Beatty Secondary School
Science Department (Chemistry Unit)
Chemistry 6092

Name: _____ ( ) Date: _____

Class: 3E___

TOPIC: REACTIVITY SERIES AND RUSTING (WORKSHEET 2)

Learning Objectives:

(a) Place in order of reactivity calcium, copper, (hydrogen), iron, lead, magnesium, potassium, silver, sodium and zinc by reference to
  (i) the reactions, if any, of the metals with water, steam and dilute hydrochloric acid,
  (ii) the reduction, if any, of their oxides by carbon and/or by hydrogen.

(b) Describe the reactivity series as related to the tendency of a metal to form its positive ion, illustrated by its reaction with
  (i) the aqueous ions of the other listed metals,
  (ii) the oxides of the other listed metals.

(c) Deduce the order of reactivity from a given set of experimental results.

(d) Describe the action of heat on the carbonates of the listed metals and relate thermal stability to the reactivity series.

(e) Describe the essential conditions for the corrosion (rusting) of iron as the presence of oxygen and water; prevention of rusting can be achieved by placing a barrier around the metal, e.g. painting; greasing; plastic coating; galvanizing.

(f) Describe the sacrificial protection of iron by a more reactive metal in terms of the reactivity series where the more reactive metal corrodes preferentially, e.g. underwater pipes have a piece of magnesium attached to them.

Multiple-Choice Questions

1 Which element reacts with dilute hydrochloric acid to produce hydrogen?

A carbon **B** copper
C silver **D** zinc (**D**)

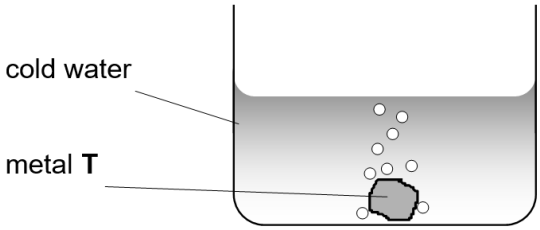
2 Which metal does **not** react with cold water but reacts when heated strongly in steam?

A calcium **B** copper
C iron **D** sodium (**C**)

3 Which oxide can be reduced to the metal by heating with carbon?

A calcium oxide **B** magnesium oxide
C potassium oxide **D** zinc oxide (**D**)

4 The diagram shows metal **T** reacting with water.



Which could metal **T** be?

A calcium **B** copper
C sodium **D** potassium (**A**)

5 Metal **Z** is placed between zinc and iron in the reactivity series. Which statement is likely to be correct?

A A heated mixture of zinc and the oxide of **Z** will react.
B **Z** will react quickly with cold water.
C Iron will displace **Z** from an aqueous solution of its chloride.
D **Z** will not react with hot dilute hydrochloric acid. (**A**)

6 Element M react in the following ways.

$$M + 2HCl \rightarrow MCl_2 + H_2$$
$$2M + O_2 \rightarrow 2MO$$
$$MO + H_2 \rightarrow \text{no reaction}$$

Which could element M be?

A aluminium **B** calcium
C copper **D** potassium (**B**)

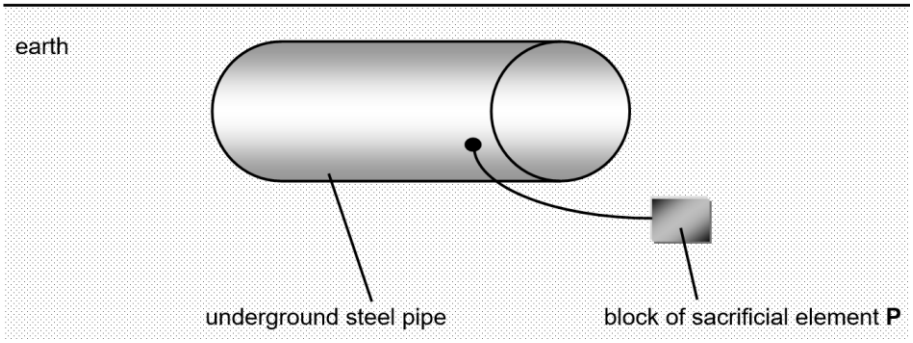
7 Magnesium is placed in aqueous copper(II) sulfate. Which change is correct?

A copper atoms lose electrons
B copper ions lose electrons
C magnesium atoms lose electrons
D magnesium ions lose electrons (**C**)

8 An excess of zinc powder is added to a solution containing a mixture of the ions Mg^{2+}, Ca^{2+}, Cu^{2+} and Ag^{+}. Which metals will be displaced from the solution?

A calcium and magnesium
B copper and calcium
C magnesium and silver
D silver and copper (**D**)

9 The corrosion of underground steel pipes can be prevented by sacrificial protection. This is shown in the diagram.



Which element is most suitable for use as sacrificial element **P**?

A carbon **B** copper
C magnesium **D** silver (**C**)

10 The table shows the results of tests to compare the reactivity for metals **X**, **Y** and **Z**.

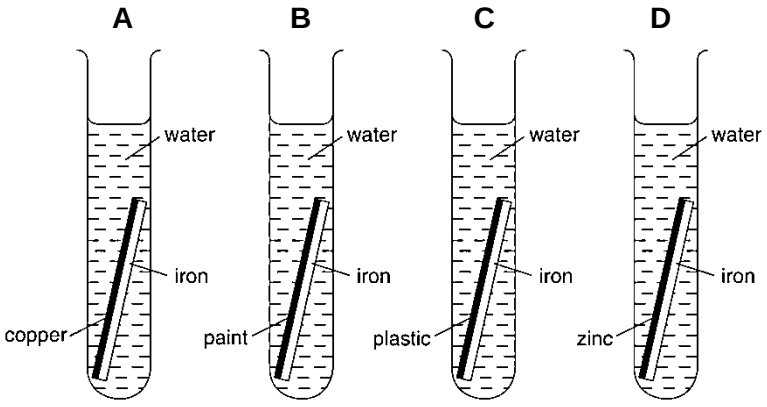
Test	Results metal **X**	metal **Y**	metal **Z**
Does carbon reduce the metal oxide?	yes	no	yes
Does the metal react with hydrochloric acid to produce hydrogen gas?	yes	yes	no

What is the order of reactivity of the metals?

	most reactive ⟶		least reactive
A	Y	X	Z
B	Z	X	Y
C	Z	Y	X
D	Y	Z	X

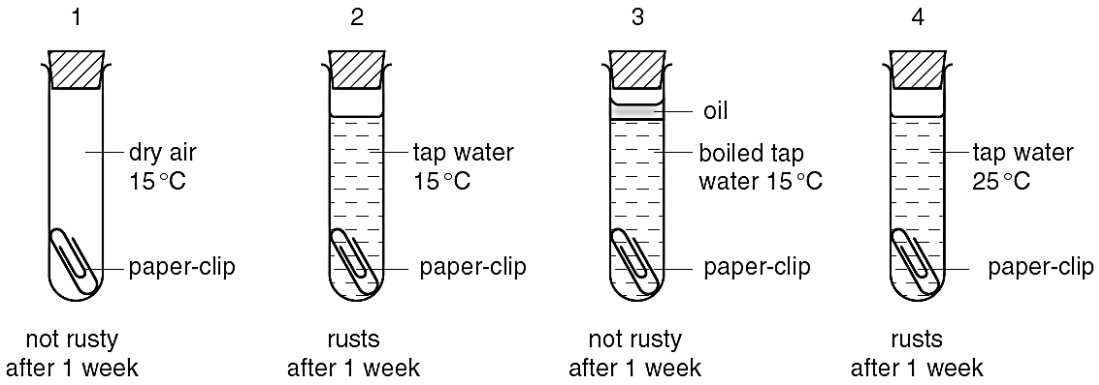
(**A**)

11 In which test-tube is the iron **least** likely to rust?



(**D**)

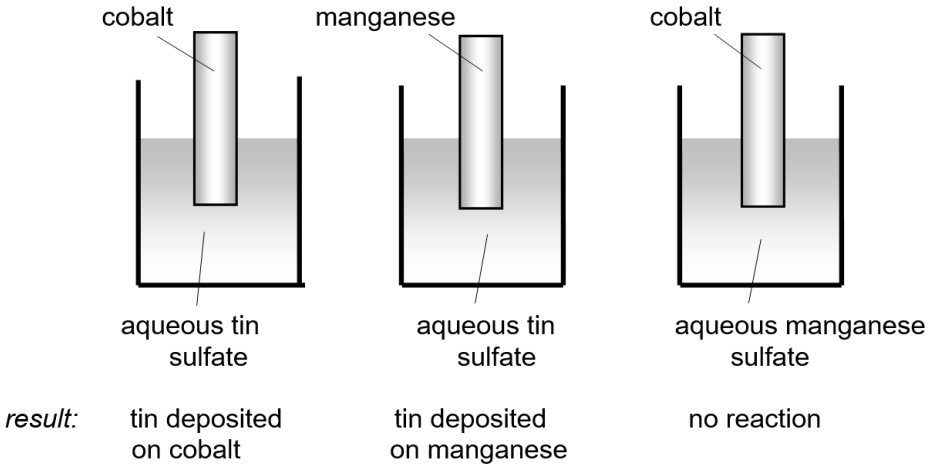
12 Four experiments on rusting are shown.



Which two experiments can be used to show that air is needed for iron to rust?

A 1 and 3 **B** 1 and 4
C 2 and 3 **D** 2 and 4 (**C**)

13 Three experiments to compare the reactivities of three metals are shown in the diagram.

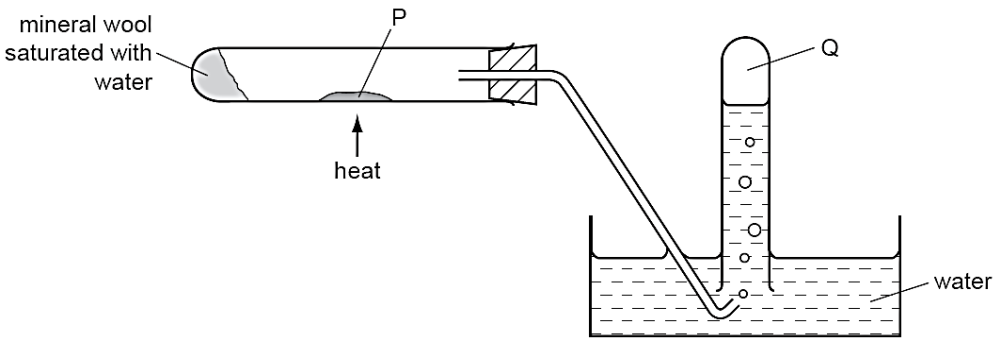


What is the correct order of reactivity for the three metals?

	most reactive ⟶		least reactive
A	cobalt	manganese	tin
B	manganese	cobalt	tin
C	manganese	tin	cobalt
D	tin	cobalt	manganese

(**B**)

14 In the experiment shown in the diagram, steam is passed over a heated solid P. Gas Q is collected.

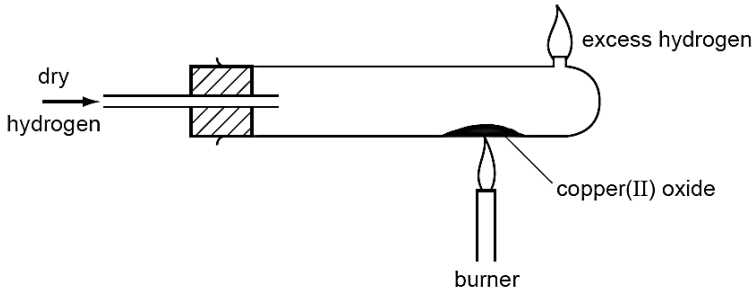


What are substances P and Q?

	P	Q
A	copper	hydrogen
B	lead	oxygen
C	silver	oxygen
D	zinc	hydrogen

(**D**)

15 Copper(II) oxide is reduced to copper as shown. The burner is then turned off but the hydrogen is kept flowing until the tube is cold.



What is the main reason why hydrogen is kept flowing?

A to lessen the risk of explosion in the hot tube
B to make certain that the reaction is complete
C to prevent the copper from reacting with the air
D to remove traces of water left in the tube (**C**)

16 Which is correct, comparing calcium and iron?

	ease of metal in giving up electrons	**ease of decomposition of the metal carbonate when heated**
A	greater for calcium than for iron	greater for calcium than for iron
B	greater for calcium than for iron	greater for iron than for calcium
C	greater for iron than for calcium	greater for calcium than for iron
D	greater for iron than for calcium	greater for iron than for calcium

(**B**)

17 Compound **X** decomposes when heated to give a black solid and a colourless gas. What could **X** be??

A calcium carbonate **B** copper(II) carbonate
C magnesium carbonate **D** sodium carbonate (**B**)

18 The carbonate of metal **X** is a white solid. It decomposes when heated to form carbon dioxide and a yellow solid. What is metal **X**?

A copper **B** lead
C iron **D** sodium (**B**)

Structured Questions

19 The reaction between aluminium and iron(III) oxide can be used to join lengths of steel railway tracks. This reaction is known as the thermit reaction. The equation for the thermit reaction is given below.

$$Fe_2O_3(s) + 2Al(s) \rightarrow Al_2O_3(s) + 2Fe(l)$$

(a) (i) What does (*l*) after the Fe in the chemical equation mean?

liquid / molten state

(ii) Why does the aluminium react with the iron(III) oxide?

Aluminium is more reactive than iron. As such, aluminium displaces / reduces iron from iron(III) oxide.

(iii) Suggest why the thermit reaction can be used to join lengths of railway track.

Thermit reaction is exothermic, hence it releases large amounts of heat energy, which is used to weld railway lines together where molten iron flows into the gaps between rails, joining them tightly together.

(b) Calculate the mass of aluminium required to react with 640 g of iron(III) oxide

No of mol of Fe_2O_3 = $\frac{640}{160}$ = 4.00 mol

Compare mole ratio:

Fe_2O_3	:	Al
1	:	2
4	:	8

Mass of Al = 8 × 27
= 216 g

20 The effects of water on five metals **A**, **B**, **C**, **D** and **E**, are given in the table.

metal	effect of water
A	Reacts very slowly when placed in boiling water. The hot metal burns in steam with a white flame.
B	Explodes with cold water.
C	No reaction when steam is passed over the red-hot metal.
D	No reaction with hot or cold water. The hot metal reacts with steam.
E	Reacts slowly with cold water.

(a) Place the metals in order of reactivity, with the most reactive first.

B, E, A, D, C

(b) Which metals could be calcium and silver respectively?

calcium **E** silver **C**

(c) Why is it not possible for metal **E** to be copper?

Copper is unreactive and will not react with cold water.

21 **V**, **W**, **X**, **Y** and **Z** represent five different metals placed in order of reactivity. Metal **V** is the most reactive.

(a) Metal **W** is denser than water. **W** reacts with cold water, producing bubbles of a gas.

(i) Suggest the identity of metal **W**.

calcium

(ii) Name the gas and describe the test you would carry out to identify it

Hydrogen. Place a lighted splint at the mouth of the test tube. If gas produced extinguishes a lighted splint with a 'pop' sound, hydrogen gas is present.

(b) Metal **V** explodes with cold water. Name one metal that could be **V**.

potassium

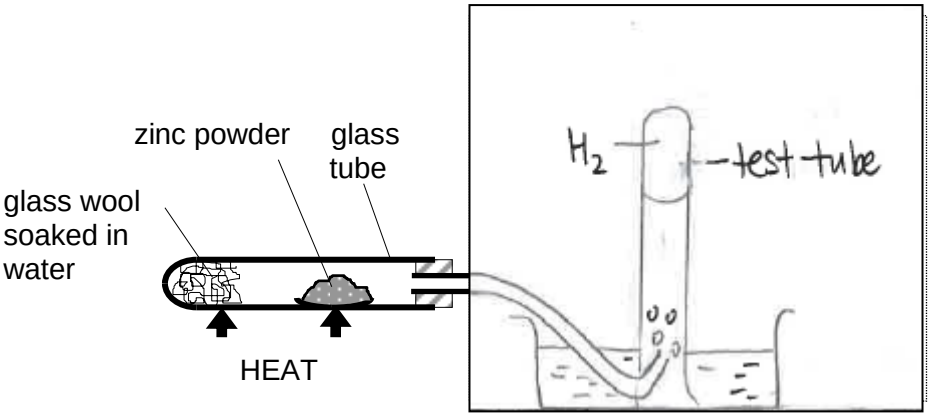
(c) Two of these metals are displaced from solutions of their ions when metal **X** is put into them. What are the letters of these two metals?

Y and Z

(d) Which one of these metals is likely to be most easily produced by heating its oxide with carbon?

Z

22 The apparatus shown in the diagram was used to react steam with hot zinc powder. A colourless gas **Z** was produced in the reaction.



(a) Complete the diagram to show how you would attempt to collect a test tube full of gas **Z**.

(b) **(i)** Name gas **Z**.

hydrogen

(ii) Name the other product of the reaction.

zinc oxide

(c) Construct a balanced equation, with state symbols, for the reaction.

$Zn\ (s) + H_2O\ (g) \rightarrow ZnO\ (s) + H_2\ (g)$

(d) Calculate the maximum volume of gas **Z**, measured at room conditions, that could be produced from the reaction of 1.3 g of zinc powder.

No of mol of Zn = $\frac{1.3}{6.5}$ = 0.0200 mol

Compare mole ratio:

Zn	:	H_2
1	:	1
0.02	:	0.02

Volume of H_2 = 0.02 × 24
= 0.480 dm^3

23 **(a)** How does the action of heat on metal carbonates depend on the position of the metal in the reactivity series?

The higher the position of the metal in the reactivity series, the greater the thermal stability of the metal carbonate. As such, a larger amount of heat / thermal energy is needed to decompose the carbonate.

(b) Construct a balanced equation, with state symbols, for the effect of heat on magnesium carbonate, $MgCO_3$.

$MgCO_3$ (s) → MgO (s) + CO_2 (g)

(c) The effect of heat on silver carbonate is shown in the following equation:

$$2Ag_2CO_3 \rightarrow 4Ag + 2CO_2 + O_2$$

Calculate the **total** volume of gas, measured at r.t.p., which is obtained from the reaction of 276 g of silver carbonate.

No of mol of Ag_2CO_3 = $\frac{276}{276}$ = 1.00 mol

Compare mole ratio:

Ag_2CO_3	:	CO_2	:	O_2
2	:	2	:	1
1.00	:	1.00	:	0.500

Total volume of gas = 1.5 × 24
= 36.0 dm^3

24 A student made the following observations:

- *When a piece of nickel is placed in aqueous lead(II) nitrate, it becomes coated with a black deposit and the colour of the solution changes from colourless to green.*
- *When a piece of nickel is placed in aqueous magnesium nitrate, no change in appearance is observed.*
- *When a piece of lead is placed in aqueous copper(II) nitrate, it becomes coated with a brown-pink deposit and the colour of the solution changes from blue to colourless.*

(a) Predict what changes (if any) will be seen when a piece of nickel is placed in aqueous copper(II) nitrate:

(i) appearance of nickel,

Nickel will become coated with a brown-pink deposit.

(ii) appearance of solution.

Solution changes from blue to green.

(b) Predict what changes (if any) will be seen when a piece of lead is placed in aqueous magnesium nitrate:

(i) appearance of lead,

Lead remains grey.

(ii) appearance of solution.

Solution remains colourless.

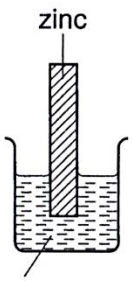
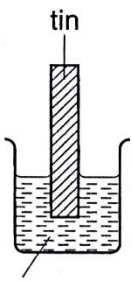
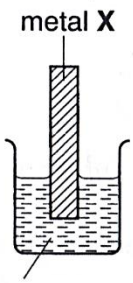
(c) Arrange the metals copper, lead, nickel and magnesium in order of decreasing reactivity.

magnesium, nickel, lead, copper

(d) Nickel forms compounds containing the ion Ni^{2+}. Construct the ionic equation, with state symbols, for the reaction of nickel with aqueous copper(II) nitrate.

$Ni\ (s) + Cu^{2+}\ (aq) \rightarrow Ni^{2+}\ (aq) + Cu\ (s)$

25 Three experiments were carried out to find the order of reactivity of three metals. The metals used were zinc, tin and an unknown metal **X**.

		experiment 1	experiment 2	experiment 3
				
colour of metal	start	silver-grey	silver-grey	orange-brown
	end	silver-grey with crystals formed on surface	brown coating on surface	**orange-brown**
colour of solution	start	colourless	blue	colourless
	end	colourless	paler blue	**colourless**

(a) Suggest the name of metal **X**.

copper

(b) Complete the table to show the colour of the metal and the solution at the end of experiment 3.

(c) Give the order of reactivity of the three metals.

most reactive **zinc**

tin

least reactive **X**

(d) Write an ionic equation, with state symbols, for the reaction in experiment 1.

$Zn\ (s) + Sn^{2+}\ (aq) \rightarrow Zn^{2+}\ (aq) + Sn\ (s)$

26 In separate experiments, powdered samples of metal **X** and metal **Y** reacted with solutions of nickel(II) sulfate and of iron(II) sulfate. The following table shows how the colours of the solutions changed.

	nickel(II) sulfate	iron(II) sulfate
X	solution goes from green to colourless	solution stays pale green
Y	solution goes from green to colourless	solution goes from pale green to colourless

(a) Predict the order of reactivity for the four metals, **X**, **Y**, nickel and iron, starting from the most reactive metal.

Y, iron, X, nickel

(b) Metal **Y** was placed in aqueous copper(II) sulfate. State **two** observations made from this reaction.

The solution changes from blue to colourless. A reddish-brown deposit is formed.

27 **(a)** Iron(III) chloride is formed when iron is heated in chlorine gas.

(i) Write a chemical equation, with state symbols, for this reaction.

$2Fe\ (s) + 3Cl_2\ (g) \rightarrow 2FeCl_3\ (s)$

(ii) Explain why the reaction in **(a)(i)** is considered as a redox reaction.

Iron is oxidised to iron(III) chloride while chlorine is reduced to iron(III) chloride at the same time / simultaneously. Oxidation state of iron increases from 0 in Fe to +3 in $FeCl_3$ while oxidation state of chlorine decreases from 0 in Cl to −1 in $FeCl_3$.

(b) State why coating iron with grease prevents iron from rusting.

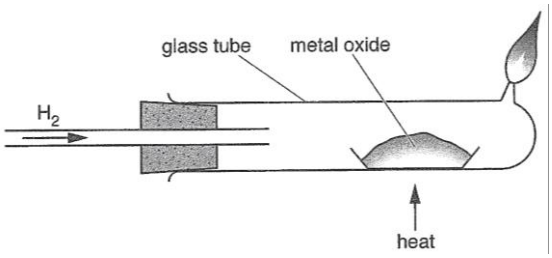
Coating iron with grease acts as a protective barrier which prevents oxygen and water in the air from coming into contact with iron. This prevents iron from reacting with oxygen and water to form rust.

(c) Describe a laboratory investigation that can be used to decide which of two different alloys of iron is more resistant to rusting.

You are provided with the two alloys as very thin metal foils.

Place a fixed length (e.g. 2 cm) of equal width of one alloy into a test tube containing fixed volume (e.g. 5 cm^3) of water and stopper the test tube.
The experiment is duplicated in another test tube with the same length of alloy, and volume of water, this time using the other alloy.
Both setup were left for a few days to allow rusting to occur.
The increase in the mass of the alloy is then measured from both alloys of iron.
The alloy that has the smaller increase in the mass of alloy is more resistant to rusting.

28 Hydrogen is passed over a heated metal oxide in a glass tube. The unreacted hydrogen gas is burned as it leaves the tube.



(a) The experiment uses silver(I) oxide. The reaction forms liquid silver in the hot tube. Write an equation, with state symbols, for this reaction.

Ag_2O (s) + H_2 (g) → 2Ag (*l*) + H_2O (g)

(b) In two separate experiments, hydrogen was passed over heated magnesium oxide and heated copper(II) oxide. Describe the changes, if any, you would expect to see in each experiment.

Explain your reasoning.

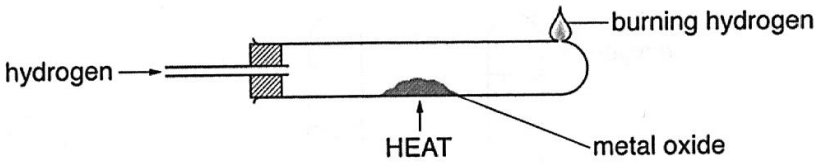
observations

Magnesium oxide remains unchanged (white) while copper(II) oxide changed from black to pink/reddish brown.

reasons

Hydrogen is less reactive than magnesium and hence cannot reduce magnesium oxide to magnesium.
Hydrogen is more reactive than copper and hence can reduce copper(II) oxide to copper.

29 Experiments are set up to investigate the reduction of three metal oxides by hydrogen.



The table shows the appearance of each metal oxide when cold.

experiment	metal oxide	colour when cold
1	calcium oxide	white
2	copper oxide	red
3	lead oxide	yellow

(a) What would you expect to **see** happen in each experiment?

In experiment 1, the metal oxide remained as a white solid.
In experiment 2, the metal oxide changed from a red solid to reddish-brown.
In experiment 3, the metal oxide changed from a yellow solid to silvery-grey/grey.

(b) In which tube would you expect to see the fastest reaction?

In the tube in experiment 2 containing copper oxide

(c) **(i)** Write an equation for the reaction that happens between lead oxide, PbO, and hydrogen.

$PbO + H_2 \rightarrow Pb + H_2O$

(ii) Explain, in terms of oxidation state, why lead is said to be reduced in the reaction.

The oxidation state of lead in PbO decreases from +2 to 0 in Pb. Thus, lead is said to be reduced.

(c) The following table shows the mass change in experiment 2. Use the results to work out the empirical formula of the copper oxide used in experiment 2.

mass of copper oxide at start	0.72 g
mass of copper at end	0.64 g

	Cu	**O**
Mass/g	0.64	0.08
No. of moles	$\frac{0.64}{64} = 0.01$	$\frac{0.08}{16} = 0.005$
Mole ratio	$\frac{0.01}{0.005} = 2$	$\frac{0.005}{0.005} = 1$

Thus the empirical formula is Cu_2O.