



GuideMyGrades

— YOUR GOALS. OUR EXPERTISE. —

EDEXCEL GCSE CHEMISTRY: QUESTIONS BY TOPIC

Extracting Metals and Equilibria (4)

GCSE Chemistry (Higher) Topic 4

14 questions · 153 marks · Mark schemes included

Pearson Edexcel GCSE (9-1) Chemistry 1CH0, Higher Tier, June 2018 - June 2025

 [guidemygrades.com](https://www.guidemygrades.com)

 @Guidemygrades

 @Guidemygrades

 @Guidemygrades

 info@guidemygrades.com

 Piccadilly Business Centre, Unit C, Aldow Enterprise Park
Blackett Street, Manchester, M12 6AE

HOW TO USE THIS BOOKLET

Questions run from the lowest mark tariff to the highest, so similar questions sit together.

Click any row below to jump straight to that question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

QUESTION	SOURCE	MARKS	PAGE
1. Q3	Paper 1 June 2018	9	4
2. Q6	Paper 1 June 2022	9	6
3. Q3	Paper 1 June 2023	9	8
4. Q5	Paper 1 June 2024	9	11
5. Q5	Paper 1 June 2023	10	14
6. Q7	Paper 1 June 2018	11	17
7. Q7	Paper 1 November 2020	11	20
8. Q10	Paper 1 November 2020	11	23
9. Q7	Paper 1 November 2021	11	25
10. Q9	Paper 1 June 2018	12	28
11. Q10	Paper 1 June 2022	12	31
12. Q9	Paper 1 June 2022	13	35
13. Q9	Paper 1 June 2024	13	38
14. Q10	Paper 1 June 2024	13	41



QUESTIONS

14 questions · 153 marks · lowest tariff first



9-MARK QUESTIONS

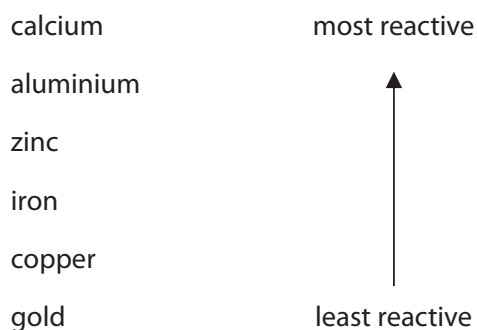
4 questions in this booklet



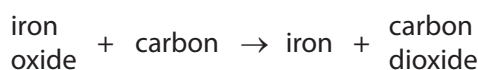
3 Most metals are extracted from ores found in the Earth's crust.

The method used to extract a metal from its ore is linked to the reactivity of the metal.

Part of the reactivity series is shown in Figure 2.

**Figure 2****(a)** Iron ore contains iron oxide.

Iron is extracted from iron oxide by heating the oxide with carbon.

**(i)** In this reaction

- ☐ **A** carbon is reduced
- ☐ **B** iron oxide is neutralised
- ☐ **C** iron oxide is reduced
- ☐ **D** iron is oxidised

(1)**(ii)** The formula of the iron oxide is Fe_2O_3 .

Calculate the maximum mass of iron that can be obtained from 240 tonnes of iron oxide, Fe_2O_3 .

(relative atomic masses: O = 16, Fe = 56)

(3)

.....

.....

.....

.....

.....

.....

mass of iron = ... tonnes



- (b) Aluminium cannot be extracted by heating its oxide with carbon.
Aluminium has to be extracted from its oxide by electrolysis.

Explain why.

(2)

- (c) Predict the method that will have to be used to extract calcium from its ore.

(1)

- (d) In recent years, researchers have been investigating alternative methods of extracting metals from soils.

Researchers have found that growing certain plants in appropriate areas can result in the phytoextraction of copper.

Describe how growing plants can result in the phytoextraction of copper.

(2)

(Total for Question 3 = 9 marks)



- 6 The method used to extract a metal from its ore depends on the position of the metal in the reactivity series.

(a) Aluminium is extracted from its ore by electrolysis.

Explain why this method is used to extract aluminium from its ore.

(2)

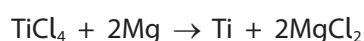
.....

.....

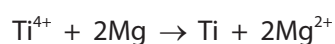
.....

.....

(b) (i) One step in the extraction of titanium metal involves the displacement reaction between titanium chloride, TiCl_4 , and magnesium.



This equation can be simplified as



Explain why this displacement reaction can be described as a redox reaction.

(3)

.....

.....

.....

.....

.....

.....

(ii) The formula of the sulfate ion is SO_4^{2-} .

Which of the following is the formula of titanium sulfate containing the Ti^{4+} ion?

(1)

- ☐ A TiSO_4
- ☐ B Ti_2SO_4
- ☐ C $\text{Ti}(\text{SO}_4)_2$
- ☐ D $\text{Ti}_2\text{S}_2\text{O}_8$

- (c) Phytoextraction is an alternative biological method that can be used to extract metals from very low-grade ores.

Give **one** disadvantage of phytoextraction as a method of extraction of metals.

(1)

- (d) Copper is low down in the reactivity series and can be obtained from copper oxide.

Devise a simple method to obtain a sample of copper from copper oxide in the laboratory.

(2)

(Total for Question 6 = 9 marks)



3 Figure 5 shows part of the reactivity series of metals.

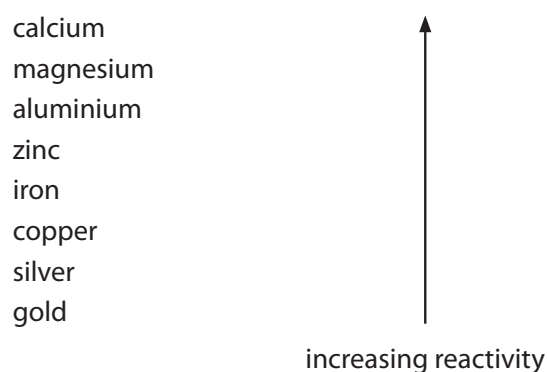


Figure 5

(a) Which metal reacts when added to cold water?

(1)

- ☐ **A** calcium
- ☐ **B** copper
- ☐ **C** gold
- ☐ **D** silver

(b) A student investigates the reactivity of four different metals.

The student adds an equal-sized piece of each metal to separate test tubes containing dilute hydrochloric acid.

The student's observations for zinc and copper are recorded in Figure 6.

metal	observations
magnesium	
zinc	bubbles produced at a steady rate test tube feels slightly warm
iron	
copper	no reaction

Figure 6



- (i) Use the information in Figure 5 and in Figure 6 to predict the observations for the reactions of magnesium and of iron with dilute hydrochloric acid.

(2)

magnesium

.....

.....

iron

.....

.....

- (ii) When metals react with acids, hydrogen gas is produced.

Describe the test to show that the gas is hydrogen.

(2)

.....

.....

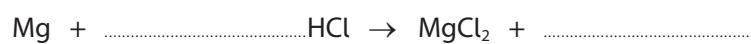
.....

.....

- (iii) When magnesium reacts with hydrochloric acid, magnesium chloride and hydrogen are formed.

Complete the balanced equation for the reaction.

(2)



- (c) An excess of magnesium is added to some dilute hydrochloric acid of pH 2.
The mass of hydrogen gas produced is measured.

The experiment is repeated with excess magnesium but with the same volume of dilute hydrochloric acid of pH 1.

- (i) State how many times greater the concentration of hydrogen ions is in the acid of pH 1 than in the acid of pH 2.

(1)

.....

.....

- (ii) With the acid of pH 2, the mass of hydrogen gas produced when the reaction is complete is 0.005 g.

Predict the mass of hydrogen gas produced in the reaction with acid of pH 1.

(1)

.....

.....

mass = ... g

(Total for Question 3 = 9 marks)



5 This question is about the extraction of metals.

- (a) Give **two** advantages of obtaining metals by recycling rather than by extracting them from their metal ores.

(2)

1

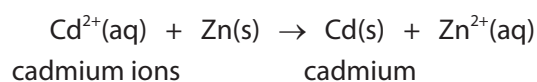
.....

2

.....

- (b) (i) Small amounts of some metals are extracted using displacement reactions.

In one process, zinc dust is used to precipitate cadmium metal from a solution containing cadmium ions.



Explain why this displacement reaction can be described as a **redox reaction**.

(3)

.....

.....

.....

.....

.....

.....

.....

.....



- (ii) The formula of the cadmium ion is Cd^{2+} .
The formula of the phosphate ion is PO_4^{3-} .

Which is the formula of cadmium phosphate?

(1)

- ☐ A $\text{Cd}_2(\text{PO}_4)_3$
- ☐ B $\text{Cd}_3\text{PO}_{12}$
- ☐ C $\text{Cd}_3(\text{PO}_4)_2$
- ☐ D $\text{Cd}_3\text{P}_2\text{O}_8$

- (c) One of the alternative biological methods of extracting metals from very low-grade ores is bioleaching using bacteria.

Give one **disadvantage** of this method of extracting metals from low-grade ores.

(1)

.....

.....

- (d) Lead is low in the reactivity series.

Describe how to obtain a sample of lead from some lead oxide in the laboratory.

(2)

.....

.....

.....

.....

.....

.....

.....

.....

(Total for Question 5 = 9 marks)

10-MARK QUESTIONS

1 question in this booklet



5 (a) Ammonia is manufactured in the Haber process by the reversible reaction between nitrogen and hydrogen.

- (i) Write the balanced equation for the reversible reaction between nitrogen and hydrogen to make ammonia, NH_3 .

(3)

- (ii) Which row shows the typical conditions of temperature and pressure used in the Haber process?

(1)

	temperature in $^{\circ}\text{C}$	pressure in atmospheres
☐ A	250	100
☐ B	250	200
☐ C	450	500
☐ D	450	200

- (iii) In the Haber process, iron is added to the vessel where the nitrogen and hydrogen react.

State the purpose of the iron.

(1)

- (iv) The reaction between nitrogen and hydrogen to make ammonia can reach dynamic equilibrium.

The reaction gives out heat.

Explain how the position of equilibrium changes if the temperature is decreased.

(2)



(b) Compound **A** is a dark brown gas.

Compound **B** is a colourless gas.

Two molecules of **A** combine to form one molecule of **B** in a reversible reaction.

You are given

- a sealed glass tube containing an equilibrium mixture of **A** and **B**
- a beaker
- a kettle
- some ice

At room temperature, the equilibrium mixture is a pale brown colour.

Devise an experiment to show how the position of equilibrium of this reaction is affected by temperature.

The sealed tube must **not** be opened.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

(Total for Question 5 = 10 marks)



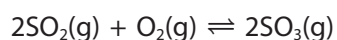
11-MARK QUESTIONS

4 questions in this booklet



7 The industrial production of sulfuric acid involves several steps.

One of these steps is the reaction of sulfur dioxide, SO_2 , with oxygen to form sulfur trioxide, SO_3 .



- (a) What volume of sulfur trioxide, in dm^3 , is produced by the complete reaction of 750 dm^3 of sulfur dioxide?
(all volumes of gases are measured under the same conditions of temperature and pressure)

(1)

- ☐ **A** 375.5
☐ **B** 750
☐ **C** 1125.5
☐ **D** 1500

- (b) Calculate the volume of oxygen needed to react completely with 750 dm^3 of sulfur dioxide.
(all volumes of gases are measured under the same conditions of temperature and pressure)

(1)

.....
.....
.....

volume of oxygen = ... dm^3

- (c) Calculate the mass, in kilograms, of 750 dm^3 of sulfur dioxide, measured at room temperature and pressure.
(relative formula mass: $\text{SO}_2 = 64$;
1 mol of any gas at room temperature and pressure occupies 24 dm^3)

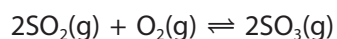
(3)

.....
.....
.....
.....
.....
.....

mass of sulfur dioxide = ... kg



*(d) The reaction to produce sulfur trioxide reaches an equilibrium.



The forward reaction is exothermic.

The rate of attainment of equilibrium and the equilibrium yield of sulfur trioxide are affected by pressure and temperature.

A manufacturer considered two sets of conditions, A and B, for this reaction.

In each case sulfur dioxide is mixed with excess oxygen.

The manufacturer changed the temperature and the pressure and only used a catalyst in B.

The sets of conditions A and B are shown in Figure 7.

set of conditions	pressure in atm	temperature in °C	catalyst
A	2	680	no catalyst used
B	4	425	catalyst used

Figure 7

The manufacturer chooses set of conditions B rather than set of conditions A.

Explain, by considering the effect of changing the conditions on the rate of attainment of equilibrium and on the equilibrium yield of sulfur trioxide, why the manufacturer chooses the set of conditions B rather than the set of conditions A.

(6)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

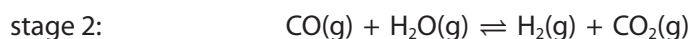
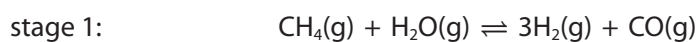


(Total for Question 7 = 11 marks)



- 7 (a) Methane reacts with steam to form hydrogen and carbon dioxide.

The reaction takes place in two stages.



- (i) Stage 1 takes in heat energy, it is endothermic.

Explain the effect of increasing the temperature on the yield of the products of stage 1.

(2)

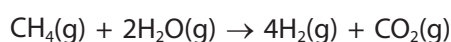
.....

.....

.....

.....

- (ii) The overall equation for the process is



0.40 g of methane were fully reacted with steam to form carbon dioxide and hydrogen.

Calculate the maximum volume of hydrogen in dm^3 , measured at room temperature and pressure, that could be made in this reaction.

(relative formula mass: $\text{CH}_4 = 16$,

1 mol of any gas at room temperature and pressure occupies 24 dm^3)

(3)

.....

.....

.....

.....

.....

.....

maximum volume of hydrogen = ... dm^3



*(b) Hydrogen-oxygen fuel cells can be used to provide electrical energy in a spacecraft.

The reaction that takes place in the fuel cell is

hydrogen + oxygen $\rightarrow$ water

Evaluate the advantages and disadvantages of providing electrical energy in a spacecraft using hydrogen-oxygen fuel cells rather than chemical cells.

(6)

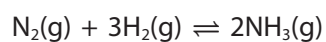
[illegible]

(Total for Question 7 = 11 marks)



10 (a) Ammonia is manufactured by the Haber process.

The equation for the reaction is



The reaction is reversible and can reach equilibrium.

(i) An iron catalyst can be used in the reaction.

Which row of the table shows how adding the iron catalyst affects the rate of attainment of equilibrium and the equilibrium yield of ammonia?

(1)

	rate of attainment of equilibrium	equilibrium yield of ammonia
☐ A	increases	increases
☐ B	decreases	does not change
☐ C	decreases	increases
☐ D	increases	does not change

(ii) Which of the following statements is correct when the reaction reaches equilibrium?

(1)

- ☐ A the reverse reaction starts to take place
- ☐ B the amounts of nitrogen, hydrogen and ammonia are equal
- ☐ C the amounts of nitrogen, hydrogen and ammonia become constant
- ☐ D the reaction stops

(iii) The reaction is carried out at a pressure of 200 atmospheres.

Explain what effect a pressure higher than 200 atmospheres would have on the rate of attainment of equilibrium and on the equilibrium yield of ammonia.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

(b) Ammonium sulfate and ammonium nitrate are used as fertilisers as they both contain nitrogen, which will increase the yield of crops.

(i) Suggest **one** other reason for using solid ammonium sulfate and solid ammonium nitrate as nitrogenous fertilisers.

(1)

.....

.....

(ii) Ammonium nitrate can be made by the reaction of ammonia with nitric acid.

Write the balanced equation for this reaction.

(2)

.....

(iii) Describe **one** similarity and **one** difference between the industrial production of ammonium sulfate and the laboratory preparation of ammonium sulfate.

(2)

similarity.....

.....

difference.....

.....

(Total for Question 10 = 11 marks)



- 7 (a) The order of reactivity of copper, magnesium and zinc can be determined by the displacement reactions between these metals and solutions of their salts.

You are provided with

- samples of the three metals
- solutions of copper sulfate, magnesium sulfate and zinc sulfate.

Describe the experiments that can be done to determine the order of reactivity of these metals by displacement reactions.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

- (b) Metals can be extracted from ores found in the Earth's crust.

Explain why aluminium cannot be extracted from its ore by heating with carbon but can be extracted by electrolysis.

(2)

.....

.....

.....

.....

- (c) Titanium is extracted from its ore in several stages.

In the first stage, titanium chloride is formed as a gas.

The gas is cooled to form liquid titanium chloride containing **dissolved** impurities.

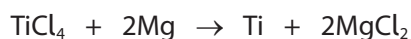
Suggest how pure titanium chloride could be separated from the impurities.

(1)

.....



- (d) In another stage, the pure titanium chloride, TiCl_4 , is reacted with 500 moles of magnesium, an excess.



- (i) Calculate the number of moles in 45 000 grams of titanium chloride.

(relative atomic masses: Cl = 35.5, Ti = 48.0)

(2)

number of moles titanium chloride = ...

- (ii) Show that the 500 moles of magnesium added is an excess.

(1)

- (e) After this reaction, there is a mixture of the solids magnesium, titanium and magnesium chloride.

Titanium does not react with dilute hydrochloric acid.

Suggest a simple method to separate titanium from the mixture.

(2)

(Total for Question 7 = 11 marks)



12-MARK QUESTIONS

2 questions in this booklet



- 9 (a) A student placed a piece of metal **P** in a test tube containing excess dilute sulfuric acid. The student repeated this with three other metals, **Q**, **R** and **S**. All the pieces of all four metals were the same size.

- (i) The student recorded the observations until each metal had reacted with the acid for two minutes.

The observations are shown in Figure 9.

metal	observations
P	bubbles produced very slowly some metal remained
Q	bubbles produced quickly no metal remained
R	bubbles produced slowly no metal remained
S	bubbles produced very quickly no metal remained

Figure 9

Use this information to put the four metals in order of reactivity from the least reactive to the most reactive.

(2)

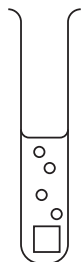
least reactive

--	--	--	--

most reactive

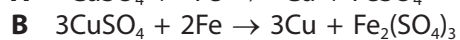
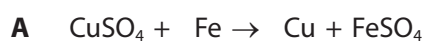
- (ii) Complete the diagram below to show how the student could add to the apparatus to measure the volume of gas produced in the two minutes.

(2)



- (b) When iron reacts with copper sulfate solution, solid copper is formed.

Two possible equations for this reaction are



It was found that 10.00 g of iron powder reacted with excess copper sulfate solution to produce 11.34 g of copper.

Carry out a calculation to decide which equation, **A** or **B**, represents the reaction taking place.

(relative atomic masses: Fe = 56.0, Cu = 63.5)

(2)

.....

.....

.....

.....

- (c) Acid solutions contain hydrogen ions.

Aluminium reacts with dilute hydrochloric acid to form a solution containing aluminium ions, Al^{3+} .

Complete the balanced ionic equation for this reaction.

(2)



- (d) The hydrogen ion concentration in a solution is decreased by a factor of 10.

State how the pH of this solution changes.

(1)

- (e) Calculate the mass, in g, of a hydrogen atom, using the data below.

(relative atomic mass: $\text{H} = 1.00$;

Avogadro constant = 6.02×10^{23})

(3)

.....

.....

.....

.....

.....

.....

.....

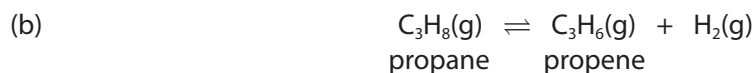
mass of hydrogen atom = ...g

(Total for Question 9 = 12 marks)



Handwriting practice area with 25 horizontal dotted lines.





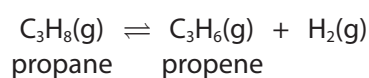
State the maximum volume of propene, in dm^3 , formed by the dehydrogenation of 300 dm^3 of propane.

(assume all volumes of gases are measured under the same conditions of temperature and pressure)

(1)

maximum volume of propene = ... dm^3

- (c) 900 dm^3 of propane, measured at room temperature and pressure, were dehydrogenated to form propene.



Calculate the maximum mass, in kg, of hydrogen formed in this reaction.

(relative atomic mass: $\text{H} = 1.0$;

1 mol of any gas at room temperature and pressure occupies 24 dm^3)

(4)

mass of hydrogen = ... kg

(Total for Question 10 = 12 marks)



13-MARK QUESTIONS

3 questions in this booklet



- 9 (a) A student carried out an investigation to determine the order of reactivity of four metals, **W**, **X**, **Y** and **Z**.

A piece of metal **W** was added to a test tube containing excess dilute hydrochloric acid.

This was repeated with the other three metals, **X**, **Y** and **Z**.

In each case, the size of each piece of metal was the same.

The student recorded observations on each reaction for three minutes.

The observations obtained are shown in Figure 8.

metal	observations with dilute hydrochloric acid
W	Bubbles formed quickly with some metal remaining after three minutes.
X	A few bubbles were seen to form. The metal looked unchanged after three minutes.
Y	Bubbles formed quickly. After three minutes all the metal had reacted.
Z	Bubbles formed very quickly with no metal remaining after three minutes.

Figure 8

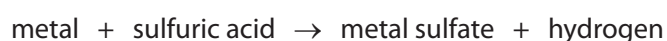
- (i) Use the information in Figure 8 to place the metals in order of reactivity from the least reactive to the most reactive.

(2)

least reactive $\longrightarrow$ most reactive

--	--	--	--

- (ii) The experiment was repeated using an excess of dilute sulfuric acid in place of the dilute hydrochloric acid.



When metal **Y** reacts with dilute sulfuric acid, bubbles form quickly at first and then the reaction stops.

Most of the solid metal remains.

Explain why the reaction between metal **Y** and excess dilute sulfuric acid stopped even though there was solid metal **Y** left.

(2)

.....

.....

.....

.....



- (iii) The reactions between metals and dilute ethanoic acid are slower than reactions between metals and dilute hydrochloric acid.
This is because ethanoic acid is a weak acid.

Explain the meaning of the term **weak acid**.

(2)

- (b) The formula of aluminium sulfate is $\text{Al}_2(\text{SO}_4)_3$.

Calculate the total number of atoms that combine to form 5.13 g of aluminium sulfate.

(relative atomic masses: O = 16.0, Al = 27.0, S = 32.0

Avogadro number = 6.02×10^{23})

(4)

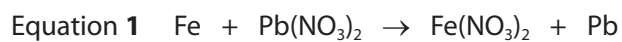
number of atoms = ...



(c) Iron is more reactive than lead.

Iron reacts with lead nitrate solution to form solid lead.

Two possible balanced equations for the reaction are



In one experiment, it was found that 4.48 g of iron reacted with excess lead nitrate solution to form 24.84 g of lead.

Carry out a calculation, using the information above, to show which equation represents the reaction taking place.

(relative atomic masses: Fe = 56.0, Pb = 207)

(3)

.....

.....

.....

.....

(Total for Question 9 = 13 marks)



9 (a) An investigation was carried out on the reactivity of four metals, **D**, **E**, **F** and **G**.

Equal sized pieces of these metals were placed in excess dilute hydrochloric acid and left for three minutes.

Figure 9 shows the observations of the reactions for metals **D**, **E** and **F**.

metal	observations with dilute hydrochloric acid
D	Bubbles formed quickly. After three minutes all the metal had reacted.
E	Bubbles formed very quickly. No metal remaining after three minutes.
F	A few bubbles were seen to form. The metal looked unchanged after three minutes.
G	

Figure 9

The order of reactivity for these metals is shown in Figure 10.

E	D	G	F
most reactive		least reactive	

Figure 10

(i) Use the information in Figure 9 and Figure 10 to suggest the observations that would be made for metal **G**.

(2)

(ii) The dilute hydrochloric acid used in this reaction is a strong acid.

Explain the meaning of the terms **dilute** and **strong acid**.

(4)

dilute

strong acid

(b) The formula of lead ethanoate is $\text{Pb}(\text{CH}_3\text{COO})_2$.

Calculate the number of **atoms** that combine together to form 16.25 g of lead ethanoate.

(relative atomic masses: H = 1.00, C = 12.0, O = 16.0, Pb = 207

Avogadro number = 6.02×10^{23})

(4)

number of atoms = ...



(c) Iron is more reactive than copper.

Iron will displace copper from copper nitrate solution.

Two possible balanced equations for the reaction are



It was found that 2.24 g of iron reacted with excess copper nitrate solution to form 3.81 g of copper.

Carry out a calculation, using the information above, to show which equation represents the reaction taking place.

(relative atomic masses: Fe = 56.0, Cu = 63.5)

(3)

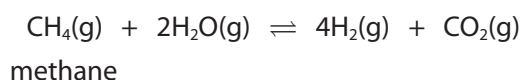
(Total for Question 9 = 13 marks)



10 Hydrogen can be produced by the reaction of methane with steam.

- (a) Methane reacts with steam in the presence of a nickel catalyst to produce hydrogen and a dynamic equilibrium is reached.

The equation for this equilibrium reaction is



The forward reaction takes in heat energy and is endothermic.

- (i) Describe the effect of the catalyst on the rate of attainment of equilibrium and on the equilibrium yield of products.

(2)

.....

.....

.....

.....

- *(ii) A manufacturer produces hydrogen by the reaction of methane with steam in the presence of a nickel catalyst using the conditions

temperature 600 °C

pressure 20 atmospheres

Explain what effect there would be on the rate of attainment of equilibrium and the equilibrium yield of hydrogen if the manufacturer were to use a higher temperature of 1000 °C at a lower pressure of 10 atmospheres without changing the catalyst.

(6)

.....

.....

.....

.....

.....

.....

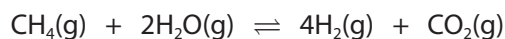
.....

.....





(b) Using the equation for the reaction



calculate the maximum volume of products, in dm^3 , that could be formed by the complete reaction of 650 dm^3 of methane.

(assume all volumes of gases are measured under the same conditions of temperature and pressure)

(2)

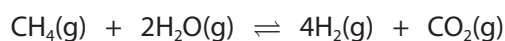
.....

.....

.....

maximum volume of products = ... dm^3

(c) Using the same equation for the reaction



calculate the maximum mass, in g, of carbon dioxide for every 1800 dm^3 of hydrogen, measured at room temperature and pressure, produced in this reaction.

(relative formula mass: $\text{CO}_2 = 44$;

1 mol of any gas at room temperature and pressure occupies 24 dm^3)

(3)

.....

.....

.....

.....

.....

.....

.....

mass of carbon dioxide = ... g

(Total for Question 10 = 13 marks)



MARK SCHEMES

official Pearson Edexcel mark schemes



Question Number	Answer	Mark
3(a)(i)	C iron oxide is reduced The only correct answer is C <i>A is not correct because carbon gains oxygen</i> <i>B is not correct because it is not an acid-base reaction</i> <i>D is not correct because iron oxide loses oxygen</i>	(1) AO 1 1

Question Number	Answer	Additional guidance	Mark
3(a)(ii)	final answer of 168 (tonnes) with or without working (3) OR relative formula mass $\text{Fe}_2\text{O}_3 = 2 \times 56 + 3 \times 16 (= 160)$ (1) 160 tonnes Fe_2O_3 produces $\{2 \times 56 / 112\}$ tonnes Fe (1) 240 tonnes Fe_2O_3 produces $\frac{2 \times 56}{160} \times 240$ (1) = 168 (tonnes) OR relative formula mass $\text{Fe}_2\text{O}_3 = 2 \times 56 + 3 \times 16 (= 160)$ (1) $\frac{240}{160}$ (1) = 1.5 1.5×112 (1) = 168 (tonnes) OR relative formula mass $\text{Fe}_2\text{O}_3 = 2 \times 56 + 3 \times 16 (= 160)$ (1) $\frac{112}{160}$ (1) = 0.7 0.7×240 (1) = 168 (tonnes)	allow ECF throughout $M_r [\text{Fe}_2\text{O}_3] = 160$ seen without working (1) allow 320 tonnes : 224 tonnes (1) final answer 84 (tonnes) with or without working (2) Note : final answer 1.5 scores 2 overall	(3) AO 2 1

Question Number	Answer	Additional guidance	Mark
3(b)	An explanation linking the following points - aluminium is high in reactivity / aluminium oxide is (very) stable (1) - aluminium (oxide) cannot be reduced by carbon (1)	allow carbon is less reactive than aluminium / ORA / aluminium is very reactive ignore 'aluminium is more reactive' (alone) allow carbon cannot displace aluminium / aluminium oxide does not react with carbon ignore aluminium extracted by electrolysis	(2) AO 1 1

Question Number	Answer	Mark
3(c)	electrolysis	(1) AO 3 2a

Question Number	Answer	Additional guidance	Mark
3(d)	A description to include - plants absorb {copper/metal} (ions) from the {soil/ores} / plants concentrate copper ions (1) - plants (harvested and) burned (to leave copper/metal compound) (1)	ignore plants absorb copper from solid metal ignore copper {atoms/metal/compounds} ignore plants heated mark independently	(2) AO 1 1

Total for question 3 = 9 marks

Question number	Answer	Additional guidance	Mark
6(a)	An explanation linking - aluminium is (very) high in the reactivity series / very reactive (1) - needs a lot of energy (to remove oxygen from the oxide) (1)	allow aluminium more reactive than carbon allow cannot be {extracted by heating with / extracted by / reduced by} carbon allow cannot be displaced by carbon	(2) AO1-1

Question number	Answer	Additional guidance	Mark
6(b)(i)	An explanation linking (redox involves both) reduction and oxidation (1) - magnesium (atoms) loses electrons (and are oxidised) (1) - titanium ions accept electrons (and are reduced) (1)	ignore references to loss and gain of oxygen allow $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^{(-)}$ allow $\text{Ti}^{4+} + 4\text{e}^{(-)} \rightarrow \text{Ti}$ If no other mark awarded, then allow description of what happens to both reactant particles without mention of electrons (1) OR allow titanium gains electrons and magnesium loses electrons (1)	(3) AO1-1

Question number	Answer	Mark
6(b)(ii)	C $\text{Ti}(\text{SO}_4)_2$ is the only correct answer A, B and D are incorrect formulae	(1) AO1-1



Question number	Answer	Additional guidance	Mark
6(c)	slow process / large area of land required / only extracts metal from the ground surface / metals need further extraction	ignore expensive / cost implications ignore { carbon dioxide / greenhouse gases } evolved ignore references to bioleaching allow {harmful / toxic} gas released on burning plants allow specific environmental effect	(1) AO1-1

Question number	Answer	Additional guidance	Mark
6(d)	A method to include • mix copper oxide with {carbon / powdered charcoal} (in a suitable container) (1) • heat (with carbon) (strongly until no further change) (1) OR • react copper oxide with dilute {sulfuric / hydrochloric} acid (1) • electrolyse the solution formed (1) OR • pass hydrogen (or methane) (1) • over heated copper oxide (1)	In each the 2nd MP depends on the 1st reject burn / combust allow {react/displace} with carbon (alone) (1) allow heat with more reactive metal (1) suitable method to isolate copper from other oxide (1)	(2) AO3-3a

Total for Question 06 = 9 marks



Question number	Answer	Mark
3(a)	A calcium is the only correct answer B , C and D are incorrect because copper, silver and gold do not react with cold water	AO1 1 (1)

Question number	Answer	Additional guidance	Mark
3(b)(i)	MAGNESIUM many bubbles / bubbles produced quickly / bubbles vigorously OR test tube feels hot / warm / warmer than with zinc (1) IRON few bubbles / bubbles produced slowly / some bubbles OR test tube feels <u>very</u> slightly warm (1)	Mark answer lines first, if blank or only contain statements that can be ignored, then look at the table. Ignore hydrogen / gas / reactivity of metal reject incorrect additional observations for each metal allow 'magnesium disappears/ dissolves' ignore steady bubbling / slightly warm ignore steady bubbling / no bubbling allow does not feel warm ignore test tube feels slightly warm	AO3 2 (2)

Question number	Answer	Additional guidance	Mark
3(b)(ii)	a description to include the following points • apply lighted splint (to the gas) (1) • (squeaky) pop (1)	allow apply flame / ignite ignore 'squeaky pop test' reject glowing splint MP2 depends on MP1	AO1 2 (2)



Question number	Answer	Additional guidance	Mark
3(b)(iii)	$\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$ H_2 (1) 2 (1)	reject H2, H ² , 2H, 2h, h ₂ , h ²	A02 1 (2)

Question number	Answer	Mark
3(c)(i)	ten (times) / 10 (x) / (x) 10	A01 1 (1)

Question number	Answer	Additional guidance	Mark
3(c)(ii)	0.05 (g) OR 0.005 x factor from (c)(i)	0.05 scores whether (c)(i) correct or not. if answer not 0.05, only then apply ecf and no working is required e.g x2 AND 0.01 (1); x100 AND 0.5 (1)	A03 1 (1)



Question number	Answer	Additional guidance	Mark
5(a)	Any two advantages of recycling metals • preserves ore reserves/ ores are finite (1) • prevents waste of the metal (1) • uses less energy (1) • less fossil fuels burned (1) • less {carbon dioxide/ greenhouse gases} emitted (1) • less waste material formed (1) • mining causes {loss of habitat/ noise/ dust} • doesn't fill up landfill (1)	allow uses less electricity ignore less land used for mining/ visual pollution ignore cost arguments ignore vague statements about 'environment' or 'pollution' or 'sustainable'	(2) AO1-1



Question number	Answer	Additional guidance	Mark
5(b)(i)	An explanation linking - reduction and oxidation occurring (1) {Zinc (atoms)/ Zn} lose electrons and are oxidised (1) {Cadmium ions/ Cd²⁺} gain electrons and are reduced (1)	ignore numbers of electrons correct or otherwise MP1 scores even if wrong (or no) species identified reject zinc ions reject cadmium (atoms) gains electrons allow half-equations for gain/loss of electrons part of answer For MP2 and MP3 if both marks not scored: {Zinc (atoms)/ Zn} lose electrons and {Cadmium ions/ Cd²⁺} gain electrons (1) OR {Zinc (atoms)/ Zn} are oxidised and {Cadmium ions/ Cd²⁺} are reduced (1)	(3) AO1-1
Question number	Answer		Mark
5(b)(ii)	C Cd₃(PO₄)₂ is the only correct answer A, B and D are incorrect formulae of cadmium phosphate		(1) AO1-1



Question number	Answer	Additional guidance	Mark
5(c)	very slow / low yield / {toxic substances / acids / sulfuric acid} can be produced / (leachate) needs further processing	allow time consuming allow inefficient ignore vague statements such as 'damages the environment' or 'causes pollution' or 'produces harmful substances' ignore cost	(1) AO1-1

Question number	Answer	Additional guidance	Mark
5(d)	A plan to include a suitable method • add {carbon / hydrogen / methane} (1) • and heat (1) OR • electrolyse (1) • solution formed <u>with acid</u> (1)	MP2 depends on MP1 allow ' <u>more</u> reactive {metal / element} ' or sensible named metal e.g. zinc but not sodium allow any named acid allow {liquid / molten} lead oxide / after melting (1)	(2) AO3-3a

Total for question 05 = 9 marks



Question number	Answer	Additional guidance	Mark
5(a)(i)	$\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$ (3)	MP1: three formulae and no others on correct sides of an equation. allow incorrect cases and subscripts e.g. n^2 (1) MP2 depends on MP1: balancing these correct formulae, allow multiples (1) MP3: stand alone mark: equilibrium symbol, allow $\rightleftharpoons$, $\rightleftharpoons$ (1) allow equation written in reverse	AO2 1 (3)

Question number	Answer	Mark
5(a)(ii)	D 450 200 is the only correct answer A, B and C are incorrect because the temperature is 450°C and the pressure is 200 atm.	AO1 1 (1)

Question number	Answer	Additional guidance	Mark
5(a)(iii)	catalyst/ increase rate of reaction(s)/ lower activation energy/ increase rate of attainment of equilibrium	ignore provide an alternative route for the reaction	AO1 1 (1)

Question number	Answer	Additional guidance	Mark
5(a)(iv)	An explanation including any two from: <u>moves in</u> exothermic direction (1) - moves {right/ forwards / towards ammonia/ to products} (1) - to oppose the temperature reduction / to release heat / to increase the temperature (1)	MP1/ MP2/ MP3 are marked independently reject contradictions within MP2 or within MP3 allow to increase yield ignore just 'to oppose the (temperature) change' allow to increase heat	AO1 1 (2)



Question number	Answer	Additional guidance	Mark
5(b)	A description including METHOD OF HEATING AND COOLING - put tube into hot water (1) - then into cold water/ add cold water/ add ice (1) OBSERVATIONS - colour goes darker AND colour goes lighter/ colourless	steps 1 and 2 can be reversed, but must be practical e.g. ignore 'heat tube up' allow water from kettle reject placing tube in kettle/ heating with steam MP3 is for <u>observation</u> but depends on tube being heated and cooled (even if MP1 and/or MP2 not scored) allow colour changes in <u>both</u> hot and cold ignore clear allow suitable diagram(s) ignore opening of tube ignore attempts at explanation	A03 3a (3)

Question Number	Answer	Mark
7(a)	B 750 The only correct answer is B <i>A is not correct because 375.5 dm^3 is half the actual volume formed</i> <i>C is not correct because 1125.5 dm^3 is one and a half times the actual volume formed</i> <i>D is not correct because 1500 dm^3 is double the actual volume formed</i>	(1) AO 2 1

Question Number	Answer	Additional guidance	Mark
7(b)	$\frac{1}{2} \times 750 \text{ (1)} = 375 \text{ (dm}^3\text{)}$	375 alone (1)	(1) AO 2 1

Question Number	Answer	Additional guidance	Mark
7(c)	final answer of 2 (kg) with or without working (3) OR moles of $\text{SO}_2 = \frac{750}{31.25} \text{ (1)} (= 24)$ mass of $\text{SO}_2 = \frac{750}{24} \times 64 \text{ (1)}$ $(= 2000)$ mass of $\text{SO}_2 = \frac{2000}{1000} \text{ (1)}$ $(= 2 \text{ (kg)})$	allow ECF throughout $31.25 \times 64 \text{ (2)}$ allow ECF allow any calculated mass / 1000 (1) final answer 2000 (kg) (2)	(3) AO 2 1

Question Number	Indicative content	Mark
7(d)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlines in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. • equilibrium reached faster because of higher temperature in set A / equilibrium reached slower because of lower temperature in set B • higher temperature means more frequent collisions because molecules have more energy / ORA for lower temperature in set B • decrease in temperature increases equilibrium yield but system takes longer to reach equilibrium • temperature chosen for optimum conditions • yield lower as forward reaction is exothermic • high temperature favours back reaction which is endothermic • equilibrium reached faster because of higher pressure in set B / equilibrium reached slower because of lower pressure in set A • higher pressure causes molecules to be closer together so more frequent collisions / ORA for lower pressure in set A • yield higher because products occupy smaller volume than reactants for set B • catalyst in set B causes equilibrium to be reached faster • catalyst increases rate of both forward and back reactions • equilibrium position not affected so catalyst does not affect yield • catalyst reduces the need for the higher temperature	(6) AO 2 1 AO 3 1a AO 3 1b
Level	Mark	Descriptor
	0	No rewardable material.
Level 1	1–2	• Interpretation and evaluation of the information attempted but will be limited with a focus on mainly just one variable. Demonstrates limited synthesis of understanding. (AO3) • The explanation attempts to link and apply knowledge and understanding of scientific ideas, flawed or simplistic connections made between elements in the context of the question. (AO2)
Level 2	3–4	• Interpretation and evaluation of the information on both variables, synthesising mostly relevant understanding. (AO3) • The explanation is mostly supported through linkage and application of knowledge and understanding of scientific ideas, some logical connections made between elements in the context of the question. (AO2)
Level 3	5–6	• Interpretation and evaluation of the information, demonstrating throughout the skills of synthesising relevant understanding. (AO3) • The explanation is supported throughout by linkage and application of knowledge and understanding of scientific ideas, logical connections made between elements in the context of the question. (AO2)

Total for question 7 = 11 marks



Question number	Answer	Additional guidance	Mark
7(a)(i)	an explanation linking • shift equilibrium to right / in forward direction (1) • increase yield of {product / hydrogen / carbon monoxide} (1)	allow favours forward/endothermic reaction ignore references to decreasing amounts of reactants. marks are independent	(2)

Question number	Answer	Additional guidance	Mark
7(a)(ii)	final answer of 2.4 with or without working (3) OR $\frac{0.4}{16} = 0.025$ (1) $0.025 \times 4 = 0.1$ (1) $0.1 \times 24 = 2.4$ (1)		(3)

Question number	Indicative content	Mark
*7(b)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material that is indicated as relevant. Additional content included in the response must be scientific and relevant. A01 and A02 (6 marks) advantages • once set up, fuel cells require no maintenance • chemical cells will need to be replaced / chemical cells have a limited lifetime • fuel cells operate as long as reactants are supplied • voltage drops in chemical cells as reactants are used up • once used chemical cells cannot be used again or need re-charging • used chemical cells take up valuable space on spacecraft • new chemical cells need to be transported to spacecraft • used chemical cells need to be transported back to earth • water produced in the fuel cell is the only product • water can be used on the spacecraft as drinking water disadvantages • hydrogen and oxygen must be supplied • gas tanks need to be transported by spacecraft • storage of hydrogen is difficult because it is a gas • hydrogen is flammable • fuel cells are expensive to manufacture conclusion • either cell can be chosen as the preferable one but suitable reasons must be given	(6)



Level	Mark	Additional Guidance	General additional guidance Eg - At each level, as well as content, the scientific coherency of what is stated backed up by planning detail will help place the answer at the top, or the bottom, of that level.
	0	No rewardable material.	
Level 1	1–2	<u>Additional guidance</u> Describes an advantage or disadvantage or states two advantages and/or disadvantages	<u>Possible candidate responses</u> - hydrogen is flammable (1) - new chemical cells need to be brought to the spacecraft (1) - water is the (only) product and can be used by astronauts as drinking water (2) - storage of hydrogen is difficult as hydrogen is a gas (2)
Level 2	3–4	<u>Additional guidance</u> Describes two advantages and/or disadvantages	<u>Possible candidate responses</u> - fuel cells are expensive to manufacture and are difficult to repair if they stop working, but fuels cells will continue to work whilst hydrogen and oxygen are supplied (3) - voltage of chemical cells drops as they are used so the energy produced decreases over time. Fuel cells produce water which can be used on the space craft (4)
Level 3	5–6	<u>Additional guidance</u> Describes three advantages and/or disadvantages and Evaluates the advantages and disadvantages to form a conclusion	<u>Possible candidate responses</u> fuel cells are better than chemical cells. This is because water is the only product from the reaction of hydrogen and water. This water can be used on the space craft as drinking water. Chemical cells will become obsolete when reactants have been used up, therefore more chemical cells will be needed and the waste cells will take up valuable space on the space craft (6)



Question number	Answer	Mark
10(a)(i)	D increases does not change A, B, C are incorrect because catalysts increase rate of attainment of equilibrium and do not change equilibrium yield	(1)

Question number	Answer	Mark
10(a)(ii)	C the amounts of nitrogen, hydrogen and ammonia become constant A, B, D are incorrect because when the reaction reaches equilibrium the amount of nitrogen, hydrogen and ammonia remain constant	(1)

Question number	Answer	Additional guidance	Mark
10(a)(iii)	an explanation linking • equilibrium attained in a shorter period of time / rate of attainment of equilibrium {faster/ increases} (1) • equilibrium yield increases (1) • equilibrium shifts to the {right / forward / to products side} (1) • decrease in number of molecules (1)	allow moves to fewer molecules	(4)

Question number	Answer	Additional guidance	Mark
10(b)(i)	both are {soluble/will dissolve} (in water)		(1)

Question number	Answer	Additional guidance	Mark
10(b)(ii)	$\text{NH}_3 + \text{HNO}_3 \rightarrow \text{NH}_4\text{NO}_3$ LHS (1) RHS (1)	allow multiples	(2)

Question number	Answer		Mark
10(b)(iii)	a similarity from : both use sulfuric acid (1) both (are examples of) neutralisation (1) and a difference from : the industrial process is on a much larger scale than the laboratory process / ORA (1) the industrial process involves more stages than the laboratory process / ORA (1) ammonia is a gas in the industrial process but a solution in the laboratory process (1) laboratory preparation uses titration and crystallisation (1)	ignore both produce ammonium sulfate allow both use same reactants allow both give out heat energy / exothermic (1) allow laboratory preparation is a batch process, industrial preparation is continuous process (1) ignore industrial is more dangerous	(2)

Question number	Answer	Additional guidance	Mark
7(a)	A description to include - place separate pieces of each metal into solutions of each of salt (in spotting tray/container) (1) - observe changes in appearance/colour of {metal/solution} (1) - the more reactive metal shows the greater number of reactions (1)	two reactions of different metals in different metal sulfate solutions plus conclusion about reactivity (2) Allow 1 mark for one correctly described reaction between a metal and a different metal sulfate solution	(3) AO2

Question number	Answer	Additional guidance	Mark
7(b)	An explanation linking any two from - aluminium is more reactive than carbon (so electrolysis required) (1) - carbon cannot remove the oxygen / there is no reaction between carbon and aluminium oxide / carbon cannot displace aluminium (1) - electrolysis can be used to reduce aluminium ions (1)	allow electrolysis is a more powerful method of reduction (1)	(2) AO1

Question number	Answer	Additional guidance	Mark
7(c)	(simple) distillation	allow fractional distillation	(1) AO2



Question number	Answer	Additional guidance	Mark
7(d)(i)	$M_r \text{ TiCl}_4 = 48.0 + (4 \times 35.5) \text{ (1) (= 190)}$ moles of $\text{TiCl}_4 = 45\,000/190 = 236.8 \text{ (1)}$	ecf allow two or more sig figs	(2) AO2

Question number	Answer	Additional guidance	Mark
7(d)(ii)	(minimum) moles of Mg needed = $236.8 \times 2 = 473.6 \text{ (1)}$ 500 moles of Mg added > minimum 473.6 moles required	allow ecf from 7d(i) for moles of TiCl_4	(1) AO2

Question number	Answer	Additional guidance	Mark
7(e)	A description to include either • add dilute hydrochloric acid (to solid mixture sample to react with the magnesium to form magnesium chloride solution) (1) • filter the mixture (to remove titanium) / filter off the titanium (1) or • filter the mixture (to remove titanium) / filter off the titanium (1) • wash the titanium (1)		(2) AO3

(Total for question 7 = 11 marks)



Question Number	Answer	Additional guidance	Mark
9(a)(i)	P R Q S (2)	two in correct order (1)	(2) AO 3 2a AO 3 2b

Question Number	Answer		Mark
9(a)(ii)	A workable diagram showing a method to measure the volume of the gas - delivery tube between test-tube and (1) - gas syringe / (graduated tube / inverted burette / measuring cylinder) over water bath (1)	if diagram is not workable (eg no bung at top of test tube), max 1 mark allow connection shown as  if collection vessel not labelled, graduations must be shown for the second mark	(2) AO 3 3a AO 3 3b

Question Number	Answer	Additional guidance	Mark
9(b)	iron $\frac{10.00}{0.2} = 0.179$ / 0.18 / 0.2 and copper $\frac{11.34}{0.2} = 0.179$ / 0.18 / 0.2 (1) 63.5 (ratio 1:1) so reaction A (1)	allow max 1 mark for Fe : $\frac{56}{10.00} = 5.6$ Cu : $\frac{63.5}{11.34} = 5.6$ so reaction A other methods of calculation include 10.00 g Fe forms $\frac{10.00}{56} \times 63.5$ (1) g copper $\frac{56}{11.34} = 5.6$ copper so reaction A (1) second mark dependent on first	(2) AO 3 2a AO 3 2b

Question Number	Answer	Additional guidance	Mark
9(c)	$2\text{Al} + 6\text{H}^+ \rightarrow 2\text{Al}^{3+} + 3\text{H}_2$ (2)	Al and H₂ (1) balancing of correct species (1) allow multiples	(2) AO 2 1

Question Number	Answer	Additional guidance	Mark
9(d)	pH {increases / goes up} by <u>one</u> / moves <u>1</u> closer to neutral	ignore {increases / goes up} alone	(1) AO 1 1

Question Number	Answer	Additional guidance	Mark
9(e)	1 mol of hydrogen atoms = a mass of 1.00 g = 6.02×10^{23} atoms 6.02×10^{23} H atoms has mass = 1.00 g (1) mass of 1 H atom = <u>1.00</u> (1) $= \frac{6.02 \times 10^{23}}{6.02 \times 10^{23}} = 1.66 \times 10^{-24}$ (g) (1)	correct answer alone (3) if $1 \times 6.02 \times 10^{23}$ is followed by atoms or particles, then award 1st marking point on answer line 3.32×10^{-24} (g) (2) ignore sig figs except for one	(3) AO 2 1

Total for question 9 = 12 marks



Question number	Answer	Additional guidance	Mark
10(a)(i)	both forward and back(ward) reactions take place at same time	allow forward and back(ward) reactions occur at same rate	(1) AO1-1

Question number	Indicative content	Mark
*10(a)(ii)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material that is indicated as relevant. Additional content included in the response must be scientific and relevant. AO1 (3 marks) AO2 (3 marks) • use of suitable catalyst (any suitable metal eg Pt) • helps increase rate of forward reaction • and helps increase rate of back reaction • so increases rate of attainment of equilibrium • but has no effect on equilibrium yield • increase temperature would increase rate of reaction • shifts equilibrium to right hand side • so increases equilibrium yield • so use a high temperature (range 200–600 °C – anything would be reasonable) • use of very high temperatures increases energy use • so makes product more expensive • as fewer molecules on left hand side than right • so use low pressures • moves equilibrium to right hand side • so increases equilibrium yield • high pressure increases rate but decreases yield OR low pressure increases yield but decreases rate • pressure used is a compromise between rate and yield	(6) AO1-1 AO2-1



Level	Mark	Descriptor
	0	No awardable content
Level 1	1-2	- Demonstrates elements of chemical understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) - The explanation attempts to link and apply knowledge and understanding of scientific ideas, flawed or simplistic connections made between elements in the context of the question. (AO2)
Level 2	3-4	- Demonstrates chemical understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) - The explanation is mostly supported through linkage and application of knowledge and understanding of scientific ideas, some logical connections made between elements in the context of the question. (AO2)
Level 3	5-6	- Demonstrates accurate and relevant chemical understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) - The explanation is supported throughout by linkage and application of knowledge and understanding of scientific ideas, logical connections made between elements in the context of the question. (AO2)



Level	Mark	Additional Guidance	General additional guidance - the decision between levels
	0	No rewardable material.	Read whole answer and ignore all incorrect material/ discard any contradictory material then:
Level 1	1-2	<u>Additional Guidance</u> - One factor is discussed with a statement of effect on yield and/or rate (1) - One factor is discussed with explanation of yield and/or rate (2) - Two or three factors are discussed with statement of effect on yield and/or rate (2)	<u>Possible Candidate Responses</u> High temperature gives high yield of propene as equilibrium moves to products side. A low pressure gives a higher yield because there are more gas molecules on the right-hand side (ORA) Addition of catalyst increases rate of attainment of equilibrium Factor and reason – 2 marks
Level 2	3-4	<u>Additional Guidance</u> - One factor is fully discussed with explanation of yield and rate (3) - Two factors are discussed with explanation of yield and/or rate in one case and just statement of yield and/or rate in one case (3) - Two factors are discussed with explanation of yield and/or rate in each case (4) - Three factors are discussed with statement of effect on yield and/or rate with explanation for at least one (4)	<u>Possible Candidate Responses</u> A higher pressure gives a lower yield because there are more gas molecules on the right-hand side. A higher temperature gives a higher yield because the forward reaction is endothermic. 2 factors both with reasons – 4 marks
Level 3	5-6	<u>Additional Guidance</u> To get into level 3 yield and rate must be both discussed at least once. - All three factors are discussed, with explanation of yield and/or rate in each case (6) - All three factors are discussed, with explanation of yield and/or rate in two cases (5)	<u>Possible Candidate Responses</u> use of catalyst increases rate of forward reaction and increases rate of back reaction so increases rate of attainment of equilibrium but has no effect on equilibrium yield; increase temperature increases rate of reaction and shifts equilibrium to product side so use a high temperature; use low pressures as fewer molecules on reactant side than products so moves equilibrium to right hand side & yield increases but high pressure increases rate but decreases yield 3 factors detailed with at least 2 reasons – 6 marks



Question number	Answer	Mark
10(b)	300 (dm ³)	(1) AO2-1

Question number	Answer	Additional guidance	Mark
10(c)	1 mol C ₃ H ₈ produces 1 mol H ₂ (1) no moles propane = $\frac{900}{24}$ (1) (= 37.5) = no moles H ₂ mass of H ₂ = 37.5 x 2 g (1) (= 75.0 (g)) = 7.50 x 10 ⁻² (kg) (1) (= 0.075)	Answer of 0.075 with or without working scores full marks Allow ECF throughout allow 37.5 (moles) for 2 marks Allow 75.0 x 10 ⁻³ (kg) as a correct final answer 0.0375 scores 3 75(.0) scores 3	(4) AO2-1

Total for Question 10 = 12 marks



Question number	Answer	Additional guidance	Mark
9(a)(i)	least most X – W – Y – Z (2)	X – Y – W – Z (1)	(2) AO3-1

Question number	Answer	Additional guidance	Mark
9(a)(ii)	An explanation linking - metal sulfate {insoluble / coats the metal / forms a barrier} (1) - prevents further reaction of metal with acid (1)	ignore tarnish	(2) AO2-2

Question number	Answer	Additional guidance	Mark
9(a)(iii)	An explanation linking - partially {dissociated / ionised} (1) {concentration of H⁺ ions lower / fewer H⁺ ions} than expected (1)	concentration of H ⁺ ions lower than concentration of acid (1) ignore references to pH	(2) AO1-1

Question number	Answer	Additional guidance	Mark
9(b)	formula mass $\text{Al}_2(\text{SO}_4)_3$ $= 2 \times 27 + 3 \times (32 + 16 \times 4)$ (1) (= 342) moles of $\text{Al}_2(\text{SO}_4)_3$ $= \frac{5.13}{342}$ (1) (= 0.015) no of atoms in formula $\text{Al}_2(\text{SO}_4)_3 = 17$ no of atoms in 0.015 moles = $17 \times 0.015 \times 6.02 \times 10^{23}$ (1) $= 1.5351 \times 10^{23}$ (1)	final answer of 1.5351×10^{23} scores full marks allow ECF from formula mass 0.015 scores 2 marks allow any number of sig figs except one 3.1×10^{24} scores 1 (mass $\times L$) 1.0234×10^{25} scores 1 (no of atoms $\times L$) 2.05884×10^{26} scores 2 ($M_r \times L$) 9.03×10^{21} scores 3 (moles $\times L$)	(4) AO2-1

Question number	Answer	Additional guidance	Mark
9(c)	moles Fe = $\frac{4.48}{56.0}$ (1) (= 0.08) moles Pb = $\frac{24.84}{207}$ (1) (= 0.12) ratio moles Fe : moles Pb = 2 : 3 or 1 : 1.5 so equation 2 (1) OR mass ratio ratio equation 1 = 56 : 207 (1) ratio equation 2 = 112 : 621 (1) 112 : 621 = 4.48 : 24.84 so equation 2 (1) OR equation 1 mass of Pb (207/56) x 4.48 = 16.56 (2) OR equation 2 mass of Pb (621/112) x 4.48 = 24.84 (2) so equation 2 is correct (1)	There may be other methods – need to check calculation carefully allow shows that it is not 1:1 for final mark stating Equation 2 with no calculation to justify, scores 0	(3) AO3-1

Total for Question 09 = 13 marks



Question number	Answer	Additional guidance	Mark
9(a)(i)	A description to include - bubbles formed {slowly / steadily / quite quickly} / some bubbles form (1) - some metal remains (1)	allow bubbling faster than F / more bubbles than F / bubbling slower than D / fewer bubbles than D allow some metal has reacted allow metal looks changed mark anything written in table only if answer lines blank	(2) AO3-1a/1b

Question number	Answer	Additional guidance	Mark
9(a)(ii)	An explanation linking dilute: - low concentration (1) - of the {solute / acid / (hydrogen) ions / H^+} (1) strong acid - acid <u>fully</u> {dissociated / ionised} (1) - forming {hydrogen/ H^+} ions (1)	MP2 depends MP1 allow low {mass/ amount} ignore 'not concentrated' ignore 'weak concentration' if no MP1 or MP2. allow 'dilute acid has more water in it' / 'has had water added' for 1 mark only mark MP3 and MP4 independently ignore all references to pH	(4) AO1-1

Question number	Answer	Additional guidance	Mark
9(b)	4.515×10^{23} scores 4 with or without working relative formula mass $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$ $207 + 2 \times (2 \times 12 + 3 \times 1 + 16 \times 2) = 325$ (1) moles of $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$ $\frac{16.25}{325} = 0.05$ (1) no of "$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$" $0.05 \times 6.02 \times 10^{23} = 3.01 \times 10^{22}$ (1) no of atoms $15 \times 3.01 \times 10^{22} = 4.515 \times 10^{23}$ (1)	allow ECF at all stages for ECF using Avogadro's number, must x previously calculated attempt at moles using the data in the question allow any number of sig figs except one with correct rounding 3.01×10^{22} with working scores 3 1.204×10^{25} with working scores 2 1.9565×10^{26} with working scores 1	(4) AO2-1

Question number	Answer	Additional guidance	Mark
9(c)	moles Fe = $\frac{2.24}{56.0} = 0.04$ (1) moles Cu = $\frac{3.81}{63.5} = 0.06$ (1) ratio moles Fe : moles Cu = 2 : 3 or 1 : 1.5 and so equation 2 (1) OR moles Fe = $\frac{2.24}{56.0} = 0.04$ (1) moles Cu if equation 1 = 0.04 (1) expected mass Cu equation 1 = $0.04 \times 63.5 = 2.54\text{g}$ and so not equation 1, equation 2 (1) OR moles Fe = $\frac{2.24}{56.0} = 0.04$ (1) moles Cu if equation 2 = $0.04 \times \frac{3}{2} = 0.06$ (1) expected mass Cu equation 2 = $0.06 \times 63.5 = 3.81\text{g}$ and so equation 2 (1)	must state Equation 2 to score MP3 stating Equation 2, with no calculation to justify, scores 0 No ECF in this question moles of "2Fe" = $\frac{2.24}{112} = 0.02$ scores 0, BUT: with either: moles of "3Cu" = $\frac{3.81}{190.5} = 0.02$ these are same so equation 2, scores 3 or: mass of Cu = $3 \times 63.5 \times 0.02 = 3.81\text{g}$ so equation 2, scores 3	(3) AO3-1a/b

Total for question 09 = 13 marks



Question number	Answer	Additional guidance	Mark
10(a)(i)	A description including - rate (of attainment of equilibrium) increased (1) - no effect equilibrium yield (1)	allow rate of (forward and backward) reaction(s) increased allow equilibrium reached faster ignore any reference to activation energy	(2) AO1-1

Question number	Indicative content	Mark
*10(a)(ii)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material that is indicated as relevant. Additional content included in the response must be scientific and relevant. Increase temperature to 1000 °C - increase temperature increases rate (of attainment of equilibrium) - higher temperature means more frequent collisions because molecules have more energy - equilibrium between reactants and products reached faster - higher temperature favours forward reaction which is endothermic - increasing temperature moves equilibrium to the right/products side - higher temperature increases equilibrium yield as forward reaction is endothermic Decrease pressure to 10 atm - equilibrium reached slower because of lower pressure - lower pressure causes molecules to be further apart so less frequent collisions - lower pressure moves equilibrium to the right/products side - higher yield because products occupy larger volume than reactants	(6) AO1-1 AO2-1



Level	Mark	Descriptor
	0	No awardable content
Level 1	1-2	- Demonstrates elements of chemical understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) - The explanation attempts to link and apply knowledge and understanding of scientific ideas, flawed or simplistic connections made between elements in the context of the question. (AO2)
Level 2	3-4	- Demonstrates chemical understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) - The explanation is mostly supported through linkage and application of knowledge and understanding of scientific ideas, some logical connections made between elements in the context of the question. (AO2)
Level 3	5-6	- Demonstrates accurate and relevant chemical understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) - The explanation is supported throughout by linkage and application of knowledge and understanding of scientific ideas, logical connections made between elements in the context of the question. (AO2)



Level	Mark	Descriptor	Possible candidate response
Read whole answer. Ignore all incorrect material and reject any contradictory material. Ignore references to catalysts			
	0	No rewardable material.	
Level 1	1–2	describe effect of one condition on rate and yield OR describes the effect of both conditions on rate or yield	increase in temperature increases rate (1) decrease in pressure decreases rate (1) increase in temperature increases rate and decrease in pressure decreases rate of attainment of equilibrium (2) decrease in pressure decreases rate but increases yield (2) increase in temperature increases rate and yield (2)
Level 2	3–4	describes the effect of both conditions on rate and yield OR explains fully the effects of both conditions on the rate or yield OR explains fully the effects of one condition on the rate and yield	Increasing the temperature and decreasing the pressure will decrease the yield and the decreased pressure will decrease the rate (3) increased temperature increases the rate and increases the yield, whereas decreasing the pressure will decrease the rate but still increase the yield (4) increased temperature will increase the rate but decreased pressure will decrease the rate as the particles are further apart so there are less frequent collisions, but the lower pressure will move equilibrium to the right (3) increased temperature means an increased rate of reaction, as there are more frequent collisions and particles have more energy. The reaction is endothermic so a higher temperature favours the forward reaction so equilibrium moves to the right, resulting in a higher yield (4)
Level 3	5–6	explains fully the effect of both conditions on rate and yield	increased temperature will increase the rate and will increase the yield but decreased pressure will decrease the rate because the molecules are further apart so there are less frequent collisions, but the lower pressure will move equilibrium to the right because the products occupy a larger volume than the reactants (5) increased temperature means an increased rate, as there are more frequent collisions and particles have more energy. The higher temperature favours the forward reaction so equilibrium moves to the right, resulting in a higher yield, whereas the decrease in pressure will increase the yield as the equilibrium will move to the right, the decrease in pressure will decrease the rate (6)



Question number	Answer	Additional guidance	Mark
10(b)	3250 (dm ³) with or without working scores 2 1 mole CH ₄ produces 5 moles products (1) 5 x 650 = 3250 (dm ³) (1)	allow 1x 650 = 650 or 4x 650 = 2600 for 1 mark.	(2) AO2-1

Question number	Answer	Additional guidance	Mark
10(c)	825 (g) with or without working scores 3 no moles H ₂ $\frac{1800}{24} = 75$ (1) no moles CO ₂ $\frac{75}{4} = 18.75$ (1) mass of CO ₂ 18.75 x 44 g = 825 (g) (1)	allow ECF from incorrect answer but only if using 1800 and 24 allow ECF from an incorrect calculation of number of moles 450 with working gains 1 mark 3300 with working gains 2 marks 13200 with working gains 2 marks	(3) AO2-1

Total for question 10 = 13 marks

