Name : _____( ) **Sec 4** _____

Sources of Errors in Chemistry Experiments

Sources of errors in an experiment are errors that are **inherent in an experiment** due to the design of the experiment. It is not due to the mistakes made by the experimenter. These **sources of errors** can be caused by the following aspects in the design of an experiment: 1. apparatus, 2. materials, 3. purpose of experiment.

1 Apparatus

The criteria for selecting an apparatus for an experiment are as follows:

a) function
b) degree of accuracy
c) ease of use

Usually if ease of use is chosen as a criteria, the degree of accuracy may be compromised and it can be a source of error for the experiment. An obvious improvement to this experiment is to use an apparatus of an appropriate degree of accuracy.

Example 1

You are going to investigate what happens when dilute hydrochloric acid reacts with two different alkaline solutions, **F** and **G**.

Read all instructions below carefully before starting the experiments.

Instructions
You are going to carry out two experiments.

(a) *Experiment 1*

Fill the burette with the dilute hydrochloric acid provided to the 0.0 cm^3 mark.

Using a measuring cylinder, pour 25 cm^3 of solution **F** into a conical flask. Add 4 to 6 drops of phenolphthalein indicator to the conical flask.

Add the hydrochloric acid from the burette 1 cm^3 at a time while shaking the flask. When the colour of the phenolphthalein changes, record in the table the volume of acid added.

(b) *Experiment 2*

Fill the burette with dilute hydrochloric acid to the 0.0 cm^3 mark.

Empty the conical flask and rinse it with water. Using a measuring cylinder, pour 25 cm^3 of solution **G** into the conical flask. Add 4 to 6 drops of phenolphthalein to the conical flask.

Add the hydrochloric acid from the burette 1 cm^3 at a time while shaking the flask. When the colour of the phenolphthalein changes, record in the table the volume of acid added.

experiment	solution	volume of hydrochloric acid added / cm^3
1	**F**	
2	**G**	

(a) State two sources of error in the experiment.

1. The measuring cylinder used to measure volume of solution F is not as precise as a pipette. It can only measure accurately to 0.5 cm^3 of solution.

2. The experiment was conducted only once to find volumes of HCl used.

OR Adding 1.00 cm^3 of HCl solution each time means that the end point cannot be determined accurately.

Note: pipette measure fixed volume e.g. 25.0 cm^3, 20.0 cm^3 …

(b) Suggest two improvements to reduce the sources of errors in the experiments.

1. Use a pipette to measure 25 cm^3 of F

2. Repeat the experiment 3 times for each solution F and G to obtain average volume of HCl used in the titration

3.Add HCl dropwise near the end-point to obtain accurate volume of HCl used.

Example 2

A student investigated the rate of reaction between hydrogen peroxide and aqueous potassium iodide. When these chemicals react they form iodine. Sodium thiosulfate solution reacts with iodine and can be used to show how fast the reaction proceeds.

(a) A burette was filled up to the 0.0 cm^3 mark with sodium thiosulfate solution.
Using a large measuring cylinder, 100 cm^3 of distilled water were poured into a conical flask.
Using a small measuring cylinder, 6 cm^3 of sulfuric acid, 1 cm^3 of starch solution and 4 cm^3 of aqueous potassium iodide were added to the flask. **(conical flask)**
0.5 cm^3 of sodium thiosulfate solution was added from the burette to the mixture in the flask and swirled to mix. **(using a teat pipette)**
The reaction was then started by adding 3 cm^3 of hydrogen peroxide solution to the mixture, and the timer started.
The time taken for a blue colour to appear was noted.
A further 0.5 cm^3 of sodium thiosulfate solution was added to the mixture in the conical flask, swirled and the blue colour disappeared. The time when the blue colour reappeared was noted.
The experiment continued by adding further 0.5 cm^3 portions of sodium thiosulfate solution until a total of 3.0 cm^3 of sodium thiosulfate solution had been added, noting the times at which the blue colour reappeared.

(a) Suggest the purpose of the starch solution.

To detect the presence of iodine.

Iodine reacts with starch to form a complex (blue-black colour)

(b) Suggest one advantage of using a pipette to measure the volume of hydrogen peroxide.

Pipette is a more precise apparatus and hence the volume of hydrogen peroxide measured is more accurate.

(c) Suggest and explain one **disadvantage** of using a pipette to measure the volume of the hydrogen peroxide.

Solution is slow to run out of the pipette/difficult to know when to start timer. This leads to inaccurate time measurements.

(d) Explain one disadvantage of using a beaker instead of a conical flask.

It is more difficult to swirl or mix the chemicals without spillage.

2 Materials

The materials used in an experiment refer to the chemicals, reagents, indicators or wooden splints required.

Sources of error can be due to:

1. Using different sizes of marble chips for each experiment, timing the experiment all at the same time

2. Stability of chemicals
   e.g. hydrogen peroxide decomposes at room temperature and pressure, chemical reacts with moisture or oxygen in the air.

Sources of Error and its effects on the experiment

1. Hydrogen peroxide decomposes into water and oxygen at room temperature and pressure and this will result in loss of the chemical while 2. aqueous potassium iodide can be oxidised to iodine on exposure to oxygen and this will result in the loss of the chemical.

2. Sodium hydroxide and some salts like zinc chloride and calcium chloride can absorb moisture in the air and dissolve in it. This will increase the mass of the solid.

In titration experiment, if methyl orange is used as an indicator, it will change colour between pH 3 – 4. However if the pH of the resulting salt solution at point of neutralisation is 7 then the volume of the titre will be smaller than what it should have been since the methyl orange changes colour before the acid or alkali is completely neutralised to form the salt solution at pH 7.

Example 1

You are going to investigate the speed of reaction between aqueous hydrochloric acid and marble chips (calcium carbonate).

Read **all** the **Instructions** below carefully before starting the Experiments.

Instructions

Put 5 test-tubes in a line in the rack provided so you can see the graph paper through them.

To each test-tube you are going to add 3 cm^3 of different solutions of aqueous hydrochloric acid and a marble chip. The marble chips are the same size.

Experiment 1

Using the measuring cylinder pour 3 cm^3 of the solution **P** of aqueous hydrochloric acid into the first test-tube.

Experiment 2

Using the measuring cylinder pour 3 cm^3 of the solution **Q** of aqueous hydrochloric acid into the second test-tube.

Experiments 3, 4 and 5

Repeat Experiment 1 using 3 cm^3 of the solutions of aqueous hydrochloric acid **R**, **S** and **T** in the third, fourth and fifth test-tubes.

Into all of the test-tubes quickly place a marble chip and start the timer. Shake the tubes from time to time.

Look at the tubes from the side. Take the time in seconds for **each** tube when the lines on the graph paper can be seen through all of the acid in that tube. **Do not stop the timer until all the reactions are finished.**

Record the times in the table.

(a) State two sources of error in the experiment.

Same size of marble was used does not mean same mass of marble was used in each experiment. This will lead to inaccurate time measurement.

Starting the timer is a source of error because one stopwatch is used for all the experiment.

Or the experiment for each solution is done only once.

(b) Suggest two improvements to reduce the sources of errors in the experiments.

Weigh a fixed mass of marble chip for each solution.

Time individual experiment.

Repeat the experiment at least 2 times for each solution to get the average time taken.

Example 2 – Excerpt from Experiment 4.12

Aqueous hydrogen peroxide works as an antiseptic by releasing oxygen when applied on the affected area. It decomposes readily when exposed to sunlight.

Hydrogen peroxide reacts with acidified aqueous potassium manganate(VII) according to the equation.

$5H_2O_2 + 2MnO_4^- + 6H^+ \rightarrow 5O_2 + 2Mn^{2+} + 8H_2O$

You are going to determine the concentration of hydrogen peroxide in an antiseptic solution by titrating with aqueous acidified potassium manganate(VII).

Read all the instructions carefully before starting the experiment in Question 1.

Instructions

You are going to carry out a titration experiment.

P is 0.2 mol/dm^3 aqueous acidified potassium manganate(VII).

Q is an antiseptic solution containing hydrogen peroxide.

(a) (i) Fill the burette provided up to the 0.0 cm^3 mark with solution P.

Pipette 25.0 cm^3 of solution Q, aqueous hydrogen peroxide of an unknown concentration, into a conical flask.

Add solution P from the burette while swirling the flask, until solution Q just changes colour.

Record your titration results in the space provided, repeating the titration as many times as you consider necessary to achieve consistent results.

(i) State a possible source of error in the experiment.

Hydrogen peroxide decomposes / is not stable when exposed strong light/ sunlight/ heat. [1]

(ii) Explain how the source of error will affect the results of the experiment.

When hydrogen peroxide decomposes, the number of moles of hydrogen peroxide in solution Q will decrease. Hence, the volume of solution P needed for reaction will decrease leading to calculated concentration of hydrogen peroxide to be lower than expected.

(iii) Suggest an improvement for the experiment.

Store solution Q in a dark bottle/ dark room before use or
Prepare solution Q just before the experiment. Or
Conduct the experiment in a cool place.

Unacceptable suggestions:
Conduct the experiment in a dark room/ room without sunlight/ room with all curtains drawn / Use a dark conical flask or cover the conical flask

3 Purpose of Experiment

The aim of an experiment determines the variable to be measured or dependent variable in the investigation of the effect of the independent variable.

When the dependent variables are either temperature change or time taken for observation to be made, sources of error can be caused by **inherent inaccuracies** when these dependent variables are measured.

Example 1 – Excerpt from Experiment 3.3

(a) *Experiment 1* **Heat experiment**

Use a measuring cylinder to measure 50 cm^3 of aqueous sodium hydroxide and pour into the polystyrene cup provided. Put the cup into a 250 cm^3 beaker. Measure the initial temperature (T_o) of the solution. Leave the thermometer in the Styrofoam cup. Record T_o in the table on the next page.

Fill the burette with the solution of acid **A** provided. Add 5.00 cm^3 of acid **A** to the aqueous sodium hydroxide in the cup and stir the mixture. Measure and record the maximum temperature (T_i) of the solution in the table below. Add a further 5.00 cm^3 of acid **A** to the cup and stir the mixture. Measure and record the maximum temperature (T_i) of the mixture in the table below.

Continue to add 5.00 cm^3 portions of acid **A** to the cup, until a total volume of 40.00 cm^3 of acid has been added. Stir after each addition and measure and record the temperatures (T_i) in the table.

Calculate the values of temperature rise ($T_i - T_o$). Tabulate all your results to show the total volumes of hydrochloric acid added and the corresponding values of highest temperature reached (T_i) and temperature rise ($T_i - T_o$).

At the end of this experiment, pour the solution away and rinse the Styrofoam cup.

(a) State one source of error in the experiment and how it will affect the **results** of the experiment. (results is about temperature)

Heat lost to the surrounding due to poor insulation of the mixture.

This will cause the temperatures measured to be lower than expected.

(NOT: actual)

Or slow run of the acid from burette causes more heat lost to the surroundings. This caused temperatures measured/recorded to be lower than expected.

(b) Suggest an improvement to reduce the source of error in the experiments.

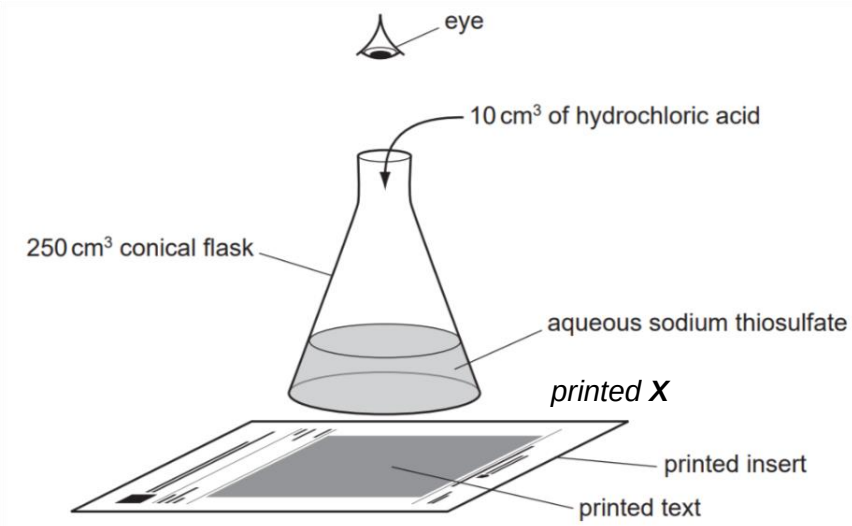
Cover the polystyrene cup to minimise heat lost to the surrounding.

Or Use measuring cylinder instead of burette

Example 2 – Excerpt from Experiment 4.4

Instructions
You are required to carry out five experiments using the apparatus shown.

Time experiment



(a)

Experiment 1

Use a measuring cylinder to measure 50 cm^3 of aqueous sodium thiosulfate into a conical flask. Place the conical flask on the printed ***X*** provided.
Fill the small measuring cylinder with 10 cm^3 of the hydrochloric acid provided.
Add acid to the solution in the conical flask and immediately start your stopwatch and swirl the mixture.
Measure the time taken for the printed ***X*** to disappear from view. Record the time in the table. Pour the solution away and rinse the conical flask with distilled water.

(b) *Experiment 2*

Use a measuring cylinder to measure 40 cm^3 of aqueous sodium thiosulfate into a conical flask, followed by 10 cm^3 of distilled water. Place the conical flask on the printed ***X*** provided.
Fill the small measuring cylinder with 10 cm^3 of the hydrochloric acid provided.
Add acid to the solution in the conical flask and immediately start your stopwatch and swirl the mixture.
Measure the time taken for the printed ***X*** to disappear from view. Record the time in the table. Pour the solution away and rinse the conical flask with distilled water.

(a) State one source of error in the experiment and how it will affect the results of the experiment.

Human reaction time (NOT: human error) when starting and stopping the stopwatch leading to inaccurate time measurements.

OR inconsistent swirling of solution mixture which lead to inaccurate time measurement.

(b) Suggest an improvement to reduce the source of error in the experiments.

Use a magnetic stirrer or use a burette to measure volume of aqueous sodium thiosulfate.

Repeat the experiment at least twice to obtain average time taken

Example 3 – Excerpt from Experiment 3.6

Title:
To determine the percentage purity of a sample of impure sodium hydroxide solution by titrating the solution against a standard solution of hydrochloric acid.

Description:
A sample of 4.0 g of impure sodium hydroxide crystals were dissolved in water and the volume was made up to 1000 cm^3. To determine the purity of the sample, 25.0 cm^3 of the solution is titrated against 0.100 mol/dm^3 of hydrochloric acid.
Sodium hydroxide and hydrochloric acid reacts according to the equation:

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

Materials:
Impure sodium hydroxide solution
Hydrochloric acid of concentration 0.100 mol/dm^3
Methyl orange indicator

Procedure:

1 Put hydrochloric acid into the burette.
2 Pipette 25.0 cm^3 of the sodium hydroxide solution into a conical flask.
3 Add two drops of methyl orange indicator into the flask and swirl the flask to ensure thorough mixing.
4 Note the initial reading of the burette.
5 Titrate with hydrochloric acid, using the indicator provided until the end-point is reached when one additional drop of hydrochloric acid causes the methyl orange to turn from yellow to orange.
6 Record your results in the table, repeating the titration as many times as you consider necessary to achieve consistent results.

State one source of experimental error and explain how it will affect the results of the experiment.

The impurities inside sodium hydroxide might react with the hydrochloric acid and this will result in higher volume of hydrochloric acid recorded. The percentage purity would have been higher than the expected.

Example 4:

Salt Preparation or collecting of solids

State one source of experimental error and explain how it will affect the results of the experiment.

The solids <u>may not be completely dry</u>. Hence, the mass obtained is higher than expected. (water increases the mass of the solids)
Or
Some of the <u>solids is lost</u> during filtration, sputtering of the solids leading to the mass collected to be lower than expected.

Thinking Questions

1. **A student did not rinse the thermometer/ measuring cylinder between changes of solution. What will be the likely source of error?**

   Incorrect temperature measurement will be obtained as the thermometer needs time to adjust to the new temperature of the solution. This will result …..

2. **A student helper prepared a standard solution but did not shake the 250 cm^3 graduated flask thoroughly before the titration.**

   State and explain how this will affect his titre value (titration volume).

   Inconsistent and inaccurate titration volume (titre value) will be obtained as a non-homogenous solution is prepared. This will result ……

3. **In heat experiment involving large pieces of e.g. metal with acid may be a disadvantage. Explain.**

   Large piece of magnesium ribbon does not allow for fast reaction, hence **more heat loss** to the surroundings due to slow reaction. Hence, **temperature** recorded may be lower than expected.