), wash bottle, weighing bottle
- anhydrous sodium carbonate, concentrated hydrochloric acid (12 M), 95 % ethanol, distilled water, methyl orange, phenolphthalein, litmus powder

(a) Preparation of base solutions

The reagent solution of exactly known concentration that is used in titration is called a standard solution. To prepare a standard base solution, use the following steps:

- select a primary standard (highly pure and stable, high molecular weight, readily available at reasonable cost and non-hygroscopic compound);
- determine the molar mass of the solid;
- decide the volume of the solution required, V;
- decide the molarity of the solution required, M.

Anhydrous sodium carbonate can be used as a primary standard. A 100 mL of 0.5 M standard sodium carbonate solution can be prepared according to the procedure shown below.

Procedure

- Calculate the required amount of Na_2CO_3 as follows:

molar mass of Na_2CO_3 = $(2 \times 23) + 12 + (3 \times 16) = 106 \text{ g mol}^{-1}$

$$\text{mass of } Na_2CO_3 = 100 \text{ mL of } Na_2CO_3 \times \frac{0.5 \text{ mmol of } Na_2CO_3}{1 \text{ mL of } Na_2CO_3} \times \frac{1 \text{ mol of } Na_2CO_3}{1000 \text{ mmol of } Na_2CO_3} \times \frac{106 \text{ g of } Na_2CO_3}{1 \text{ mol of } Na_2CO_3} = 5.3 \text{ g}$$

- Accurately weigh 5.3 g of sodium carbonate and put into a 100 mL volumetric flask through a funnel.
- Add distilled water and shake well to dissolve the solid.
- Make up the volume to the mark with the distilled water to get 100 mL of 0.5 M sodium carbonate solution.
- Close the volumetric flask with a stopper and shake well to get a homogeneous solution.

How can you prepare 1 L of 0.25 M of sodium carbonate solution?

(b) Preparation of acid solutions

Generally, the commercial mineral acid is a concentrated solution. Therefore, it cannot be used directly in the laboratory. It is necessary to dilute to the required concentrations. The concentrations of some commercial acids are given below.

Acid	Concentration
hydrochloric acid	12 M
nitric acid	16 M
sulphuric acid	18 M

To dilute a more concentrated solution, decide what volume and molarity of the final solution should be, and calculate the required volume of the concentrated solution according to the following equation.

$$M_1V_1 = M_2V_2$$

where M_1, V_1 = molarity (M) and volume (mL or L) before dilution, respectively

M_2, V_2 = molarity (M) and volume (mL or L) after dilution, respectively

This process keeps the amount of solute constant, but increases the total volume of solution, thereby decreasing its final concentration.

A 100 mL of 1.2 M hydrochloric acid solution can be prepared by dilution of the 12 M concentrated HCl solution according to the following procedure.

Procedure

- Calculate the required volume of the concentrated HCl solution.

$$M_1V_1 = M_2V_2$$
$$(12\ M)(V_1) = (1.2\ M)(100\ mL)$$
$$V_1 = 10\ mL$$

- Add slowly 10 mL of the concentrated HCl solution to distilled water in a 100 mL volumetric flask.
- Make up the volume to the mark with distilled water to get 100 mL of 1.2 M HCl solution.
- Insert and secure the stopper, and invert the flask several times to mix.

How can you prepare a 1000 mL of 0.1 M sulphuric acid solution from the concentrated sulphuric acid (18 M)?

How can you prepare a 250 mL of 0.5 M nitric acid solution from the concentrated nitric acid (16 M)?

(c) ***Preparation of indicator solutions***

Different indicators require different methods of preparation.

Procedure

Preparation of 1 % methyl orange indicator

- Accurately weigh 1 g of methyl orange and put into a 100 mL volumetric flask through a funnel.
- Add distilled water and shake well to dissolve the solid.
- Make up the volume to the mark with the distilled water to get 1 % methyl orange indicator solution.
- Close the volumetric flask with a stopper and shake well to get a homogeneous solution.

Preparation of 0.5 % phenolphthalein indicator

- Accurately weigh 0.5 g of phenolphthalein and put into a 100 mL volumetric flask through a funnel.
- Add 95 % ethanol and shake well to dissolve the solid.
- Make up the volume to the mark with the ethanol to get 0.5 % phenolphthalein indicator solution.
- Close the volumetric flask with a stopper and shake well to get a homogeneous solution.

Preparation of 0.5 % blue or red litmus solution

- Accurately weigh 0.5 g of litmus powder and put into a beaker.
- Add 100 mL of boiling water and stir well to dissolve the solid.
- Allow the solution cool to room temperature to get blue litmus solution.
- Add a few drops of 0.1 M HCl into the above litmus solution to obtain red litmus solution.
- To prepare red litmus papers, dip the strips of filter paper into the red litmus solution and dry.
- To prepare blue litmus papers, dip the strips of filter paper into the blue litmus solution and dry.
- Observe the colour of the prepared litmus papers dipped in the acid and base solutions.

CAUTION

- Always add acid to water very slowly.
- If you spill acid, you can neutralise it with a weak base (safer than using a strong base) and dilute it with a large volume of water.
- If you contact with acid, rinse with large amounts of water.
- Be sure to wear safety goggles, gloves, and a lab coat as well.
- Do not touch sodium hydroxide. It is caustic and could cause chemical burns. If you get NaOH on your skin, immediately, rinse it with a large volume of water.

Conclusion

Fill up the table for the given five solutions. (H = 1, O = 16, Na = 23, K = 39)

No.	Solution prepared	Calculation	Amount required (volume / mass)
1	0.5 M HCl solution (1 L)		
2	0.5 M H_2SO_4 solution (100 mL)		
3	0.1 M HNO_3 solution (500 mL)		
4	~2 M NaOH solution (500 mL)		
5	~0.25 M KOH solution (100 mL)		

EXPERIMENT 5

Standardization of Hydrochloric Acid Solution

Learning Objectives

- To develop skills in titration technique
- To find the accurate concentration of a solution by using a primary standard solution

Introduction

A titration is a technique where a solution of known concentration is used to determine the concentration of an unknown solution.

In titration, a solution of accurately known concentration (standard solution) reacts with another solution of unknown concentration, until the chemical reaction between the two solutions is complete. This point in the reaction is called the equivalence point. In practice, the equivalence point cannot be seen, and the end point can only be seen. To detect the end point of the acid-base titration, different indicators (organic dyes), such as methyl orange, phenolphthalein, etc., are used. End point is the point at which a titration is complete, usually marked by a change in colour of an indicator.

The process by which the molarity or concentration of a solution is determined volumetrically by the use of a primary standard solution is called standardization.

In this experiment, the molarity of approximately 1.2 M hydrochloric acid solution will be determined by conducting a titration with 0.5 M standard Na_2CO_3 solution. Methyl orange will be used as an indicator in this titration. It is observed as red colour in an acid solution and as yellow colour in a base solution. At the end point, it shows orange colour. The standardized HCl solution left over after this experiment may be used in Experiment 6.

Apparatus and materials

- beaker, burette, burette stand and clamp, conical flasks, pipette, funnel, wash bottle
- approximately 1.2 M hydrochloric acid solution (from Experiment 4), 0.5 M standard Na_2CO_3 solution (from Experiment 4), distilled water, 1 % methyl orange indicator

Procedure

- Take a burette and a small funnel and rinse them first with distilled water and then with HCl solution.

  What happens when the burette is not washed with HCl solution?
- Fill the burette with HCl solution through a funnel. Then remove the funnel. Make sure that no air bubbles trapped in the tip, i.e., the tip is also filled with the solution.

  Is it necessary to fill the burette with HCl solution up to zero mark?
- Take four conical flasks and wash them with distilled water.

  What happens when the conical flasks are washed with standard Na_2CO_3 solution?
- Take a pipette and wash it with distilled water and then with 0.5 M standard Na_2CO_3 solution.
- Put a 10 mL each of standard Na_2CO_3 solution into each of the conical flasks by means of a pipette.
- Add 1-2 drops of methyl orange to Na_2CO_3 solution in the conical flasks.

  Which indicators are used in the acid-base titrations?

- Titrate it with HCl solution according to the following steps:
  - Read the initial volume on the burette, and record in a lab notebook. Let the solution out of the burette 1 mL at a time into the conical flask until the yellow colour turns red. Record the end point to obtain a rough volume of the titre (total volume of solution delivered by the burette). (At this stage, we want a rough estimate of the amount of known solution necessary to neutralise the unknown solution. This is the first titration and it is not very precise; it should be excluded from any calculations.)
  - Add HCl solution from the burette into another 10 mL of the standard Na_2CO_3 solution in the conical flask; run in that volume of acid which is 1 mL less than the rough volume.
  - Swirl the flask and continue the titration by adding the acid drop by drop until the yellow colour of the solution turns orange. Record the volume of the titre.
  - Repeat the titration three times and tabulate the results.
  - Find the mean volume of the titre from the results except the rough volume.

  Why do you need to do at least 3 times of titration?
  What is the difference between the end point and the equivalence point?
  Write down the chemical equation for reaction of sodium carbonate and hydrochloric acid solutions.

CAUTION

- Do not rinse conical flask with acid or base solutions. Only rinse with distilled water.
- Burette and pipette are rinsed with distilled water and then rinsed with the solutions used in the titration.
- Do not hold the bulb at the centre of pipette.
- Do not blow out or shake out the last drop of liquid left in the pipette.
- Make sure that any air bubbles are not trapped in the tip of burette or pipette.
- Read the volume only after removal of the air bubbles trapped in the tip of burette or pipette.

Observations, results and calculation

Table Volume of HCl Solution Titrated with 10 mL of 0.5 M Standard Na_2CO_3 Solution
Indicator: methyl orange

No. of determination	Initial reading (mL)	Final reading (mL)	Difference (mL)
Rough			
1			
2			
3			
		Mean volume =	(X) mL

Calculation of the molarity of HCl solution

(X) mL of HCl solution ≡ 10 mL of 0.5 M Na_2CO_3 solution

$$2HCl\,(aq) + Na_2CO_3\,(aq) \longrightarrow 2NaCl\,(aq) + CO_2\,(g) + H_2O\,(l)$$

2 mmol 1 mmol

$$\text{mmol of HCl} = 10\text{ mL of }Na_2CO_3 \times \frac{0.5\text{ mmol of }Na_2CO_3}{1\text{ mL of }Na_2CO_3} \times \frac{2\text{ mmol of HCl}}{1\text{ mmol of }Na_2CO_3}$$

= (Y) mmol

$$\therefore \text{molarity of HCl} = \frac{(Y)\text{ mmol of HCl}}{(X)\text{ mL of HCl}}$$

= (Z) mmol mL^{-1}

= (Z) M

∴ The concentration of HCl solution is (**Z**) M.

Conclusion

The concentration of HCl solution is (**Z**) M.

EXPERIMENT 6

Standardization of Sodium Hydroxide Solution

Learning Objective

- To find the unknown concentration of a base solution by using a known concentration of standard acid solution

Introduction

An accurate amount of sodium hydroxide is difficult to weigh because it is extremely hygroscopic. Thus, standard solution of NaOH with an accurate known concentration is not possible to prepare. However, NaOH solution can be standardized with an acid of accurately known concentration (already standardized). The acid serves as a primary standard for calibrating the concentration of NaOH solution which becomes a secondary standard.

In this experiment, the molar concentration of approximately 1.0 M NaOH solution will be determined by conducting a titration with the known concentration of hydrochloric acid solution (standardized in the Experiment 5). Phenolphthalein will be used as an indicator in this titration. It is observed as colourless in an acid solution and as pink in a base solution. At the end point, it shows colourless. The standardized sodium hydroxide solution left over in this experiment may be used in Experiment 7.

Apparatus and materials

- beaker, burette, burette stand and clamp, conical flasks, funnel, pipette
- (Z) M standard HCl solution (use the concentration resulted from Experiment 5), approximately 1.0 M NaOH solution, distilled water, phenolphthalein indicator

Procedure

- Take a burette and a small funnel and rinse them first with distilled water and then with HCl solution.
- Fill the burette with standard HCl solution through a funnel. Then remove the funnel.
- Take four conical flasks and wash them with distilled water.
- Take a pipette and wash it with distilled water and then with NaOH solution.
- Put 10 mL each of approximately 1.0 M NaOH solution into each of the conical flasks by means of a pipette.
- Add 1~2 drops of phenolphthalein to the NaOH solution in the conical flasks.
  Why is indicator used in the titration?
- Titrate it with the standard HCl solution according to the following steps:
  - Read the initial volume on burette, and record in a lab notebook. Let the solution out of the burette 1 mL at a time into the conical flask until the pink colour turns colourless. Record the end point to obtain a rough or approximate volume of the titre.
  - Add HCl from the burette into another 10 mL of NaOH solution in the conical flask; run in that volume of acid which is 1 mL less than the rough volume.

- Swirl the flask and continue the titration by adding the acid drop by drop until the pink colour of the solution turns colourless. Record the volume of the titre.
- Repeat the titration three times and tabulate the results.
- Find the mean volume of the titre from the results except the rough volume.

If the volume of HCl obtained in the rough titration is 9 mL, predict the volume of HCl at the equivalence point.

Write down the chemical equation for reaction of sodium hydroxide and hydrochloric acid solutions.

CAUTION

- Do not rinse conical flask with acid or base solutions. Only rinse with distilled water.
- Burette and pipette are rinsed with distilled water and then rinsed with the respective solution used in the titration.
- Do not hold the bulb at the center of pipette.
- Do not blow out or shake out the last drop of liquid left in the pipette.
- Make sure that any air bubbles are not trapped in the tip of burette or pipette.
- Take care of handling NaOH since it can cause severe eyes, skin and clothing damage. If contact accidentally occurs, rinse the affected parts with a large amount of water.

Observation, results and calculation

Table Volume of (Z) M Standard HCl Solution Titrated with 10 mL NaOH Solution
Indicator: phenolphthalein

No. of determination	Initial reading (mL)	Final reading (mL)	Difference (mL)
Rough			
1			
2			
3			
		Mean volume =	(X) mL

Calculation of the molarity of NaOH solution

10 mL of NaOH solution ≡ (X) mL of (Z) M HCl solution

$$HCl\ (aq) + NaOH\ (aq) \longrightarrow NaCl\ (aq) + H_2O\ (l)$$

1 mmol 1 mmol

$$\text{mmol of NaOH} = \text{(X) mL of HCl} \times \frac{\text{(Z) mmol of HCl}}{\text{1 mL of HCl}} \times \frac{\text{1 mmol of NaOH}}{\text{1 mmol of HCl}}$$

$$= \text{(P) mmol NaOH}$$

$$\text{molarity of NaOH} = \frac{\text{(P) mmol of NaOH}}{\text{10 mL of NaOH}}$$

$$= \text{(Q) mmol mL}^{-1}$$

$$= \text{(Q) M}$$

∴ The concentration of NaOH solution is **(Q)** M.

Conclusion

The concentration of NaOH solution is **(Q)** M.

EXPERIMENT 7

Determination of the Ethanoic Acid (Acetic Acid) Content in Vinegar

Learning Objective

- To find the mass in grams of pure ethanoic acid in 1 dm^3 of vinegar

Introduction

Vinegar is an aqueous solution containing 4 ~ 5 % by mass of ethanoic acid (acetic acid) and trace chemicals which may be flavourings. If the ethanoic acid content is greater than 5 %, the vinegar is very bad in taste. It is needed to calculate the ethanoic acid containing in the vinegar solution for the purity of vinegar. The given molarity of standard sodium hydroxide solution is about 1 M (according to the Experiment 6). The given vinegar solution is approximately (1 M) concentration of ethanoic acid. The reaction of NaOH with ethanoic acid is 1:1 stoichiometrically.

In this experiment, the vinegar solution will be titrated with known concentration of standard sodium hydroxide solution using phenolphthalein indicator. From this measurement, the amount in moles of standard reagent required for the reaction can be calculated. By knowing the chemical equation for the reaction, we can determine the amount in moles of the other reactant, i.e., ethanoic acid.

Apparatus and materials

- burette, burette stand and clamp, beaker, conical flasks, funnel, pipette, volumetric flask (100 mL)
- (Q) M standard sodium hydroxide solution (use the concentration resulted from Experiment 6), vinegar solution (approximately 1 M), distilled water, phenolphthalein indicator

Procedure

- Fill the burette with the standard NaOH solution by using a funnel.
- Put 10 mL of the vinegar solution into a conical flask by means of a pipette.
- Add 1~2 drops of phenolphthalein into the conical flask. The solution becomes colourless.
- Titrate it with the NaOH solution until the colour of the solution turns pink at the end point. Record the rough volume of the titre.
    - Repeat the titration three times and tabulate the results.
    - Find the mean volume of the titre from the results except the rough volume.

How can you determine the purity of vinegar?
Is ethanoic acid weak or strong acid? If so, why?
Write down the dissociation reaction of ethanoic acid.
Write down the chemical equation for the reaction of sodium hydroxide and ethanoic acid solutions.

CAUTION

- Do not rinse conical flask with acid or base solutions. Only rinse with distilled water.
- Burette and pipette are rinsed with distilled water and then rinsed with the respective solution used in the titration.

- Do not hold the bulb at the centre of pipette.
- Do not blow out or shake out the last drop of liquid left in the pipette.
- Make sure that any air bubbles are not trapped in the tip of burette or pipette.
- Rinse the burette several times including the tip with water after using alkaline solution.

Observation, results and calculation

Table Volume of (Q) M Sodium Hydroxide Solution Titrated with 10 mL Vinegar Solution
Indicator: phenolphthalein

No. of determination	Initial reading (mL)	Final reading (mL)	Difference (mL)
Rough			
1			
2			
3			
		Mean volume	(X) mL

Calculation of the content (in grams) of ethanoic acid in 1 dm^3 vinegar solution

10 mL of vinegar solution ≡ (X) mL of (Q) M NaOH solution

$$CH_3COOH\,(aq) + NaOH\,(aq) \longrightarrow CH_3COONa\,(aq) + H_2O\,(l)$$

1 mmol   1 mmol

$$\text{mmol of } CH_3COOH = (X) \text{ mL of NaOH} \times \frac{(Q) \text{ mmol of NaOH}}{1 \text{ mL of NaOH}} \times \frac{1 \text{ mmol of } CH_3COOH}{1 \text{ mmol of NaOH}}$$

$$= (R) \text{ mmol of } CH_3COOH$$

$$\text{molarity of } CH_3COOH = \frac{(R) \text{ mmol of } CH_3COOH}{10 \text{ mL of } CH_3COOH}$$

$$= (V) \text{ mmol mL}^{-1} = (V) \text{ M}$$

$$\text{molar mass of } CH_3COOH = 2(C) + 2(O) + 4(H)$$

$$= (2 \times 12) + (2 \times 16) + (4 \times 1) = 24 + 32 + 4 = 60 \text{ g mol}^{-1}$$

$$? \text{ g dm}^{-3} \text{ of ethanoic acid} = \frac{(V) \text{ mol of } CH_3COOH}{1 \text{ dm}^3 \text{ of } CH_3COOH} \times \frac{60 \text{ g of } CH_3COOH}{1 \text{ mol of } CH_3COOH} = (W) \text{ g dm}^{-3}$$

∴ One dm^3 of vinegar solution contains (W) g of ethanoic acid.

Conclusion

The ethanoic acid (acetic acid) content in 1 dm^3 of vinegar sc... (W) g

EXPERIMENT 8

Electrolysis of Aqueous Copper(II) Sulphate Solution Using Copper Electrodes

Learning Objective

To study the electrolysis of aqueous copper(II) sulphate solution using copper electrodes

Introduction

Aqueous copper(II) sulphate solution contains Cu^{2+}, SO_4^{2-}, H^+ and OH^- ions. On electrolysis, Cu^{2+} ions and H^+ ions go to copper cathode. Since Cu^{2+} ion is below H^+ ion in the electrochemical series, the Cu^{2+} ions accept electrons more readily than H^+ ions, and copper is deposited on the cathode.

The SO_4^{2-} and OH^- ions go to the copper anode. But both these ions are not discharged due to the nature of electrode. Cu atoms from the anode can lose electrons forming Cu^{2+} ions which can dissolve into the solution since copper is a reactive electrode.

Apparatus and materials

- beaker, 6 V battery, copper electrodes, test tubes, wires
- copper(II) sulphate solution

Procedure

- Set up the apparatus as shown in figure.
- Half fill the beaker with a dilute aqueous solution of copper(II) sulphate. Set aside a sample of this solution in a test tube.
- Switch on the current for 30 minutes and observe.

  What happens to the appearance of copper anode after electrolysis?

  What happens to the appearance of copper cathode after electrolysis?
- At the end of the electrolysis, remove a sample of the electrolyte in another test tube and compare its colour with original solution.

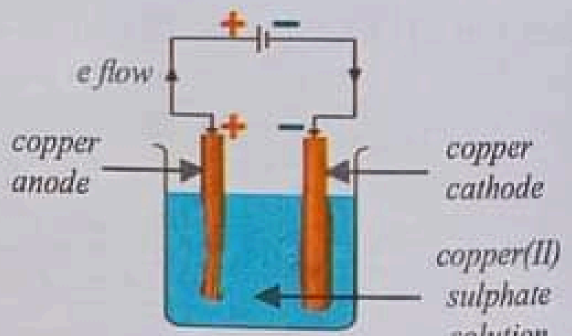


Figure Electrolysis of Aqueous Copper(II) Sulphate Solution Using Copper Electrodes

On electrolysis of aqueous copper(II) sulphate using copper electrodes, do you find any change in the intensity of colour?

Electrolysis of aqueous copper(II) sulphate using copper electrodes is a method for purification of crude copper. Why?

Write the reactions which take place at the cathode and the anode during electrolysis.

Conclusion

Write a lab report by using the following tabular form.

No.	Experiment	Observation	Inference
1	reaction at the cathode		
2	reaction at the anode		
3	change in the cathode before and after electrolysis		
4	change in 'he anode before and after electrolysis		
5	colour of the solution before and after electrolysis		

EXPERIMENT 9

Ammonia Fountain Experiment

Learning objective

- To study the solubility of ammonia gas and its alkaline nature by fountain experiment

Introduction

The ammonia fountain is a classic demonstration used to observe the solubility of ammonia in water. Litmus indicator is used to see the alkaline nature of the solution formed. Ammonia is a colourless gas and extremely soluble in water to give ammonium hydroxide solution. It has the boiling point of 38 °C. Ammonia gas can be produced by heating a mixture of ammonium chloride and calcium hydroxide. It can also be produced by warming the concentrated ammonium hydroxide solution. In this experiment ammonium hydroxide solution will be used.

Apparatus and materials

- beaker, clip, dropper, jet tube (glass tube), round-bottomed flask, rubber tube, spirit burner, stopper
- ammonium hydroxide solution, red litmus solution, water

Procedure

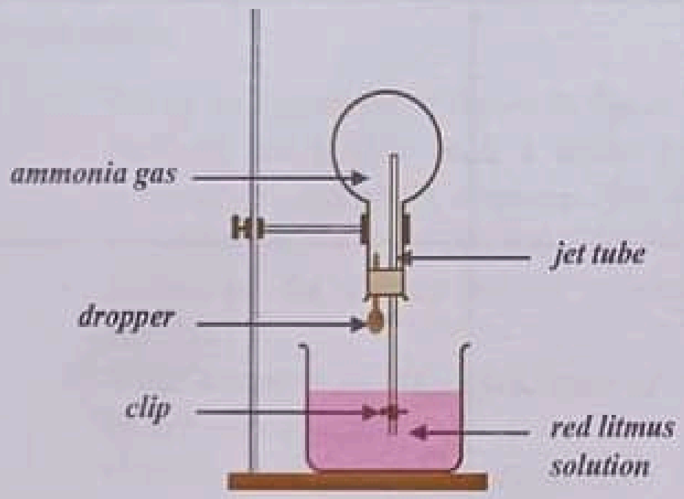


Figure 1 Set-up for the Ammonia Fountain

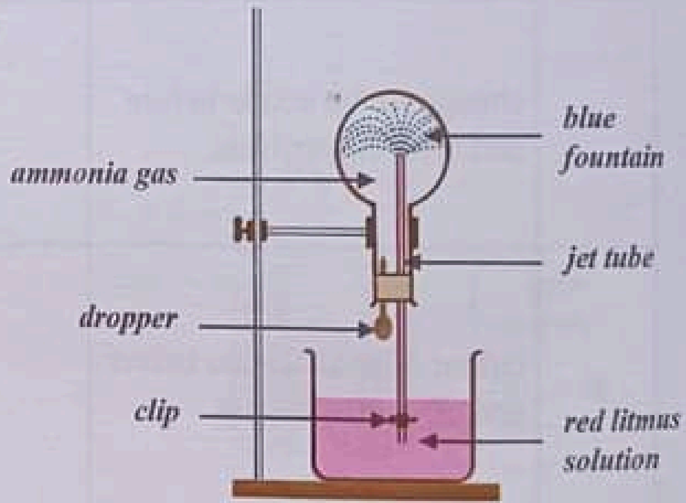


Figure 2 The Ammonia Fountain

- Fill the beaker three-fourths with water and add a few drops of red litmus solution. (If litmus solution is not available, use a few drops of phenolphthalein indicator in water which gives colourless solution.)
- Prepare the stopper fitted with jet tube connected with a piece of rubber tube. Clip the rubber tube.
- Fill the dropper with water and insert in the stopper.
- Place 20 mL of ammonium hydroxide solution in the round-bottomed flask.
- Fit the flask with the prepared stopper.
- Warm the flask over a flame of spirit burner to produce ammonia gas. So, the flask is filled with the ammonia gas.

What happens when ammonium hydroxide solution is gently warmed?
Write down the chemical equation for this reaction.

- Quickly invert the flask into the beaker of red litmus solution as shown in Figure 1.
- Put one or two drops of water into the flask by squeezing the dropper.

A few drops of water are put into the flask by squeezing the dropper before removal of the clip from the rubber tube. Why?

- Remove the clip, when you are ready to begin the demonstration.
- The red litmus solution will rise up in the glass tube and form a blue fountain inside the inverted flask as illustrated in Figure 2.

Why does the red litmus solution enter the flask? What do you observe?
What properties of ammonia gas are shown by this experiment?
Name the experiment to demonstrate the high solubility of ammonia gas.
What colour of fountain will be observed if phenolphthalein indicator were used instead of red litmus solution?

CAUTION

- The ammonium hydroxide solution in the round-bottomed flask should not cover the tip of the glass tube.
- Open the clip occasionally during warming the flask.

Conclusion

Write a lab report by using the following tabular form.

No.	Experiment	Observation	Inference
1	colour of ammonia gas		
2	odour of ammonia gas		
3	colour of fountain		
4	basic or acidic property of NH_3		
5	chemical equation for producing NH_3 gas		
6	solubility of ammonia gas		

EXPERIMENT 10

Preparation of Alcohol-Based Hand Sanitiser

Learning Objective

- To prepare the ethanol-based hand sanitiser

Introduction

Hand sanitiser is generally used to decrease infectious agents on the hands. It may be liquid, gel or foam. At present, alcohol-based hand rubs are the only known means for rapidly and effectively deactivating a wide array of potentially harmful microorganisms on hands.

Alcohol-based hand sanitisers are preferable to hand washing with soap and water because it may be better tolerated and is more effective for reducing bacteria. If water and soap are not available, your next best option is to use an alcohol-based sanitiser containing greater than 60 % v/v alcohol.

For a larger batch of hand sanitiser, the World Health Organization (WHO) Trusted Source recommends the formulation that uses ethanol or *iso*-propyl alcohol, hydrogen peroxide, glycerol, and sterile distilled or boiled cold water. Methanol is not an acceptable active ingredient for hand sanitiser products since it can be toxic and cannot kill bacteria. Ethanol is more dehydrating and can make our skin feel tight and dry. *Iso*-propyl alcohol evaporates more quickly, but it does not dry out the hands so badly. It is not as effective as ethanol at dehydrating living tissue and so is a better solution for disinfecting skin than ethanol. Once alcohol concentrations drop below 50 %, usefulness for disinfection drops sharply. Addition of glycerol as an emollient aims to protect the hand skin against dryness and dermatitis sometimes associated with repeated use. Hydrogen peroxide does kill germs, including most viruses and bacteria. A concentration of 3 % hydrogen peroxide is an effective disinfectant.

The hand sanitisers have expiration date. If the hand sanitiser bottle is unopened, it will retain much of its strength. However, an opened bottle will lose the potency of killing germs due to the evaporation of alcohol.

In this experiment, 1 L ethanol-based hand sanitiser is prepared according to the WHO recommended formula.

Apparatus and materials

- funnel, measuring cylinders (10 mL, 100 mL), plastic bowl (2 L), plastic bottles (100 mL, 500 mL) with screw-threaded stoppers, stirrer (wooden, plastic or metal paddles)
- ethanol (96 % v/v), hydrogen peroxide (3 % v/v), glycerol (98 % v/v), sterile distilled or cold boiled water

Procedure

- Pour 835 mL of the 96 % ethanol into a plastic bowl (2 L).
  How many percent of ethanol is used in the prepared hand sanitiser?
- Then add 42 mL of 3 % hydrogen peroxide to the ethanol in the bowl by using the measuring cylinder.
- Add 15 mL of glycerol to the mixture in the bowl. (Rinse well the viscous and sticky glycerol on the wall of the measuring cylinder with distilled water.)

- Stir well the mixture to mix thoroughly.
  Why are glycerol and hydrogen peroxide added in hand sanitiser?
- Place the lid or the screw cap on the bottle as soon as possible after preparation in order to prevent evaporation.
- Shake the mixture gently.
- Immediately divide up the solution into its final containers (e.g., 10 or 100 mL plastic bottles), and place the bottles in quarantine for 72 hours before use. (This allows time for any spores present in the alcohol or the new or re-used bottles to be destroyed.)
  Name the reagents or chemicals required for WHO formulation hand sanitiser.
  An alcohol-based hand sanitiser contains at the concentration of alcohol at least 60 %. Can you use the alcohol percent lower than this? Why?
  Which alcohol, ethanol or iso-propyl alcohol is better for preparation of hand sanitiser? Explain.
  Can methanol be used instead of ethanol and iso-propyl alcohol in hand sanitiser? Explain.

Note: Alternative method can also be applied as follows:

Chemicals required (1 L): carbopol 940 (5 g), triethanolamine (5 mL), pure water (or commercial purified drinking water) (130 mL), ethanol or *iso*-propyl alcohol (750 mL), glycerin (5 mL), 3 % hydrogen peroxide (5 mL), perfume (0.3 %)

Procedure: Preheat 60 mL of purified water to boil and add to another 70 mL of water to get warm water. Add 5 mL of triethanolamine to the warm water with constant stirring. Then add 5 g of carbopol to the solution with constant stirring. Add 750 mL of ethanol or *iso*-propyl alcohol after cooling the gel type homogenised liquid. After uniform mixing, add glycerin (5 mL) and hydrogen peroxide (5 mL) with slow stirring to avoid formation of air bubbles in the product. Finally, mix with 0.3 % of perfume by slow stirring to get a uniform product.

Ingredient	**Purpose**
ethanol or *iso*-propyl alcohol	used as antibacterial and antifungal agents
hydrogen peroxide	used to kill viruses and bacteria
glycerin (95 % glycerol)	protect the skin against dryness and dermatitis
carbopol 940	used as thickening and gelling agent
triethanolamine	emulsifying agent
perfume	used as fragrance

Note: Alternative thickening and gelling agents such as carboxy methyl cellulose (CMC) and carbomer, and emulsifying agent such as sodium lauryl sulphate can also be used.
Herbal leaves such as Aloe vera, neem, etc. can be used to enrich the property of hand sanitiser.

CAUTION

- For external use only.
- Avoid contact with eyes.
- Flammable: keep away from the flame and heat.

Conclusion

Calculate the amount of reagents required to prepare 25 L of hand sanitiser according to WHO formulation using *iso*-propyl alcohol. Record your results in the following table.

No.	Reagent	Volume (mL)	Content (%, v/v)	Inference

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