School of Chemical Sciences
UNIVERSITI SAINS MALAYSIA

DETERMINATION OF EMPIRICAL FORMULA OF COPPER (II) OXIDE AND CONSTRUCTING BALANCED CHEMICAL EQUATIONS HANDBOOK

http://chem.usm.my

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LIST OF AWARDS

RECEIVED GOLD AWARDS FOR:

i-IDeA™ 2018
THE 4TH INTERNATIONAL INNOVATION, DESIGN AND ARTICULATION

UNIVERSITI TEKNOLOGI MARA
PERLIS BRANCH

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INTRODUCTION

This handbook is prepared in order to integrate the microscale approach into the chemistry curriculum of Malaysian secondary schools taking into consideration the limited funding in terms of chemicals, glassware and laboratory facilities.

The programme aims at reaching out to students as well as teachers to become involved in chemistry as a subject in order to increase their interest in science besides promoting science in a smaller scale. In our part, miniaturized or microscale chemistry is part of our attempts to solve problems related to limited chemicals. Besides attending lectures on selected topics, teachers will also be involved in conducting new experiments using USM new glass-based miniaturized microscale kits developed by our staff.

COMPONENTS IN THE KIT

Components	Quantity
Combo plate (24 well)	1
Cross arm for microstand	1
Glass fusion tube	1
Glass tube 6 cm x 4 mm	1
Reaction tank with tube	1
Reaction tank without tube	1
Lighter	1
Microburner	1
Microspatula	1
Propette	3
Silicone tube 4 cm x 4 cm	3
Syringe (3 mL)	1

COMPONENTS IN THE KIT

Chemicals	Volume / weight
CuO powder	5 g
1 mol dm^{-3} $CuSO_4$	5 mL
$CuCO_3$ powder	5 g
Granulated Zn	5 g
1 mol dm^{-3} $(PbNo_3)_2$	5 mL
Lime water	10 mL
Methylated spirit	10 mL
1 mol dm^{-3} KI	5 mL
2 mol dm^{-3} H_2SO_4	10 mL

Exp 1: Determination of Empirical Formula of Copper (II) Oxide

The quantitative relationships between mass and amount will be studied using the combustion reaction of copper oxide. Copper is reacted with oxygen from the air inside reaction tank, and the masses before and after the oxidation are measured. The resulting masses are used to calculate the experimental empirical formula of copper oxide, which is then compared to the theoretical empirical form

Objective:

To determine the empirical formula of copper (II) oxide

Engage:

Role play
A student will play the role of a news reader. The teacher will give the 'news reader' news that report on copper thieves, to be read aloud. The teacher will later highlight the usage of copper as a conductor of heat which led to the high value of copper as the motives for the theft.

Refer
https://www.nst.com.my/opinion/columnists/2018/03/343538/beware-cable-thieves

The teacher will then ask students to name other material(s) that is made of or contains copper, such as wire cable, microchips, water pipes, taps, jewelleries and coins.

Explore:

The students will be asked to set up the following experiment:

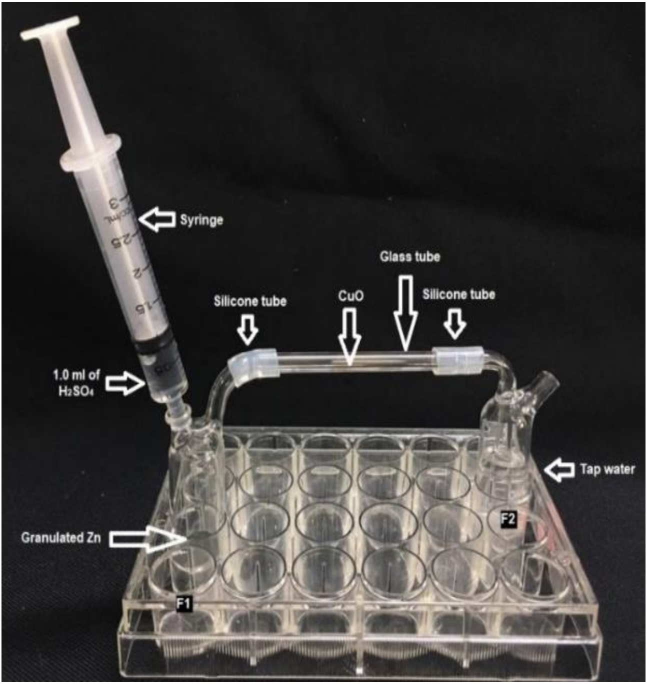
Apparatus:

1 comboplate, 1 2 cm^3 syringes, 1 glass tube (6 cm $\times$ 4 mm), 1 reaction tank with tube, 1 reaction tank without tube, 1 microspatula, 1 propette, 2 silicone tubes (4 cm $\times$ 4 mm), 1 microburner and 1 lighter.

Chemicals:

2 mol dm^{-3} H_2SO_4, granulated zinc, Zn, 1 mol dm^{-3} copper (II) sulphate, $CuSO_4$ solution, copper (II) oxide, CuO powder, and methylated spirit.

Microscale chemistry set-up:



Procedure:

1. Use a microspatula to add about 0.5 to 1 g of granulated zinc to reaction tank without tube (F1).
2. Fill two-thirds of reaction tank with tube (F2) with tap water from a propette.
3. Seal well F1 with lid 1. Seal well F6 with lid 2 so that the vent hole faces outwards.
4. Connect one end of a silicone tube to the tube connector on F1 to the tube connector on F2.
5. Weigh the glass tube and record the weight.
6. Hold the glass tube in a horizontal position. Use the narrow end of a clean microspatula to place a small quantity of copper (II) oxide powder in the center of the glass tube.
7. Weigh the glass tube with the copper (II) oxide and record its weight.
8. Keep the glass tube horizontal and attach one end to the silicone tube of F1 to the silicone tube on F2. Note keep the glass tube horizontal at all times otherwise the powder might spill into reaction tank F1 or F2.
9. Fill the syringe with 1 ml of 2 mol dm^{-3} sulphuric acid. Fit the nozzle of the syringe into the syringe inlet on F1.

Watch Out! Be careful when you handle acids. Acids are corrosive.

10. Light the microburner and place it away from the comboplate.
11. Add the sulphuric acid very slowly from the syringe into well F1.
12. Using a propette, add slowly through the tube connector, 2 – 3 drops of copper (II) sulphate solution into well F1.
13. When a few bubbles have come through the water in well F2, bring the flame of the microburner to the middle of the glass tube where the copper (II) oxide powder has been placed. Hold the microburner in this position.

Caution: Do not bring the flame of the microburner near the silicone tubes (as they will melt) or the vent of well F1 (as hydrogen is explosive)

14. Stop heating the copper (II) oxide powder after about 2 minutes or after it has changed in appearance. Blow out the microburner flame.
15. Continue the flow of hydrogen gas, H_2, until the apparatus cools down to room temperature.
16. Weigh the glass tube and its content and record the weight.

17. Disconnect it from F2 if there is water being sucked up from F2 into the glass tube.
18. Repeat heating, cooling and weighing in steps 13 to 16 until a constant mass is achieved. Record the constant mass in your notebook.

Caution A mixture of hydrogen and air will explode when lighted.

Note The 2 mol dm^{-3} sulphuric acid, granulated zinc and 1 mol dm^{-3} copper(II) sulphate solution can be replaced by 5.5 mol dm^{-3} hydrochloric acid and zinc powder.

Data and Observations:

Description	Mass (g)
Glass tube	
Glass tube + copper (II) oxide	
Glass tube + copper	
Copper	
Oxygen	
	Moles
Moles of copper	
Moles of oxygen	
Mole ratio	

Conclusions:

Questions:

1. Describe what happens to the CuO(s).
2. What other changes occur in the glass tube?
3. What chemical reaction has occurred in the tube? Write down the chemical reaction to produce hydrogen.
4. Why do you need to repeat heating, cooling and weighing until a constant mass is achieved?
5. Based on your results, calculate the empirical formula of copper(II) oxide.

Explain:

The teacher will assist students by explaining the following points:

Chemical formula helps us to know the composition of a substance based on the elements that make up the substance and the ratio/number of atoms of each element in the substance. The empirical formula of a compound gives the simplest whole number ratio of atoms of each element present in the compound.

The empirical formula of copper (II) oxide is CuO where the simplest ratio of moles for both Cu and O is 1. In this experiment, (CuO) is black in color will react with hydrogen gas (H_2) to produce brown copper (Cu) metal. In the experiment, the flame is turned off when the CuO turns completely brown.

$$H_2\ (g) +\ CuO\ (s) \rightarrow Cu\ (s) +\ H_2O\ (l)$$

Heating, cooling and weighing are repeated until a constant mass is achieved to ensure all CuO has changed into Cu. This experiment can also be used to determine the empirical formulae of oxides of other low reactivity metals like tin(II) oxide (SnO) and lead(II) oxide (PbO). However, this method cannot be replaced by heating CuO with reactive metals such as magnesium (Mg) or calcium (Ca).

$$\mathrm{Mg}\ (s) + \mathrm{CuO}\ \rightarrow \mathrm{MgO}\ (s) + \mathrm{Cu}\ (s)$$

Elaborate:

The teacher will encourage a two-way discussion with the students. The teacher needs to probe students with questions leading to the concepts on how to determine the empirical formula of elements or substance. Emphasis will be on the steps as follows.

1. Figure out mass (volume, gas or percentage) of each element.
2. Determine the molecular weight of the elements based on the periodic table.
3. Figure out number of moles of each element.
4. Figure out the mole ratio of each element.
5. Determine the simplest ratio based on the mole ratio.
6. Apply the concept when finding the empirical formula.

The teacher invites a few students to explain a given table on Magnesium Oxide (MgO).

Element	Mg	O
Mass (g)	0.27	0.17
No. of mole	= 0.27g / 24.31 g/mol = 0.0111	=0.17g / (16 x 2) g/mol = 0.0106
Mole ratio	=0.0111 / 0.0106 = 1.05	=0.0106 / 0.0106 = 1
Simplest ratio	1	1

The teacher invites few students to do an exercise on a given table:

Element	Na	Br	O
Mass (g)	15.23	52.98	37.79
No. of mole			
Mole ratio			
Simplest ratio			

Evaluate:

The teacher will instruct students to write the answers to a few questions on a piece of paper and fold it. Then students are asked to pass up the papers around until the teacher says stop. The idea is no one could identify the writer of the answer on the folded paper. Then, the teacher will ask students randomly on the answers from the questions and check the answers written on the paper. Students are supposed to respond if the answers on the paper in their hands is right or wrong.

1. What is an empirical formula for copper (II) oxide?
2. Why magnesium or calcium cannot replace copper oxide?
3. What element can replace copper in copper oxide?
4. Explain the basic steps in determining empirical formula.

Exp 2: Constructing Balanced Chemical Equations

Balanced chemical equation occurs when the number of atoms involved in the reactants side is equal to the number of atoms in the products side. This can be achieved when $CuCO_3$ decomposes into CuO and CO_2 prior being heated section I. Meanwhile in section II, when the reactant lead(II) nitrate ($Pb(NO_3)_2$) solution is added to potassium iodide (KI) solution, a product of PbI_2 and potassium nitrate (KNO_3) solution is produced. Noted the changes of colour during experiment.

Objective:

To construct balanced chemical equations

Engage:

A teacher will show this video**:**

https://www.youtube.com/watch?v=4jISjQvdyhs

From the video, students need to answer these two questions:

1. What is the law of conservation of mass in a chemical reaction?
2. What needs to be balanced between the reactant and product?

Explore:

The students will be asked to set up the apparatus as shown below:

Apparatus :

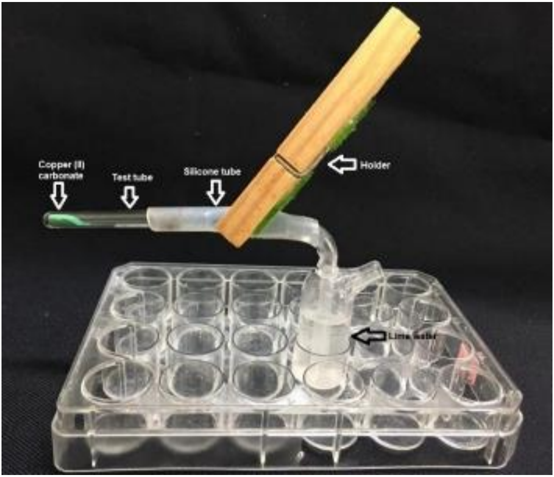
1 comboplate, 1 test tube, 1 silicone tube, 1 holder (cloth peg), 1 microspatula, 1 propette, 1 toothpick, 1 microburner and 1 lighter.

Chemicals:

$CuCO_3$ powder, $Ca(OH)_2$ (lime water), 1 mol dm^{-3} $Pb(NO_3)_2$ solution and 1 mol dm^{-3} KI solution.

Procedure:

I. Heating of copper (II) carbonate:

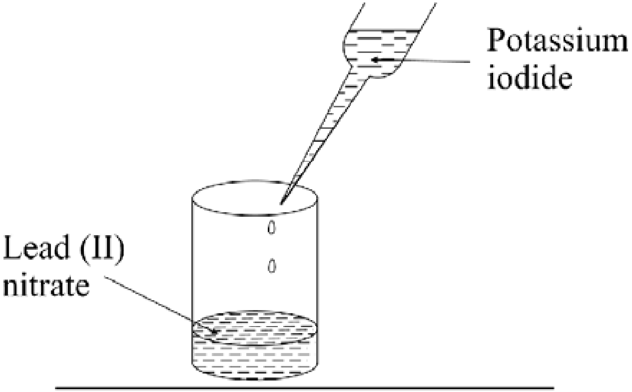


1. Hold the test tube in a horizontal position. Use the narrow end of a plastic microspatula to fill about ½ of the test tube with copper (II) carbonate powder. Note its color.
2. Heat the copper (II) carbonate and pass the gas produced through limewater in reaction tank.

Observe what happens to the copper (II) carbonate and the limewater.

3. When the reaction is completed, withdraw the silicone tube.
4. Record the observations in the notebook.

II Precipitation of lead (II) iodide



F1

1. Using a propette, place the lead (II) nitrate solution until ¼ of well F1 of the comboplate is fill up.
2. Add the potassium iodide solution until half of the well is fill up.
3. Stir the mixture using a toothpik and observe what happens.
4. Record your observations in your notebook

Data and Observations

Section	Reactants	Products
I		
II		

Conclusions:

Questions:

1. Construct a table to fill in the following data.
   a) The reactants and products in Sections I and II.
   b) The state of each reactant and product that is whether it exists as a solid, liquid, gas or aqueous solution.
   c) The chemical formula of each of the reactants and products.

2. Write a balanced chemical equation for each reaction that occurs.

Explain:

The teacher will explain to students the following points:

A chemical equation is a precise description of a chemical reaction. The equation can be represented in words, however it is usually more convenient and quicker to use chemical formula. There are two parts in the chemical equation which are reactant (left-hand side) and product (right-hand side). Starting substances are known as reactants while new substances formed called as products. Based on the law of conservation of mass, matter can neither be created nor destroyed. Therefore, the numbers of atoms before and after a chemical reaction are the same, thus the chemical equation must be balanced.
Here is the observation for each section:

Section	Reactants	Products
I	$CuCO_3$ changes color from green to black	$CuCO_3$ decomposes into CuO which is black

	and limewater turns milky	in color and CO_2 is released
II	A yellow precipitate is produced	The yellow precipitate is PbI_2

When $CuCO_3$ is heated, it decomposes into CuO and CO_2. The presence of CO_2 is detected by limewater.

$$CuCO_3\ (s) \rightarrow CuO\ (s) + CO_2\ (g)$$

When the colorless lead(II) nitrate ($Pb(NO_3)_2$) solution is added to the colorless potassium iodide (KI) solution, a yellow precipitate of Pbl_2 is produced. At the same time, colorless potassium nitrate (KNO_3) solution is also produced.

$$Pb(NO_3)_2\ (aq) + 2Kl\ (aq) \rightarrow Pbl_2\ (s) + 2KNO_3\ (aq)$$

Elaborate:

Identify the reactants and products for these reactions:

- Sulphur dioxide gas reacts with oxygen to form sulphur trioxide gas

- Methane burns in oxygen to form carbon dioxide and water
- Magnesium and fluorine gas react together to form magnesium fluoride
- Hydrochloric acid and calcium hydroxide react together to form calcium chloride and water

Evaluate:

The teacher will conduct activities with the students as listed below:

1. Magnesium oxide forms from magnesium metal and oxygen gas. Write a balanced equation and identify their physical states.
2. Aluminium reacts with oxygen to produce aluminium oxide. Write a balanced chemical equation and identify the physical states for the reaction.
3. Sulphuric acid and sodium hydroxide react together to form sodium sulphate and water. Write a balanced chemical equation and identify the physical states for the reaction.
4. Nitric acid and calcium carbonate react together to form calcium nitrate, water and carbon dioxide gas. Write a balanced chemical equation including physical states for the reaction.

SAFETY PRECAUTIONS

2 mol dm^{-3} H_2SO_4
Precautions: Keep container dry. Do not ingest. Do not breathe gas/fumes/ vapour/spray. Never add water to this product In case of insufficient ventilation, wear suitable respiratory equipment If ingested, seek medical advice immediately and show the container or the label. Avoid contact with skin and eyes Keep away from incompatibles such as metals, alkalis, moisture. May corrode metallic surfaces. Store in a metallic or coated fiberboard drum using a strong polyethylene inner package. **Storage:** May corrode metallic surfaces. Store in a metallic or coated fiberboard drum using a strong polyethylene inner package. Corrosive materials should be stored in a separate safety storage cabinet or room. **Personal Protection:** Face shield, full suit, vapor respirator, gloves and boots. Be sure to use an approved/certified respirator or equivalent.

Granulated zinc, Zn
Precautions: Avoid contact with skin, eyes, and clothing. Follow good hygiene procedures when handling chemical materials. Do not eat, drink or smoke or use personal products when handling chemical substances. **Storage:** Store in a cool location. Keep away from food and beverages. Protect from freezing and physical damage. Provide ventilation for containers. Keep containers tightly sealed. Store away from incompatible materials. **Personal Protection:** Protective eyewear, gloves and clothing. Be sure to use an approved/certified respirator or equivalent.

$1\ mol\ dm^{-3}\ CuSO_4$
Precautions: Use personal protective equipment. Ensure adequate ventilation. Avoid dust formation. Avoid contact with skin, eyes and clothing. **Storage:** Keep containers tightly closed in a dry, cool and well-ventilated place. Store under an inert atmosphere. **Personal Protection:** protective eyeglasses or chemical safety goggles, protective gloves, and clothing. Be sure to use an approved/certified respirator or equivalent.

CuO powder
Precautions: Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas. Avoid breathing dust. **Storage:** Store in cool place. Keep container tightly closed in a dry and well-ventilated place. **Personal Protection:** Chemical safety goggles, protective gloves, and clothing. Be sure to use an approved/certified respirator or equivalent

$CuCO_3$ powder
Precautions: Avoid contact with skin, eyes and clothing. Follow good hygiene procedures when handling chemical materials. Do not eat, drink or smoke or use personal products when handling chemical substances. **Storage:** Store in a cool location. Keep away from food and beverages. Protect from freezing and physical damage. Provide ventilation for containers. Keep containers tightly sealed. Store away from incompatible materials. **Personal Protection:** Chemical safety goggles, protective gloves, and clothing. Be sure to use an approved/certified respirator or equivalent.

$Ca(OH)_2$
Precautions: Minimise dust generation and accumulation. Wash hands after handling. Avoid dispersal of dust in the air. Routine housekeeping should be instituted to ensure the dusts do not accumulate on surfaces. Dry powders can build static electricity charges when subjected to the friction of transfer and mixing operations. Follow good hygiene procedures when handling chemical materials. Do not eat, drink or smoke, or use personal products when handling chemical substances. If in a laboratory setting, follow Chemical Hygiene Plan. Use only in well-ventilated areas. Avoid generation of dust or fine particulate. Avoid contact with eyes, skin and clothing. **Storage:** Store in a cool location. Provide ventilation for containers. Avoid storage near extreme heat, ignition sources or open flame. Store away from foodstuffs. Store away from oxidizing agents. Store in cool, dry conditions in well-sealed containers. Keep containers tightly sealed.

Personal Protection: Chemical safety goggles, protective gloves, and clothing. Be sure to use an approved/certified respirator or equivalent

1 mol dm^{-3} $Pb(NO_3)_2$

Precautions: Avoid contact with skin, eyes and clothing. Use only in well-ventilated areas. Wash hands after handling. Wash hands before breaks and immediately after handling the product. Use only under a chemical fume hood. Keep from contact with combustible materials. Do not breathe dust. Do not inhale gases, fumes, dust, mist, vapour and aerosols. Dry powders can build static electricity charges when subjected to the friction of transfer and mixing operations. Do not eat, drink, smoke or use personal products when handling chemical substances.

Storage: Store with like hazards. Store away from food. Keep product and empty container away from heat and sources of ignition. Keep containers tightly closed in a cool, dry, well-ventilated area away from combustible materials. Store locked up.

Personal Protection: Chemical safety goggles, protective gloves, and clothing. Be sure to use an approved/certified respirator or equivalent

1 mol dm^{-3} KI
Precautions: Avoid contact with skin, eyes and clothing. Use only in well-ventilated areas. Wash hands after handling. Follow good hygiene procedures when handling chemical materials. Do not eat, drink, smoke or use personal products when handling chemical substances. **Storage:** Provide ventilation for containers. Avoid storage near extreme heat, ignition sources or open flame. Store away from foodstuffs. Store away from oxidizing agents. Store in a cool, dry conditions in well-sealed containers. Keep container tightly sealed. Protect from freezing and physical damage. **Personal Protection:** Chemical safety goggles, protective gloves, and clothing. Be sure to use an approved/certified respirator or equivalent. Ensure adequate ventilation.

Methylated spirits
Precautions: Keep away from heat/sparks/open flame/hot surfaces. Do not get in eyes, on skin, or on clothing. Avoid ingestion and inhalation. Take precautionary measures against static discharges. **Storage:** Avoid storage near extreme heat, ignition sources or open flame. Store away from foodstuffs. Keep away from oxidizing agents. Store in a cool, dry conditions in well-sealed containers. Keep container tightly sealed. **Personal Protection:** Chemical safety goggles, protective gloves, and clothing. Be sure to use an approved/certified respirator or equivalent. Ensure adequate ventilation.

Chemical Safety Data Sheet (SDS)

No.	Chemicals	Link for SDS
1.	2 mol dm^{-3} H_2SO_4	https://bit.ly/2NmLtgl
2.	Granulated zinc, Zn	https://bit.ly/2ElX2Bl
3.	1 mol dm^{-3} $CuSO_4$	https://bit.ly/2Pou9HO
4.	CuO powder	https://bit.ly/2GRUUmD
5.	$CuCO_3$ powder	https://bit.ly/2tvT17f
6.	$Ca(OH)_2$	https://bit.ly/2ICNciT
7.	1 mol dm^{-3} $Pb(NO_3)_2$	https://bit.ly/2SOeLdC
8.	1 mol dm^{-3} KI	https://bit.ly/2hMCedv
9.	Methylated spirits	https://bit.ly/2GAyG9b

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