Cambridge Assessment International Education

Skills Pack

Determining the empirical formula of magnesium oxide

Cambridge IGCSE™

Chemistry 0620

This *Skills Pack* can also be used with the following syllabuses:
- Cambridge IGCSE® Chemistry **0620**
- Cambridge IGCSE® (9–1) Chemistry **0971**
- Cambridge IGCSE® Combined Science **0653**
- Cambridge O Level Chemistry **5070**

Version 0.1

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Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Skills Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).

There are two options for practising experimental skills. If you have laboratory facilities this pack will support, you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Skills Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.

Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this pack will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Determining the empirical formula of magnesium oxide

This *Skills Pack* focuses on an empirical formula determination experiment.

Determining the empirical formula of a substance is a key step in determining the chemical formula of the substance. In this experiment, you will produce experimental data to determine with empirical formula of magnesium oxide.

This experiment has links to the following syllabus content (see syllabus for detail):

3.1 Formulae, 3.3. The mole and the Avogadro constant

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- demonstrate knowledge of how to select and safely use techniques, apparatus, and materials (including following a sequence of instructions where appropriate)
- plan experiments and investigations.
- make and record observations, measurements and estimates.
- interpret and evaluate experimental observations and data.
- evaluate methods and suggest possible improvements.

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 2.4 Ions and ionic bonds
- 3.1 Formulae
- 3.2 Relative masses of atoms and molecules
- 3.3 The mole and Avogadro constant

Going forward

The knowledge and skills gained from this experiment can be used for when you teach learners about empirical formula and structure & bonding.

Briefing lesson: Planning the experiment

Resources	• Worksheets A, B, C
Learning objectives	By the end of the lesson: • ***all*** learners should be able to plan a suitable method for determining the empirical formula of magnesium oxide

Timings	Activity
10 min Type timings in – we will turn them into icons	**Starter/Introduction** • Hand out WS A • In pairs, ask the learners to calculate the empirical formulae from molecular formulae, and molecular formulae from empirical formulae and molecular masses.
35 min	**Main lesson** • Ask the learners to share their answers with another group and see if the groups agree. If available, use mini-whiteboard (or similar) to assess understanding across the group. Model the method if understanding is weak. Ensure that all learners have the correct answers. • Explain that determining the empirical formula of a substance is one of the key steps to determining the nature of the substance. Give contextual examples, such as analysing minerals to determine the quantity of useful metals present, or the success of synthesis of organic substances used for medicines. • Hand out WS B. Their task is to devise a method to carry of out the determination of the empirical formula of magnesium oxide. With appropriate guidance, ask learners to work in pairs to draw a fully annotated diagram of their experimental setup. Stress that all the equipment/materials must be used.
	Plenary • Show learners the expected set up in WS C and discuss any differences they may have. • Ask learners to write out a set of control measures beside their equipment, particularly focussed on the brightness of the magnesium when combusting, and the hot equipment. Remind them about general good laboratory practice including tying back long hair, wearing eye protection, not eating or drinking etc.

Lab lesson: Option 1 – run the experiment

Resources	• Teacher notes • Teacher walk through video • Worksheets B, C, D • Equipment as outlines in the notes
Learning objectives	By the end of the lesson: • ***All learners should be able to competently set up the equipment and safety complete the practical steps, including taking appropriate mass readings.*** • ***Most learners should also be able to confidently process the mass readings data and determine the empirical formula of magnesium oxide.*** • ***Some learners should also be able to explain how the calibration line method works.***

Timings	Activity
5 min	**Starter/Introduction** Ask the learners some general questions about the experiment they planned in the previous lesson. For example: 1. Why does the mass of the parcel increase when heated? The magnesium reacts with oxygen in the air, producing magnesium oxide. 2. What are the main hazards of this practical? Very bright light when the magnesium combusts that can damage our vision, very hot equipment that can burn us. 3. What do we mean by molar mass? The mass of one mole of a substance, measured in grams per mole.
40 min	**Main lesson** **Safety** Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate. • Arrange learners in groups of 2-3. Hand out WS C. Ask the learners to talk through the steps they will be carrying out, and who will be responsible for each step. For example, setting up the heating equipment can be completed by one learner, making the parcel and taking the measurements by a second. It can be useful for one learner to have special responsibility for checking safety and the setup before proceeding with the reaction. • SAFETY: Circulate the classroom at all times during the experiment so that you can make sure your learners are safe. • Learners perform the experiment following the instructions on WS C carefully.

	• During the second heating stage (the 9 minutes), learners should be monitoring their practical setup, but no active intervention is necessary. Issue the learners WS D and ask them to look through the questions so they are aware of the next steps.
15 min	**Plenary** • Once the learners have taken their mass readings, the equipment can be tidied away. If equipment is still hot, leave to cool while they are processing their results using WS D. Use the model answers to support the students as necessary. Depending on timing, the processing may need to be left until the next lesson.

Teacher notes

Watch the empirical formula of magnesium oxide video (teacher version) and read these notes.

Each group will require:

- 2 bottle top crucibles
- A Bunsen burner
- A tripod
- A clay triangle
- A balance accurate to 0.01 g
- Nichrome wire, 20 cm
- Small pliers
- A pencil
- Magnesium ribbon, 10 cm
- Metal tongs

Safety

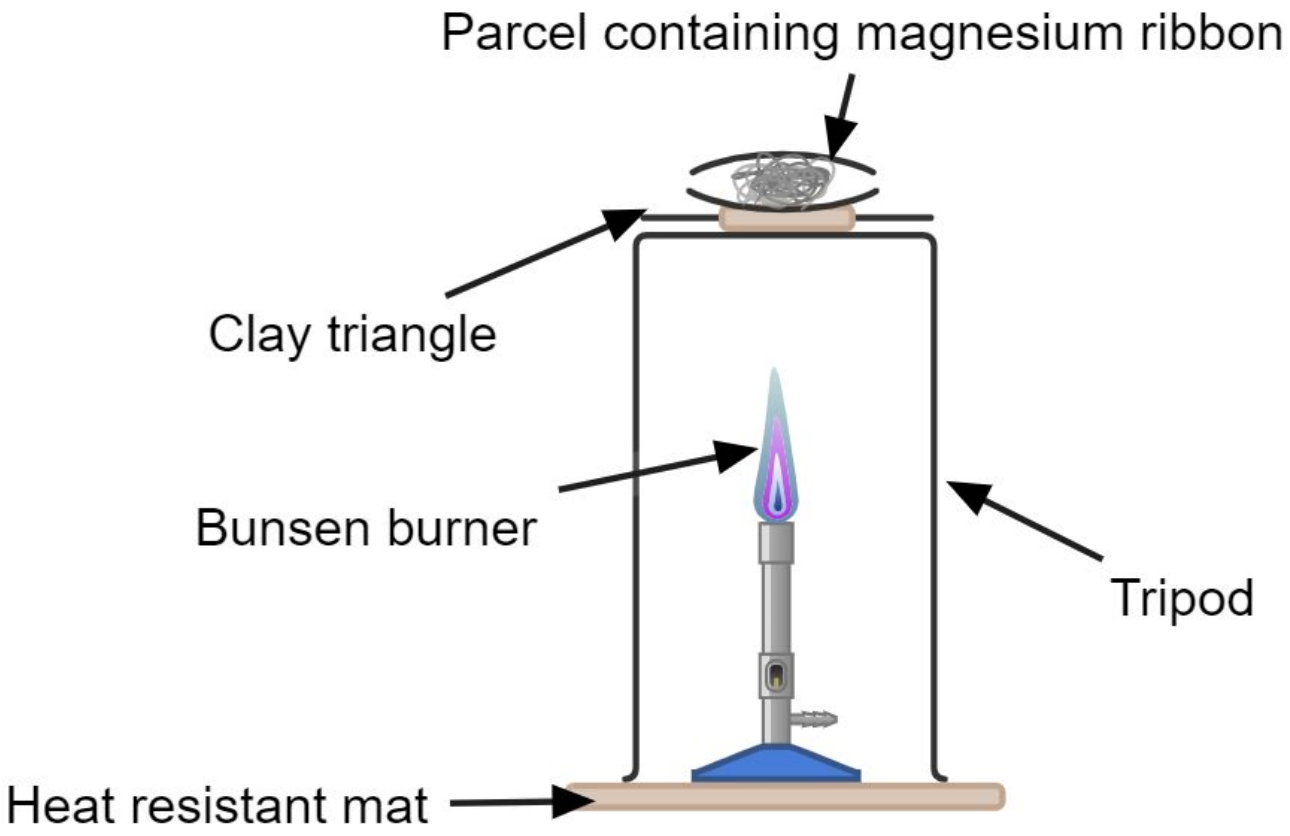
The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

- Wear eye protection
- Do not touch hot equipment – use tongs where necessary
- Do not look directly at the oxidising magnesium – a very bright white light is formed
- Long hair should be secured away from the face.
- Loose clothing should be secured so that it doesn't fall into a flame.

Substance	Hazard	First aid
Magnesium Solid	• **Magnesium is not currently classified as hazardous but is a flammable solid at high temperatures.**	• **Is burns occur, run the affect part under cool running water for 20 minutes – seek medical attention.** • **If someone looks directly at the bright light and their vision is affected, move them to an area of lower light and seek medical attention.**
	Burns	Flood burnt area with water for at least 10 minutes. For serious injuries see a doctor.

Experiment set-up



Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners. Give them **Worksheet C**.

Before you begin

Plan how you will group your learners during the experiment session.

Think about:

- the number of groups you will need (group size 2–4 learners)
- the amount of equipment/chemicals required.
- whether you are testing more than one carbonated drink.

Experiment

Walk around the learners during the experiment in case they encounter any difficulties.

Step #	Method	Notes
1	Coil a 10 cm piece of magnesium ribbon around a pencil.	**Make sure the coil fits inside one of the bottle tops.**
2	Weigh and record the mass of two bottle tops and a piece of nichrome wire on the balance.	**Make sure the balance has been tared/zeroed first**.
3	Place the magnesium coil inside one of the bottle tops and place the second bottle top on top of the first.	**Make sure the bottle tops are well aligned.**
4	Secure the bottle tops together by wrapping and twisting the nichrome wire around the tops to form the parcel.	**Use the pliers to ensure the wire is twisted tightly.**
5	Weigh and record the mass of the parcel on the balance.	**Double check the balance was tared/zeroed before weighing.**
6	Set up the clay triangle on the tripod on the heat resistant mat and set up the Bunsen burner.	
7	Place the parcel on the clay triangle.	**Make sure the parcel cannot fall through the clay triangle**.
8	Light the Bunsen onto a safety flame, then adjust to a half blue flame.	

9	Move the Bunsen under the parcel and heat for one minute.	**Use the rubber hose to position the Bunsen – never allow your hand to go under a heated object.**
10	Pull the Bunsen back out, adjust the flame to a roaring blue flame, then return the Bunsen to under the parcel.	
11	Heat for a further nine minutes.	
12	Turn off the Bunsen at the gas tap.	
13	Move the parcel to the heat resistant mat with tongs, and allow to cool for five minutes	
14	Reweigh and record the mass of the parcel using the balance.	
15	Record all of your results on Worksheet D.	

Clean-up

After the experiment learners should:

- Allow all the equipment to cool to room temperature.
- Tidy their workspace.
- Ensure any spillages have been mopped up.
- Return all equipment and unused chemicals to you. The parcels can be dismantled, cleaned, and reused.

Lab lesson: Option 2 – virtual experiment

Resources	• Virtual experiment video for empirical formula of magnesium oxide • Worksheets B & D
Learning objectives	By the end of the lesson: • ***All learners should be able to competently set up the equipment and safety complete the practical steps, including taking appropriate mass readings.*** • ***Most learners should also be able to confidently process the mass readings data and determine the empirical formula of magnesium oxide.*** • ***Some learners should also be able to explain how the calibration line method works.***

Timings	Activity
5 min	**Starter/Introduction** Ask the learners some general questions about the experiment they planned in the previous lesson. For example: 1. Why does the mass of the parcel increase when heated? The magnesium reacts with oxygen in the air, producing magnesium oxide. 2. What are the main hazards of this practical? Very bright light when the magnesium combusts that can damage our vision, very hot equipment that can burn us. 3. What do we mean by molar mass? The mass of one mole of a substance, measured in grams per mole.
30 min	**Main lesson** • Show the Virtual Experiment video from start to finish once through without stopping. • In pairs, learners compare and contrast their annotated diagrams from their planning activity (WS B) with what they saw in the video. • Give learners a copy of WS D, allowing them time to look through and understand the questions. They should not write anything at this stage. Show the video again to the learners, stopping the video as necessary. Learners then work in pairs to try to complete the sheet, helping each other when required. Project the answer sheet and go over the answers, allowing them time to correct any mistakes.
25 min	**Plenary** • Depending on how quickly learners work through the question from the Main section, the debrief lesson worksheet could be completed here. • If these is not sufficient time available to look at WS E, lead a discussion on why this method may be preferable to the traditional crucible method. Focus on the

	sustainability aspects of reusing equipment, the fragile nature of porcelain crucibles, the benefit of not having to lift the lid of the crucible (not losing magnesium oxide).

Debriefing lesson: Consolidating the underlying chemistry.

Resources	• Worksheet E • A sample/image of some minerals (eg bauxite, malachite, haematite), medicines (eg aspirin, paracetamol, amoxicillin), and an atomic absorption spectrometer.
Learning objectives	By the end of the lesson: • ***All learners should be able to competently answer questions related to calculation of empirical formula by experiment.***

Timings	Activity
10 min	**Starter/Introduction** • Ask the learners to consider the images of the minerals and the medicines, and why knowing the chemical formulae of the substances present is important. • Briefly discuss the role of atomic absorption spectroscopy in determining empirical formulae, by samples being vaporised and the amount of light absorbed being measured. Relate this to the heating of the magnesium and measuring the before and after masses from the practical experiment. Emphasise the importance of long history of chemical analysis using techniques such as heating and accurate measurements of masses and light absorption. Mention that the Bunsen burner was developed by Robert Bunsen to allow the analysis of chemical substances.
40 min	**Main lesson** • Give out WS E and ask learners to work in pairs through Q1-10. If they find themselves struggling with any questions, encourage them to consult their textbook, then with another pair of learners before asking the teacher. • Work through the answers to the questions, modelling your thinking to help learners understand the mental processes you use when tackling questions.
10 min	**Plenary** • **Ask for two pairs of volunteers to share their answers to Q9. Ask the other learners to constructively critique the shared methods.** • **Share the standard method with the learners, and check for understanding with some questioning.**

Worksheets and answers

	Worksheets	Answers
For use in the *Briefing lesson:*		
A: Starter	**x**	**x**
B: Planning the determining the empirical formula of magnesium oxide experiment	**x**	**x**
C: Experimental set-up and method	**x**	**x**
For use in *Lab lesson: Option 1:*		
D: Results and evaluation	**x**	**x**
For use in *Lab lesson: Option 2:*		
D: Results and evaluation	**x**	**x**
For use in the *Debriefing lesson:*		
E: Consolidation questions	**x**	**x**

Worksheet A: Starter

Use this worksheet with Briefing Lesson.

Instructions

1. Determine the empirical formulae of the following compound based on their molecular formulae. The first two have been completed for you.

Compound	Molecular formula	Empirical formula
Ethane	C_2H_6	CH_3
Carbon dioxide	CO_2	CO_2
Hexane	C_6H_{14}	
Hexene	C_6H_{12}	
Hydrazine	N_2H_4	
Benzene	C_6H_6	
Glucose	$C_6H_{12}O_6$	

2. Determine the molecular formulae of the following compounds based on the empirical formulae and the molecular masses. The first two have been completed for you.

Compound	Empirical formula	Molar mass	Molecular formula
Ethylene glycol	CH_3O		
Sodium hydroxide	NaOH		
Cyclohexane	CH_2		
Ethene	CH_2		
Magnesium hydroxide	$Mg(OH)_2$		
Sulfur dioxide	SO_2		
Cubane	CH		

Worksheet B: Planning the determining the empirical formula of magnesium oxide experiment.

Instructions

Using all the equipment below, design an experiment for the microscale determination of empirical formula of magnesium oxide

Labelled images of:

- 2 bottle top crucibles
- A Bunsen burner
- A tripod
- A clay triangle
- A balance accurate to 0.01 g
- Nichrome wire, 20 cm
- Small pliers
- A pencil
- Magnesium ribbon, 10 cm
- Metal tongs

Worksheet B: *continued*

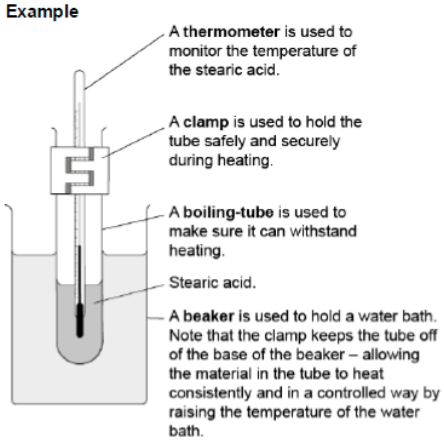
Worksheet B: Planning the extraction of iron experiment

In the space below, draw your experiment set-up.

Make sure you annotate your diagram showing the decisions you have made.

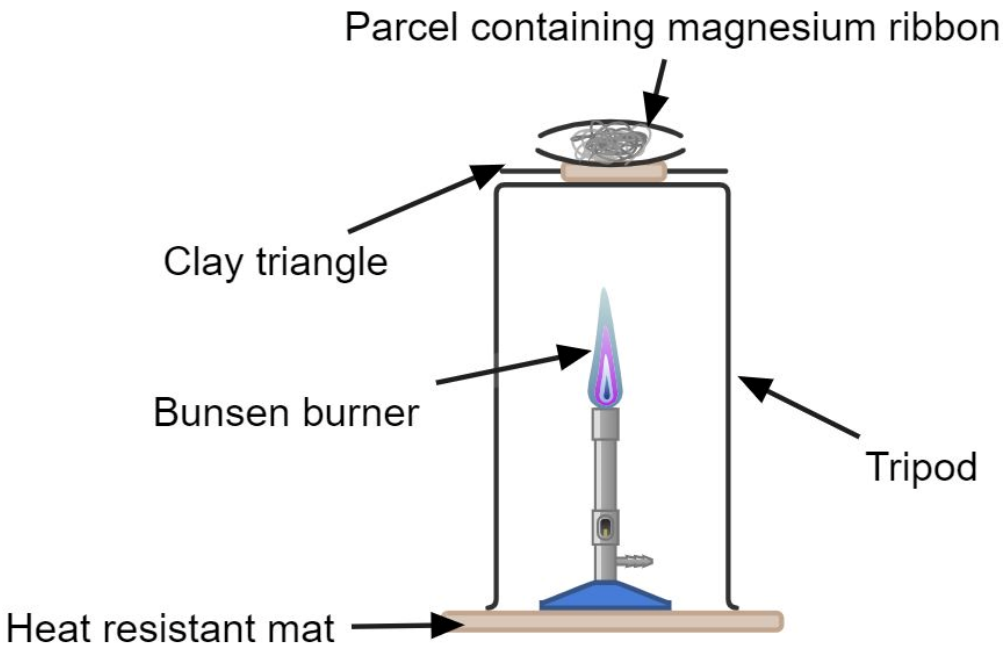
An example from a different experiment is shown

Example



Worksheet C: Experimental set-up and method

Instructions to user



Method

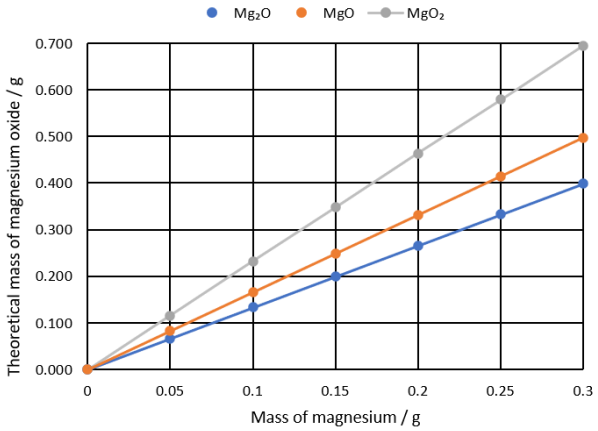
1. Coil a 10 cm piece of magnesium ribbon around a pencil. **Make sure the coil fits inside one of the bottle tops.**
2. Weigh and record the mass of two bottle tops and a piece of nichrome wire on the balance. **Make sure the balance has been tared/zeroed first**.
3. Place the magnesium coil inside one of the bottle tops and place the second bottle top on top of the first. **Make sure the bottle tops are well aligned.**
4. Secure the bottle tops together by wrapping and twisting the nichrome wire around the tops to form the parcel. **Use the pliers to ensure the wire is twisted tightly.**
5. Weigh and record the mass of the parcel on the balance. **Double check the balance was tared/zeroed before weighing.**
6. Set up the clay triangle on the tripod on the heat resistant mat and set up the Bunsen burner.
7. Place the parcel on the clay triangle. **Make sure the parcel cannot fall through the clay triangle**.
8. Light the Bunsen onto a safety flame, then adjust to a half blue flame.
9. Move the Bunsen under the parcel and heat for one minute. **Use the rubber hose to position the Bunsen – never allow your hand to go under a heated object.**
10. Pull the Bunsen back out, adjust the flame to a roaring blue flame, then return the Bunsen to under the parcel.
11. Heat for a further nine minutes.
12. Turn off the Bunsen at the gas tap.
13. Move the parcel to the heat resistant mat with tongs and allow to cool for five minutes.
14. Reweigh and record the mass of the parcel using the balance.
15. Record all of your results on Worksheet D.

Worksheet D: Results and evaluation

Results table:

Mass of parcel (M1) / g	Mass of parcel + Mg (M2) / g	Mass of parcel + MgO (M3) / g

1. Calculate the mass of magnesium by subtracting M1 from M2.
2. Calculate the mass of magnesium oxide by subtracting M1 from M3.
3. Compare your experimental data with the calibration lines on the graph below.
    a. Draw a vertical line up from your mass of magnesium on the x-axis.
    b. Draw a horizontal line across from your mass of magnesium oxide on the y-axis.
    c. Draw a circle around the point that your two lines meet.
    d. Determine which magnesium oxide calibration line your lines cross on.



4. Calculate the mass of oxygen by subtracting M2 from M3.
5. Calculate the empirical formula using the table below:

	Mg	O
Mass / g	M2-M1 =	M3-M2 =
Molar mass / $g.mol^{-1}$	24	16
Moles / mol = mass / molar mass		
Whole number ratio		
Formula		

6. Discuss any experimental errors that may have occurred when collecting your data.

Worksheet E: Consolidation questions

1. Write a word equation for the reaction of magnesium and oxygen.
2. Write a balanced symbol equation for the reaction.
3. Explain why this is a redox reaction in terms of electrons.
4. Describe the change in structure of the substances involved – refer to the type of particles and bonding involved in the substances.
5. Explain why the chemical formula and empirical formula are the same for magnesium oxide, but not for oxygen.
6. Draw a labelled diagram showing how to carry out the determination of the empirical formula of magnesium oxide using a crucible.
7. 2.25 g of aluminium was fully combusted in air forming 4.25 g of the aluminium oxide. Determine the empirical formula of aluminium oxide. Show your workings.
8. A learner wanted to carry out the method using a larger mass of magnesium. Describe the advantages and disadvantages of this method, in terms of data quality and safety.
9. This practical method can be used to determine the empirical formula of hydrated salts. Write a brief method for how you would determine the formula of hydrated copper sulfate.

Worksheet A: Answers

1. Determine the empirical formulae of the following compound based on their molecular formulae. The first two have been completed for you.

Compound	Molecular formula	Empirical formula
Ethane	C_2H_6	CH_3
Carbon dioxide	CO_2	CO_2
Hexane	C_6H_{14}	**C_3H_7**
Hexene	C_6H_{12}	**CH_2**
Hydrazine	N_2H_4	**NH_2**
Benzene	C_6H_6	**CH**
Glucose	$C_6H_{12}O_6$	**CH_2O**

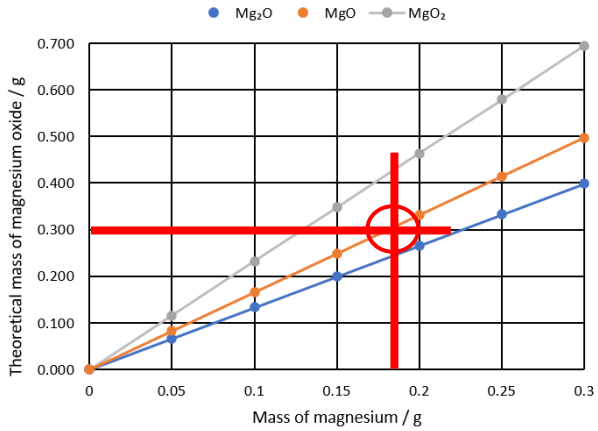
2. Determine the molecular formulae of the following compounds based on the empirical formulae and the molecular masses. The first two have been completed for you.

Compound	Empirical formula	Molar mass	Molecular formula
Ethylene glycol	CH_3O	62	$C_2H_6O_2$
Sodium hydroxide	NaOH	40	NaOH
Cyclohexane	CH_2	84	C_6H_{12}
Ethene	CH_2	28	C_2H_4
Magnesium hydroxide	$Mg(OH)_2$	58	$Mg(OH)_2$
Sulfur dioxide	SO_2	64	SO_2
Cubane	CH	104	C_8H_8

Worksheet D: Answers

Model data

Mass of parcel (M1) / g	Mass of parcel + Mg (M2) / g	Mass of parcel + MgO (M3) / g
4.20	4.38	4.50

1. 0.18 g
2. 0.30 g
3. 

    a. The lines meet on the MgO line, ie 1:1 molar ratio of magnesium and oxygen in magnesium oxide.
4. 0.12 g

	Mg	O
Mass / g	M2-M1 = 0.18	M3-M2 = 0.12
Molar mass / $g.mol^{-1}$	24	16
Moles / mol = mass / molar mass	$7.5x10^{-3}$	$7.5x10^{-3}$
Whole number ratio	1	1
Formula	MgO	

5.
6.
    a. Loss of magnesium oxide out the side of the parcel
    b. Not taring/zeroing the balance before using

c. Not heating the magnesium for long enough – some of the magnesium wasn't fully oxidised.
d. Some of the wire/bottle top is oxidised, adding extra mass to the parcel.
e. Magnesium wasn't pure/already oxidised – mass of magnesium is less than measured.

Worksheet E: Answers

1. magnesium + oxygen → magnesium oxide
2. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
3. magnesium atoms transfer electrons from oxygen atoms, so magnesium is oxidised, and oxygen is reduced.
4. Magnesium is a metallic substance, with metal ions in a giant lattice surrounded by delocalised electrons. Oxygen is a simple covalent substance, forming diatomic molecules with each oxygen atom sharing two electrons to form an oxygen-oxygen double bond. Magnesium oxide is an ionic substance, with Mg^{2+} and O^{2-} ions arranged in an alternating pattern in the giant lattice.
5. Magnesium oxide, MgO, is an ionic substance, so the chemical formula is always the empirical formula. Oxygen, O_2, is a simple covalent substance with fixed numbers of atoms in the molecules. This is shown in the chemical formula, whereas the empirical formula shows the simplest ratio, in this case O.
6.
7.
    a. 2.25 / 27 = 0.0833 mol Al;
    b. 4.25-2.25 = 2.00 g O;
    c. 2.00 / 16 = 0.125 mol O;
    d. 0.0833:0.125 = 1:1.5 = 2:3
    e. Al_2O_3
8. A larger mass of magnesium would mean a smaller percentage uncertainty in the measured masses, so a more accurate result would be achieved. Larger masses of magnesium would produce more bright light, proving potentially more hazardous to the student.
9. A method similar to WS C. The differences would be measuring the mass of the hydrated salt beforehand, heating more gently so the salt doesn't decompose once the water of crystallisation has been removed and measuring the mass of the anhydrous salt after the heating.

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