All questions are for both separate science and combined science students

Q1.

This question is about Group 1 elements.

(a) Complete Table 1 to show the electronic structure of a potassium atom.

Table 1

Atom	Number of electrons	Electronic structure
Sodium	11	2,8,1
Potassium	19	

(1)

(b) Why do Group 1 elements have similar chemical properties?

Tick (✓) one box.

They have the same number of electron shells.	☐
They have the same number of outer shell electrons.	☐
They have two electrons in the first shell.	☐

(1)

(c) What is the type of bonding in sodium?

Tick (✓) one box.

Covalent	☐
Ionic	☐
Metallic	☐

(1)

Table 2 shows observations made when lithium, potassium and rubidium react with water.

Table 2

Element	Observations

Lithium	Bubbles slowly Floats Moves slowly
Sodium	1 _____ 2 _____
Potassium	Bubbles very quickly Melts into a ball Floats Moves very quickly Flame
Rubidium	Sinks Melts into a ball Explodes with a flame

(d) Give two observations you could make when sodium reacts with water.

Write your answers in Table 2.

(2)

(e) How does the reactivity of the elements change going down Group 1?

_____

_____

(1)

(f) Give two ways in which the observations in Table 2 show the change in reactivity going down Group 1.

1 _____

_____

2 _____

_____

(2)

(g) Which gas is produced when Group 1 elements react with water?

Tick (✓) one box.

Carbon dioxide ☐

Hydrogen ☐

Nitrogen ☐

Oxygen ☐

(1)

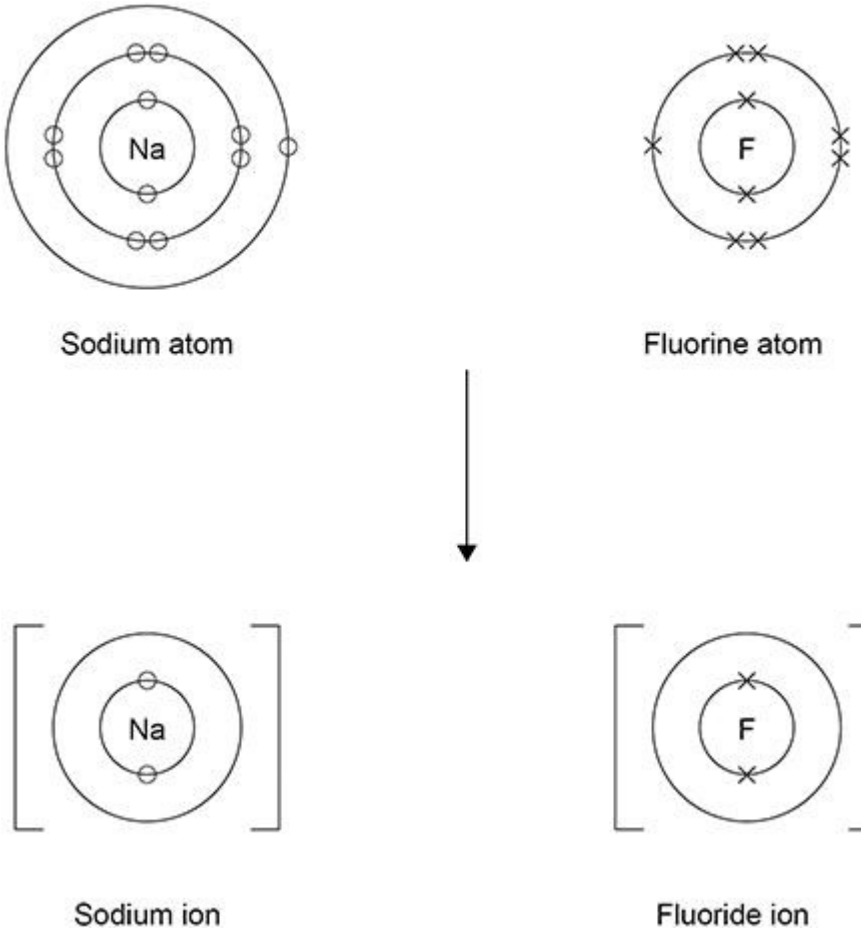
(h) Sodium fluoride is an ionic compound.

The diagram below shows dot and cross diagrams for a sodium atom and a fluorine atom.

Complete the diagram below to show what happens when a sodium atom and a fluorine atom react to produce sodium fluoride.

You should:

- complete the electronic structures of the sodium ion and the fluoride ion
- give the charges on the sodium ion and the fluoride ion.



(3)

(Total 12 marks)

Q2.

A student investigated the reactivity of metals with hydrochloric acid.

This is the method used.

1. Measure 50 cm3 of hydrochloric acid into a polystyrene cup.
2. Measure the temperature of the hydrochloric acid.
3. Add one spatula of metal powder to the hydrochloric acid and stir.
4. Measure the highest temperature the mixture reaches.
5. Calculate the temperature increase for the reaction.
6. Repeat steps 1 to 5 three more times.
7. Repeat steps 1 to 6 with different metals.

The table below shows the student's results.

Metal	Temperature increase in °C				Mean temperature increase in °C
	Trial 1	Trial 2	Trial 3	Trial 4	
Cobalt	6	7	5	9	7
Magnesium	54	50	37	55	X
Zinc	18	16	18	20	18

(a) Calculate the mean temperature increase X for magnesium in the table above.

Do not include the anomalous result in your calculation.

_____

_____

_____

_____

X = _____ °C

(2)

(b) Determine the order of reactivity for the metals cobalt, magnesium and zinc.

Use the table above.

Most reactive _____

_____

Least reactive _____

(1)

(c) The range of measurements either side of the mean shows the uncertainty in the mean temperature increase.

Complete the sentence.

Use the table above.

The mean temperature increase for zinc is 18 ± _____°C

(1)

(d) What type of variable is the volume of hydrochloric acid in this investigation?

Tick (✓) one box.

Control ☐

Dependent ☐

Independent ☐

(1)

(e) Suggest one way of improving step 3 in the method to give results which are more repeatable.

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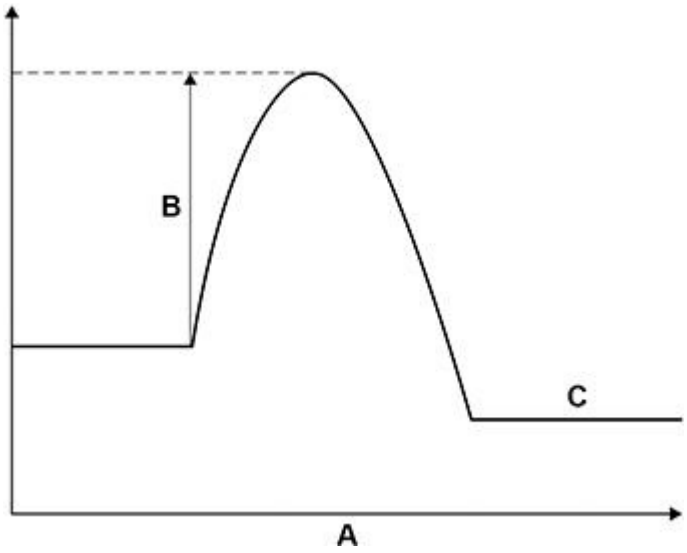
(1)

(f) The figure below shows a reaction profile for the reaction of magnesium with hydrochloric acid.



What do labels A, B and C represent on the figure above?

Choose answers from the box.

activation energy	energy	overall energy change
products	progress of reaction	reactants

A _____

B _____

C _____

(3)

(Total 9 marks)

Q3.

This question is about the extraction of metals.

Element R is extracted from its oxide by reduction with hydrogen.

The equation for the reaction is:

$$3\ H2 + RO3 \rightarrow R + 3\ H2O$$

(a) The sum of the relative formula masses (*Mr*) of the reactants (3 H2 + RO3) is 150

Calculate the relative atomic mass (*Ar*) of R.

Relative atomic masses (*Ar*):H = 1 O = 16

_____

_____

_____

_____

Relative atomic mass (*A*r) of R = _____

(2)

(b) Identify element R.

You should use:

- your answer to part (a)
- the periodic table.

Identity of R = _____

(1)

(c) Carbon is used to extract tin (Sn) from tin oxide (SnO_2).

The equation for the reaction is:

$$SnO_2 + C \rightarrow Sn + CO_2$$

Calculate the percentage atom economy for extracting tin in this reaction.

Relative atomic masses (*A*r): C = 12 O = 16 Sn = 119

_____

_____

_____

_____

_____

_____

Percentage atom economy = _____ %

(3)

(d) Tungsten (W) is a metal.

Tungsten is extracted from tungsten oxide (WO_3).

All other solid products from the extraction method must be separated from the tungsten.

The table below shows information about three possible methods to extract tungsten from tungsten oxide.

Method	Reactant	Relative cost of reactant	Products

1	Carbon	Low	Tungsten solid Carbon dioxide gas Tungsten carbide solid
2	Hydrogen	High	Tungsten solid Water vapour
3	Iron	Low	Tungsten solid Iron oxide solid

Evaluate the three possible methods for extracting tungsten from tungsten oxide.

_____

_____

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(4)

(Total 10 marks)

Q4.

This question is about Group 1 elements.

(a) Give two observations you could make when a small piece of potassium is added to water.

1 _____

_____

2 _____

_____

(2)

(b) Complete the equation for the reaction of potassium with water.

You should balance the equation.

$$K + \quad H_2O \rightarrow \quad +$$

(2)

(c) Explain why the reactivity of elements changes going down Group 1.

_____

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(4)

Sodium reacts with oxygen to produce the ionic compound sodium oxide.

Oxygen is a Group 6 element.

(d) Draw a dot and cross diagram to show what happens when atoms of sodium and oxygen react to produce sodium oxide.

Diagram

(4)

(e) Why is oxygen described as being reduced in the reaction between sodium and oxygen?

_____

_____

(1)

(f) Explain why sodium oxide has a high melting point.

_____

_____

_____

_____

_____

_____

(3)

(Total 16 marks)

Q5.

This question is about metals.

(a) The table below shows information about four substances.

Substance	Melting point in °C	Boiling point in °C	Does it conduct electricity in the solid state?	Does it conduct electricity in the liquid state?
A	–117	79	No	No
B	801	1413	No	Yes
C	1535	2750	Yes	Yes
D	1610	2230	No	No

Which substance could be a metal?

Tick (✓) one box.

A ☐ B ☐ C ☐ D ☐

(1)

(b) Explain why alloys are harder than pure metals.

_____

_____

_____

_____

_____

_____

(3)

(c) A student wants to compare the reactivity of an unknown metal, Q, with that of zinc.

Both metals are more reactive than silver.

The student is provided with:

- silver nitrate solution
- metal Q powder
- zinc powder
- a thermometer
- normal laboratory equipment.

No other chemicals are available.

Describe a method the student could use to compare the reactivity of metal Q with that of zinc.

Your method should give valid results.

_____

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_____

(4)

(Total 8 marks)

Q6.

This question is about metals and the reactivity series.

(a) Which two statements are properties of most transition metals?

Tick (√) two boxes.

They are soft metals. ☐

They form colourless compounds. ☐

They form ions with different charges. ☐

They have high melting points. ☐

They have low densities. ☐

(2)

(b) A student added copper metal to colourless silver nitrate solution.

The student observed:

- pale grey crystals forming
- the solution turning blue.

Explain how these observations show that silver is less reactive than copper.

_____

_____

_____

_____

_____

_____

(3)

(c) A student is given three metals, X, Y and Z to identify.

The metals are magnesium, iron and copper. Plan an investigation to identify the three metals by comparing their reactions with dilute hydrochloric acid.

Your plan should give valid results.

_____

_____

(4)

(d) Metal M has two isotopes.

The table below shows the mass numbers and percentage abundances of the isotopes.

Mass number	Percentage abundance (%)
203	30
205	70

Calculate the relative atomic mass (*A*r) of metal M.

Give your answer to 1 decimal place.

Relative atomic mass (1 decimal place) = _____

(2)

(Total 11 marks)

Q7.

This question is about displacement reactions.

(a) The displacement reaction between aluminium and iron oxide has a high activation energy.

What is meant by 'activation energy'?

_____

_____

(1)

(b) A mixture contains 1.00 kg of aluminium and 3.00 kg of iron oxide.

The equation for the reaction is:

$$2\,Al + Fe_2O_3 \rightarrow 2\,Fe + Al_2O_3$$

Show that aluminium is the limiting reactant.

Relative atomic masses (*Ar*): O = 16 Al = 27 Fe = 56

_____

_____

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_____

(4)

Magnesium displaces zinc from zinc sulfate solution.

(c) Complete the ionic equation for the reaction.

You should include state symbols.

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

(2)

(d) Explain why the reaction between magnesium atoms and zinc ions is both oxidation and reduction.

_____

_____

_____

_____

(2)
(Total 9 marks)

Q8.

This question is about the extraction of metals.

(a) Tungsten is a metal.

The symbol of tungsten is W

Tungsten is produced from tungsten oxide by reaction with hydrogen.

The equation for the reaction is:

$$WO3 + 3\ H2 \rightarrow W + 3\ H2O$$

Calculate the percentage atom economy when tungsten is produced in this reaction.
Use the equation:

$$\text{percentage atom economy} = \frac{184}{(M_r\ WO_3) + (3 \times M_r\ H_2)} \times 100$$

Relative formula masses (*M*r): WO3 = 232 H2 = 2

_____

_____

_____

_____

Percentage atom economy = _____%

(2)

Aluminium is extracted from aluminium oxide.

(b) 38% of a rock sample is aluminium oxide. Calculate the mass of aluminium oxide in 40 kg of the rock sample.

_____

_____

_____

_____

Mass of aluminium oxide = _____ kg

(2)

(c) The formula of aluminium oxide is Al2O3

Calculate the relative formula mass (*Mr*) of aluminium oxide.

Relative atomic masses (*Ar*): O = 16 Al = 27

_____

_____

_____

_____

Relative formula mass (*Mr*) = _____

(2)

(d) 60.0 kg of aluminium oxide produces a maximum of 31.8 kg of aluminium.

In an extraction process only 28.4 kg of aluminium is produced from 60.0 kg of aluminium oxide.
Calculate the percentage yield.

Give your answer to 3 significant figures.

Use the equation:

$$\text{percentage yield} = \frac{\text{mass of product actually made}}{\text{maximum theoretical mass of product}} \times 100$$

_____

_____

_____

_____

_____

_____

_____

Percentage yield = _____%

(3)

(e) Extracting metals by electrolysis is a very expensive process.

Explain why aluminium is extracted using electrolysis and not by reduction with carbon.

_____

_____

_____

_____

(2)

(Total 11 marks)

Q9.

A student investigated the temperature change in displacement reactions between metals and copper sulfate solution.

This is the method used.

1. Measure 50 cm3 of the copper sulfate solution into a polystyrene cup.
2. Record the starting temperature of the copper sulfate solution.
3. Add the metal and stir the solution.
4. Record the highest temperature the mixture reaches.
5. Calculate the temperature increase for the reaction.
6. Repeat steps 1-5 with different metals.

(a) Draw one line from each type of variable to the name of the variable in the investigation.

Type of variable	Name of variable in the investigation
	Concentration of solution
Dependent variable	Particle size of solid
	Temperature change
Independent variable	Type of metal
	Volume of solution

(2)

(b) The student used a polystyrene cup and not a glass beaker.

Why did this make the investigation more accurate?

Tick one box.

Glass is breakable ☐

Glass is transparent ☐

Polystyrene is a better insulator ☐

Polystyrene is less dense ☐

(1)

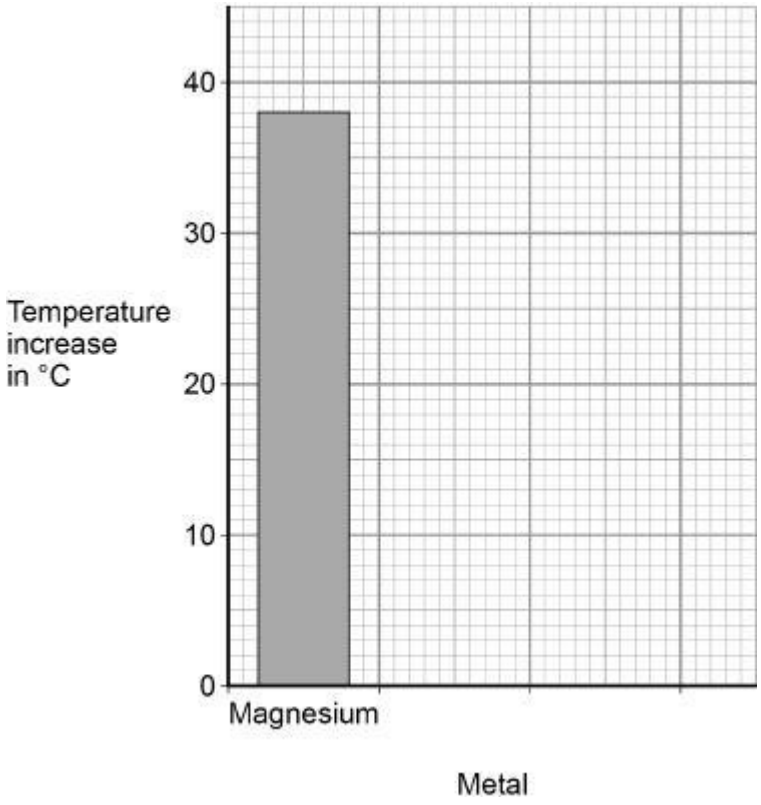
The table below shows the student's results.

Metal	Temperature increase in °C
Magnesium	38
Nickel	8
Zinc	16

(c) Complete Figure 1.

Use data from the table above.

Figure 1



(2)

(d) The student concluded that the reactions between the metals and copper sulfate solution are endothermic.

Give one reason why this conclusion is not correct.

_____

_____

(1)

(e) The temperature increase depends on the reactivity of the metal.

Write the metals magnesium, nickel and zinc in order of reactivity. Use the table above. Most reactive _____ _____ Less reactive _____

(1)

(f) Y is an unknown metal.

Describe a method to find the position of Y in the reactivity series in Question (e)

_____

_____

_____

_____

_____

_____

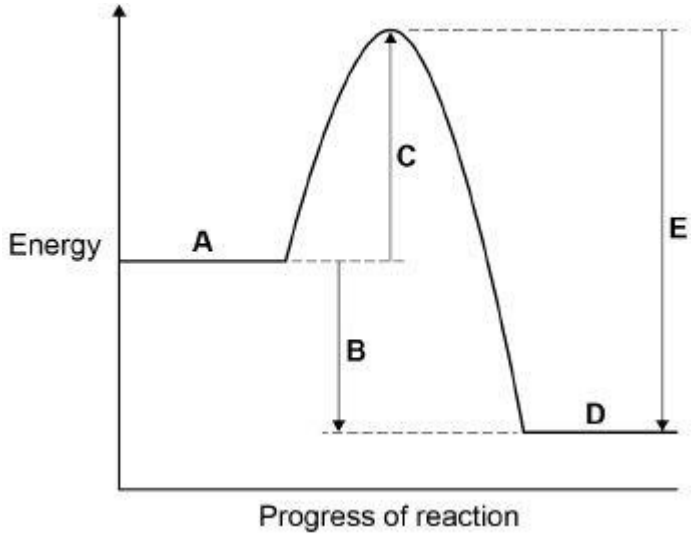
_____

_____

(3)

Figure 2 shows the reaction profile for the reaction between zinc and copper sulfate solution.

Figure 2



(g) Which letter represents the products of the reaction?

Tick one box.

A		B		C		D		E	

(1)

(h) Which letter represents the activation energy?

Tick one box.

A		B		C		D		E	

(1)

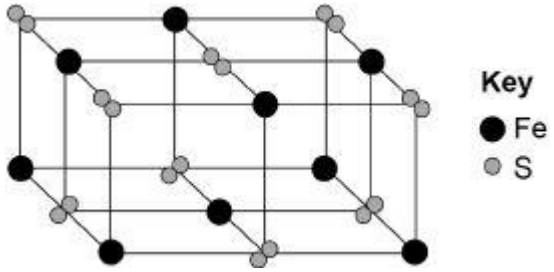
(Total 12 marks)

Q10.

This question is about metals and metal compounds.

(a) Iron pyrites is an ionic compound.

The diagram below shows a structure for iron pyrites.



Determine the formula of iron pyrites.

Use the diagram above.

_____

(1)

(b) An atom of iron is represented as $^{56}_{26}Fe$

Give the number of protons, neutrons and electrons in this atom of iron.

Number of protons _____ Number of neutrons _____ Number of electrons _____

(3)

(c) Iron is a transition metal.

Sodium is a Group 1 metal. Give two differences between the properties of iron and sodium. 1. _____

_____ 2. _____

_____

(2)

Nickel is extracted from nickel oxide by reduction with carbon.

(d) Explain why carbon can be used to extract nickel from nickel oxide.

_____

_____

_____

_____

(2)

(e) An equation for the reaction is:

$$NiO + C \rightarrow Ni + CO$$

Calculate the percentage atom economy for the reaction to produce nickel.

Relative atomic masses (*A*r): C = 12 Ni = 59 Relative formula mass (*M*r): NiO = 75 Give your answer to 3 significant figures.

_____

_____

_____

_____

_____

_____

Percentage atom economy = _____ %

(3)

(Total 11 marks)

Q11.

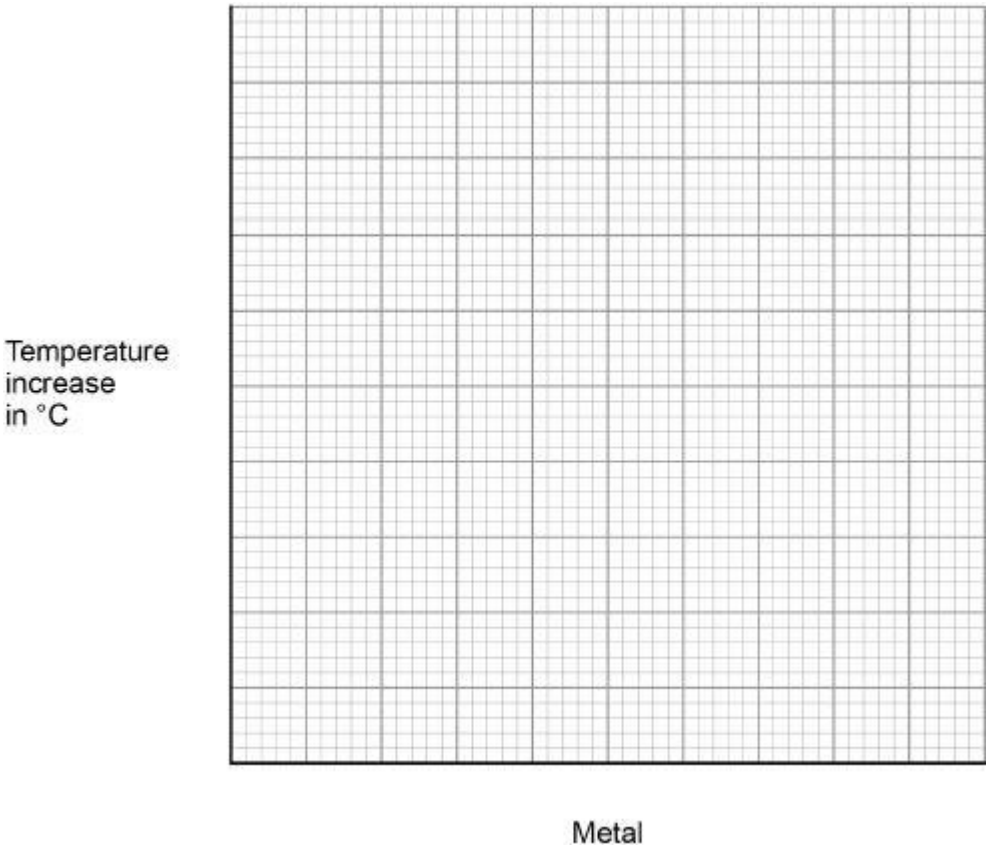
A student investigated the temperature change in displacement reactions between metals and copper sulfate solution.

The table below shows the student's results.

Metal	Temperature increase in °C
Copper	0
Iron	13
Magnesium	43
Zinc	17

(a) Plot the data from the table above on Figure 1 as a bar chart.

Figure 1



(2)

(b) The student concluded that the reactions between the metals and copper sulfate solution are endothermic.

Give one reason why this conclusion is not correct.

_____

_____

(1)

(c) The temperature change depends on the reactivity of the metal.

The student's results are used to place copper, iron, magnesium and zinc in order of their reactivity.

Describe a method to find the position of an unknown metal in this reactivity series.

Your method should give valid results.

_____

_____

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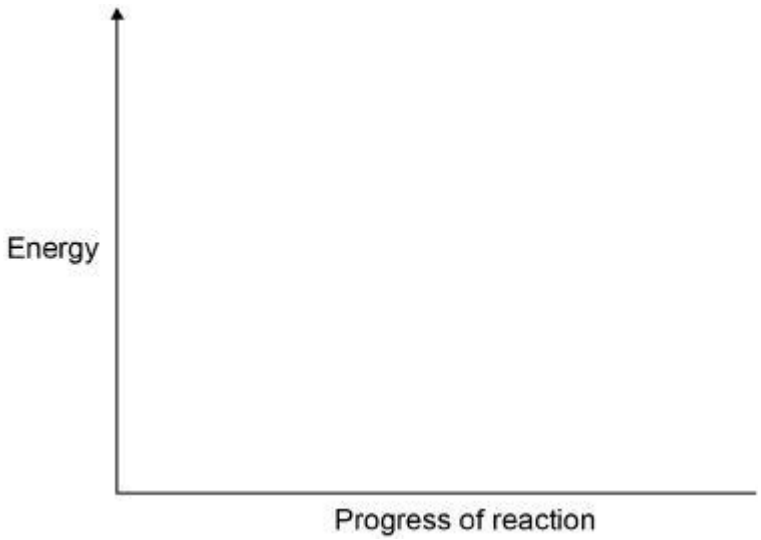
(4)

(d) Draw a fully labelled reaction profile for the reaction between zinc and copper sulfate solution on Figure 2.

Figure 2



(3)

(Total 10 marks)

Q12.

Titanium is a transition metal.

Titanium is extracted from titanium dioxide in a two-stage industrial process.

Stage 1 $TiO_2 + 2\,C + 2\,Cl_2 \rightarrow TiCl_4 + 2\,CO$

Stage 2 $TiCl_4 + 4\,Na \rightarrow Ti + 4\,NaCl$

(a) Suggest one hazard associated with Stage 1.

_____

_____

(1)

(b) Water must be kept away from the reaction in Stage 2.

Give one reason why it would be hazardous if water came into contact with

sodium.

_____

_____

(1)

(c) Suggest why the reaction in Stage 2 is carried out in an atmosphere of argon and not in air.

_____

_____

_____

_____

(2)

(d) Titanium chloride is a liquid at room temperature.

Explain why you would not expect titanium chloride to be a liquid at room temperature.

_____

_____

_____

_____

_____

_____

_____

(3)

In Stage 2, sodium displaces titanium from titanium chloride.

(e) Sodium atoms are oxidised to sodium ions in this reaction. Why is this an oxidation reaction?

_____

_____

(1)

(f) Complete the half equation for the oxidation reaction.

$$Na \rightarrow \_\_\_\_\_ + \_\_\_\_\_$$

(1)

(g) In Stage 2, 40 kg of titanium chloride was added to 20 kg of sodium.

The equation for the reaction is:

$$TiCl4 + 4\ Na \rightarrow Ti + 4\ NaCl$$

Relative atomic masses (*Ar*): Na = 23 Cl = 35.5 Ti = 48 Explain why titanium chloride is the limiting reactant. You must show your working.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(h) For a Stage 2 reaction the percentage yield was 92.3%

The theoretical maximum mass of titanium produced in this batch was 13.5 kg.
Calculate the actual mass of titanium produced.

_____

_____

_____

Mass of titanium = _____ kg

(2)

(Total 15 marks)

Q13.

A student investigated the reactivity of three different metals.

This is the method used.

1. Place 1 g of metal powder in a test tube.
2. Add 10 cm3 of metal sulfate.
3. Wait 1 minute and observe.

4. Repeat using the other metals and metal sulfates.

The student placed a tick in the table below if there was a reaction and a cross if there was no reaction.

	Zinc	Copper	Magnesium
Copper sulfate	✓	x	✓
Magnesium sulfate	x	x	x
Zinc sulfate	x	x	✓

(a) What is the dependent variable in the investigation?

Tick one box.

Time taken ☐

Type of metal ☐

Volume of metal sulfate ☐

Whether there was a reaction or not ☐

(1)

(b) Give one observation the student could make that shows there is a reaction between zinc and copper sulfate.

_____

_____

(1)

(c) The student used measuring instruments to measure some of the variables.

Draw one line from each variable to the measuring instrument used to measure the variable.

Variable	Measuring instrument
	Balance
	Measuring cylinder
Mass of metal powder	

Ruler

Burette

Volume of metal sulfate

Theromometer

Test tube

(2)

(d) Use the results shown in table above to place zinc, copper and magnesium in order of reactivity.

Most reactive _____

_____

Least reactive _____

(1)

(e) Suggest one reason why the student should not use sodium in this investigation.

_____

_____

(1)

(f) Which metal is found in the Earth as the metal itself?

Tick one box.

Calcium ☐

Gold ☐

Lithium ☐

Potassium ☐

(1)

(g) Iron is found in the Earth as iron oxide (Fe2O3).

Iron oxide is reduced to produce iron.

Balance the equation for the reaction.

___Fe_2O_3 + ___C → ___Fe + ___CO_2

(1)

(h) Name the element used to reduce iron oxide.

_____

(1)

(i) What is meant by reduction?

Tick one box.

Gain of iron ☐

Gain of oxide ☐

Loss of iron ☐

Loss of oxygen ☐

(1)

(Total 10 marks)