

Chemistry  
PAPER 1  
Higher Tier

Total Marks
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Friday 17 May 2024 – Morning

Time: 1 hour 45 minutes

In the boxes below, write your name, centre number and candidate number.

Surname					
Other names					
Centre Number					
Candidate Number					

**YOU MUST HAVE**

**Calculator, ruler, Periodic Table (enclosed)**

**YOU WILL BE GIVEN**

**Diagram Booklet**

**INSTRUCTIONS**

**Answer ALL questions.**

**Answer the questions in the spaces provided in this Question Paper or in the separate Diagram Booklet – there may be more space than you need.**

**Calculators may be used.**

**Any diagrams may NOT be accurately drawn, unless otherwise indicated.**

**You must show all your working out with your answer clearly identified at the end of your solution.**

**Turn over**

## **INFORMATION**

**The total mark for this paper is 100.**

**The marks for EACH question are shown in brackets – use this as a guide as to how much time to spend on each question.**

**In questions marked with an ASTERISK (\*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.**

**A Periodic Table is provided as a separate insert.**

**There may be spare copies of some diagrams.**

## **ADVICE**

**Read each question carefully before you start to answer it.**

**Try to answer every question.**

**Check your answers if you have time at the end.**

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**Turn over**

**Answer ALL questions. Write your answers in the spaces provided.**

**Some questions must be answered with a cross in a box ☐. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐.**

**(continued on the next page)**

**1 (a) Chemical cells produce a voltage.**

**Look at Figure 1 for Question 1(a) in the Diagram Booklet. It shows a chemical cell can be made by placing the metals copper and iron in a beaker of sodium chloride solution.**

**Describe what will happen to the reading on the voltmeter over a long period of time.  
(2 marks)**

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**(continued on the next page)**

**Turn over**

**1 continued.**

**(b) Iron is a transition metal.**

**Which of the following is most likely to be a property of iron?  
(1 mark)**

- ☐ **A iron forms a colourless oxide**
- ☐ **B iron is a poor conductor of heat**
- ☐ **C iron has a low boiling point**
- ☐ **D iron has a high density**

**(continued on the next page)**

**1 continued.**

**(c) An iron atom has a diameter  
of  $2.52 \times 10^{-10}$  m**

**What is the size of this iron atom  
in nanometres?  
(1 mark)**

☐ **A    2.52**

☐ **B    0.252**

☐ **C    0.0252**

☐ **D    0.00252**

**(continued on the next page)**

**1 continued.**

**(d) Look at Figure 2 for Question 1(d) in the Diagram Booklet. It shows the arrangement of atoms in three different alloys of copper and zinc, A, B and C.**

**Explain which of the three alloys, A, B and C, is the strongest.  
(2 marks)**

**Answer space continues on the next page.**

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**Turn over**



**1(d) continued.**

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**(Total for Question 1 = 6 marks)**

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**2 Barium hydroxide reacts with dilute hydrochloric acid to form barium chloride solution and water.**

**(a) (i) Look at the equation for Question 2(a)(i) in the Diagram Booklet. Complete the balanced equation for the reaction by adding a NUMBER in front of  $\text{HCl(aq)}$  (1 mark)**

**(ii) State what you would SEE during the reaction. (1 mark)**

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**(continued on the next page)**

**2 continued.**

**(b) A student investigated how the pH of the mixture changed as barium hydroxide was added to dilute hydrochloric acid.**

**The student used this method.**

**STEP 1 measure out  $50\text{ cm}^3$  of dilute hydrochloric acid into a beaker using a measuring cylinder**

**STEP 2 use a glass rod to place a drop of the acid onto a piece of universal indicator paper and record the pH**

**STEP 3 add one spatula measure of barium hydroxide to the acid in the beaker and stir**

**(continued on the next page)**

**Turn over**

**2(b) continued.**

**STEP 4** use the glass rod to place a drop of the mixture onto a new piece of universal indicator paper and record the pH again

**STEP 5** repeat steps 3 and 4 until there is no further change in the pH

**(continued on the next page)**

**2(b) continued.**

- (i) Name a piece of equipment that could be used to measure the pH of a substance more accurately than universal indicator paper.  
(1 mark)**

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**(continued on the next page)**

**2(b) continued.**

**(ii) Explain why, in step 3, the mixture was stirred after adding the barium hydroxide.  
(2 marks)**

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**(continued on the next page)**

**2(b) continued.**

**(iii) Figure 3 shows the student's results.**

**FIGURE 3**

<b>number of spatula measures of barium hydroxide</b>	<b>pH of mixture</b>
<b>0</b>	<b>1</b>
<b>1</b>	<b>1</b>
<b>2</b>	<b>1</b>
<b>3</b>	<b>1</b>
<b>4</b>	<b>3</b>
<b>5</b>	<b>8</b>
<b>6</b>	<b>12</b>
<b>7</b>	<b>13</b>
<b>8</b>	<b>13</b>

**(continued on the next page)**

**Turn over**

**2(b)(iii) continued.**

**Look at the graph for Question 2(b)(iii) in the Diagram Booklet. Plot a graph of the pH of the mixture against the number of spatula measures of barium hydroxide.  
(3 marks)**

**(iv) Use the graph to find the pH of the mixture when 4.5 spatula measures of barium hydroxide are added.  
(1 mark)**

**pH of the  
mixture = \_\_\_\_\_**

**(Total for Question 2 = 9 marks)**

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**Turn over**



**3 Sodium carbonate has the formula  $\text{Na}_2\text{CO}_3$**

**(a) Sodium carbonate contains  $\text{Na}^+$  ions and  $\text{CO}_3^{2-}$  ions.**

**(i) The atomic number of sodium is 11**

**What is the electronic configuration of the  $\text{Na}^+$  ion?  
(1 mark)**

☐ **A 1**

☐ **B 2.8**

☐ **C 2.8.1**

☐ **D 2.8.2**

**(continued on the next page)**

**3(a) continued.**

**(ii) Explain why solid sodium carbonate CANNOT conduct electricity but a solution of sodium carbonate CAN conduct electricity.  
(3 marks)**

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**(continued on the next page)**

**Turn over**

**3 continued.**

**(b) Calculate the percentage  
by mass of sodium in  
sodium carbonate,  $\text{Na}_2\text{CO}_3$**

**percentage by mass of element =  
$$\frac{\text{total relative atomic mass of element}}{\text{relative formula mass of compound}} \times 100$$**

**(relative atomic masses: C = 12,  
O = 16, Na = 23)  
(3 marks)**

**Answer space continues on the next page.**

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**Turn over**

**3(b) continued.**

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**percentage by  
mass of sodium =** \_\_\_\_\_

**(Total for Question 3 = 7 marks)**

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**4 (a) Titanium can be extracted from titanium oxide,  $\text{TiO}_2$ , by reaction with magnesium.**

**(i) 100 tonnes of titanium oxide was heated with magnesium. The titanium formed in the reaction was separated and purified. The mass of titanium was then determined.**

**Look at Figure 4 for Question 4(a) in the Diagram Booklet. The results are shown.**

**(continued on the next page)**

**4(a)(i) continued.**

**Use the information in Figure 4 to calculate the percentage yield of titanium in this process.**

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

**Give your answer to  
1 decimal place.  
(3 marks)**

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**percentage yield = \_\_\_\_\_**

**(continued on the next page)**

**Turn over**

**4(a) continued.**

**(ii) Give TWO reasons why the percentage yield for THIS PROCESS is less than 100% (2 marks)**

**1** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**2** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**(continued on the next page)**

**Turn over**

**4(a) continued.**

**(iii) The balanced equation for this process is**



**Calculate the atom economy of this process to produce titanium.**

**atom economy (%) =**

$$\frac{\text{total formula mass of desired product}}{\text{total formula mass of all reactants or products}} \times 100$$

**Give your answer to  
2 significant figures.**

**(relative atomic masses: O = 16,  
Mg = 24, Ti = 48)  
(3 marks)**

**Answer space continues on the next page.**

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**Turn over**



4(a)(iii) continued.

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atom economy = \_\_\_\_\_%

(continued on the next page)

**4 continued.**

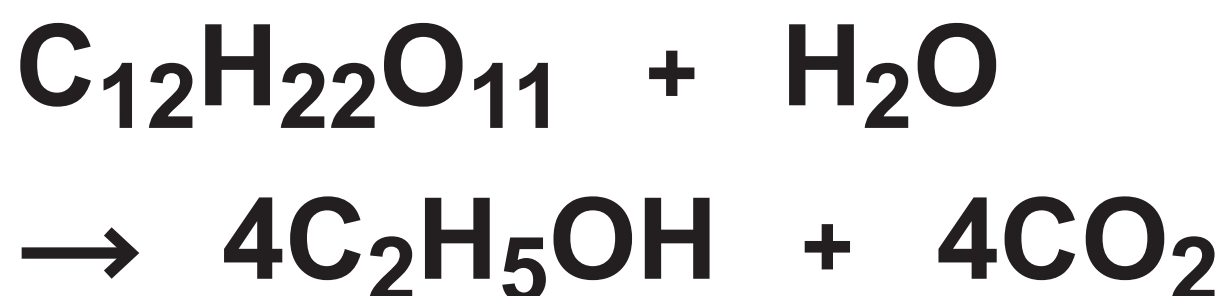
**(b) Ethanol,  $C_2H_5OH$ , can be produced by two different methods.**

- **by the hydration of ethene,  $C_2H_4$**



**atom economy = 100%**

- **and by the fermentation of a carbohydrate,  
e.g. sucrose,  $C_{12}H_{22}O_{11}$**



**atom economy = 51.1%**

**(continued on the next page)**

**Turn over**

**4(b) continued.**

- (i) State why the hydration of ethene has an atom economy of 100% (1 mark)**

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**(continued on the next page)**

**4(b) continued.**

**(ii) Explain how the atom economy of the fermentation reaction can be improved.  
(2 marks)**

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**(Total for Question 4 = 11 marks)**

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**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 marks)**

**1** \_\_\_\_\_

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\_\_\_\_\_

**2** \_\_\_\_\_

\_\_\_\_\_

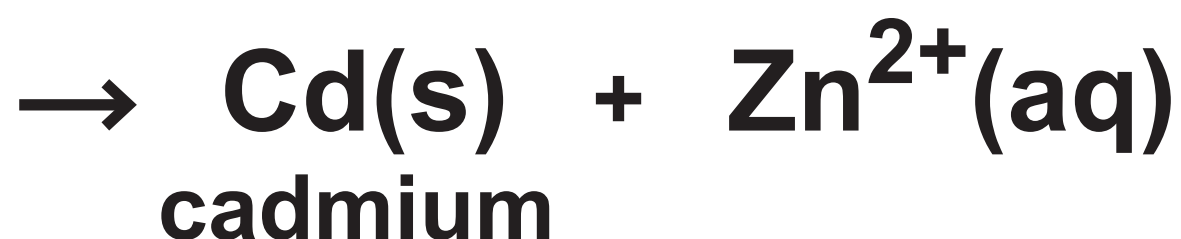
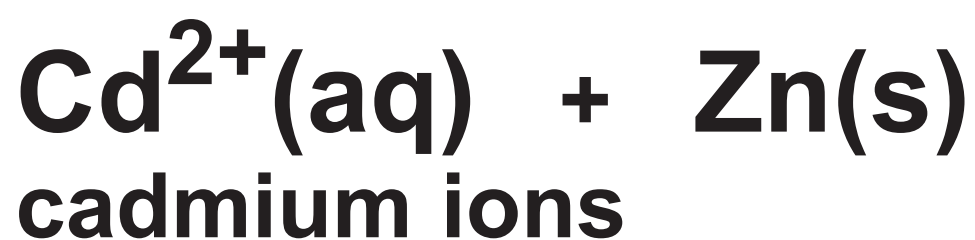
\_\_\_\_\_

**(continued on the next page)**

**5 continued.**

- (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 marks)**

**Answer space continues on the next page.**

**Turn over**

**5(b)(i) continued.**

[illegible]

**(continued on the next page)**

**Turn over**

**5(b) continued.**

**(ii) The formula of the cadmium ion  
is  $\text{Cd}^{2+}$**

**The formula of the phosphate ion  
is  $\text{PO}_4^{3-}$**

**Which is the formula of  
cadmium phosphate?  
(1 mark)**

☐ **A  $\text{Cd}_2(\text{PO}_4)_3$**

☐ **B  $\text{Cd}_3\text{PO}_{12}$**

☐ **c  $\text{Cd}_3(\text{PO}_4)_2$**

☐ **D  $\text{Cd}_3\text{P}_2\text{O}_8$**

**(continued on the next page)**



**5 continued.**

**(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 mark)**

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**(continued on the next page)**

**5 continued.**

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

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

**(2 marks)**

**Answer space continues on the next page.**

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**Turn over**

**5(d) continued.**

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**(Total for Question 5 = 9 marks)**

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**6 Titration can be used to find the volume of dilute hydrochloric acid needed to neutralise  $25.0\text{ cm}^3$  of barium hydroxide solution.**

**(a) Before the titration is carried out, the pipette and conical flask are rinsed out with pure water.**

**Explain the effect, if any, that traces of water in the pipette and conical flask after rinsing could have on the titration result.**

**(4 marks)**

**Answer space continues on the next page.**

**pipette**

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**Turn over**

**6(a) continued.**

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**conical flask**

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**(continued on the next page)**

**6 continued.**

**(b) In the titration, a few drops of phenolphthalein indicator are added to the barium hydroxide solution.**

**(i) State the change in colour of phenolphthalein at the end point, when the barium hydroxide solution has just been neutralised.  
(1 mark)**

**from \_\_\_\_\_**

**to \_\_\_\_\_**

**(ii) Write the ionic equation for the neutralisation reaction that occurs when hydrochloric acid is added to barium hydroxide solution.  
(2 marks)**

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**(continued on the next page)**

**Turn over**

**6 continued.**

**(c) When barium hydroxide solution is neutralised by dilute sulfuric acid, a white precipitate of barium sulfate is formed in the conical flask.**

**Describe an experiment to obtain a sample of pure, dry barium sulfate from the contents of the conical flask.  
(3 marks)**

**Answer space continues on the next page.**

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**Turn over**

**6(c) continued.**

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**(Total for Question 6 = 10 marks)**

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- 7 (a) Water, acidified with dilute sulfuric acid, was electrolysed for 10 minutes using inert electrodes.**

**Look at Figure 5 for Question 7(a) in the Diagram Booklet. It shows the apparatus used.**

- (i) In this electrolysis, the acidified water is an electrolyte.**

**Explain why acidified water is an electrolyte.  
(2 marks)**

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**7(a) continued.**

- (ii) Hydrogen collects at the negative electrode and oxygen collects at the positive electrode.**

**Look at the diagrams for Question 7(a)(ii) in the Diagram Booklet. Which of these shows the results after **10 minutes** of this electrolysis?  
(1 mark)**

☐ **A diagram A**

☐ **B diagram B**

☐ **C diagram C**

☐ **D diagram D**

**(continued on the next page)**

**7(a) continued.**

**(iii) Complete and balance the half equation for the formation of oxygen at the positive electrode in this electrolysis.  
(2 marks)**



**(continued on the next page)**

**7 continued.**

**(b) Copper sulfate solution was electrolysed for 10 minutes using copper electrodes.**

**Look at Figure 6 for Question 7(b) in the Diagram Booklet. It shows the mass of the cathode and the appearance of the copper sulfate solution before electrolysis and after electrolysis.**

**(continued on the next page)**

**7(b) continued.**

- (i) Describe what should be done to the copper cathode, after it has been removed from the copper sulfate solution, before its final mass is determined.  
(2 marks)**

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**(continued on the next page)**

**Turn over**

**7(b) continued.**

- (ii) Explain, in terms of ions, the change in mass of the cathode shown in Figure 6.  
(2 marks)**

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**(continued on the next page)**

**Turn over**

**7(b) continued.**

**(iii) Explain why the appearance of the copper sulfate solution did not change during the electrolysis.  
(2 marks)**

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**(Total for Question 7 = 11 marks)**

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**8 This question is about the properties of different substances.**

**(a) Silicon tetrachloride is a simple molecular covalent compound.**

**(i) A molecule of silicon tetrachloride is composed of a silicon atom and four chlorine atoms.**

- a silicon atom has  
4 outer electrons**
- a chlorine atom has  
7 outer electrons**

**Draw a dot and cross  
diagram of a molecule of  
silicon tetrachloride,  $\text{SiCl}_4$**

**Show outer electrons only.  
(2 marks)**

**Answer space continues on the next page.**



**8(a)(i) continued.**

**(continued on the next page)**

**Turn over**

**8(a) continued.**

**(ii) Explain why simple molecular covalent compounds such as silicon tetrachloride have low melting and boiling points.  
(2 marks)**

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**(continued on the next page)**

**Turn over**

**8 continued.**

**(b) Look at Figure 7 for Question 8(b) in the Diagram Booklet. Part of the structure of rubidium bromide is shown.**

**Which row shows the most likely melting point and boiling point of rubidium bromide?  
(1 mark)**

	<b>melting point in °C</b>	<b>boiling point in °C</b>
<input type="checkbox"/> <b>A</b>	<b>6·93</b>	<b>134·0</b>
<input type="checkbox"/> <b>B</b>	<b>69·3</b>	<b>134·0</b>
<input type="checkbox"/> <b>C</b>	<b>69·3</b>	<b>1340</b>
<input type="checkbox"/> <b>D</b>	<b>693</b>	<b>1340</b>

**(continued on the next page)**

**Turn over**

**8 continued.**

**\*(c) Diamond and graphite are two forms of carbon.**

**Look at Figure 8 for Question 8(c) in the Diagram Booklet. It shows how the carbon atoms are arranged in a part of the structure of each of these forms of carbon.**

- **diamond is one of the hardest known substances on Earth and is used in cutting tools.**
- **graphite is soft and flaky.**
- **diamond is a poor electrical conductor, but graphite is a good electrical conductor.**

**Explain, in terms of structure and bonding, these properties of diamond and graphite.  
(6 marks)**

**Answer space continues on the next 5 pages.**

**Turn over**

8(c) continued.

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8(c) continued.

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8(c) continued.

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8(c) continued.

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**8(c) continued.**

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**(Total for Question 8 = 11 marks)**

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- 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.**

**Look at Figure 9 for Question 9(a) in the Diagram Booklet. It shows the observations of the reactions for metals D, E and F.**

**Look at Figure 10 for Question 9(a) in the Diagram Booklet. It shows the order of reactivity for these metals.**

**(continued on the next page)**

**9(a) continued.**

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

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**(continued on the next page)**

**Turn over**

**9(a) continued.**

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

**Explain the meaning of the terms  
DILUTE and STRONG ACID.  
(4 marks)**

**Answer space continues on the next page.**

**dilute**

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**Turn over**

**9(a)(ii) continued.**

**strong acid**

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**(continued on the next page)**

**9 continued.**

**(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:  $\text{H} = 1.00$ ,  $\text{C} = 12.0$ ,  $\text{O} = 16.0$ ,  $\text{Pb} = 207$**

**Avogadro number =  $6.02 \times 10^{23}$ )  
(4 marks)**

**Answer space continues on the next page.**

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**Turn over**

9(b) continued.

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number of atoms = \_\_\_\_\_

(continued on the next page)

Turn over

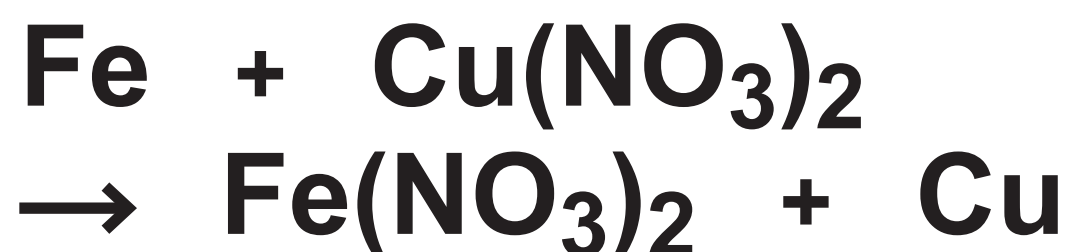
**9 continued.**

**(c) Iron is more reactive than copper.**

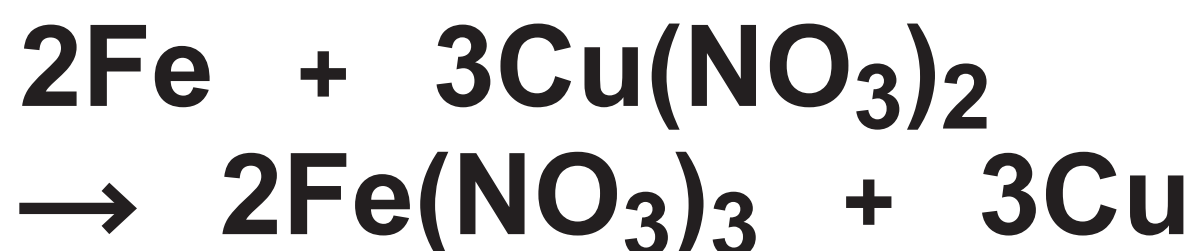
**Iron will displace copper from copper nitrate solution.**

**Two possible balanced equations for the reaction are**

**Equation 1**



**Equation 2**



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

**(continued on the next page)**

**Turn over**



**9(c) continued.**

**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 marks)**

**Answer space continues on the next page.**

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**Turn over**

**9(c) continued.**

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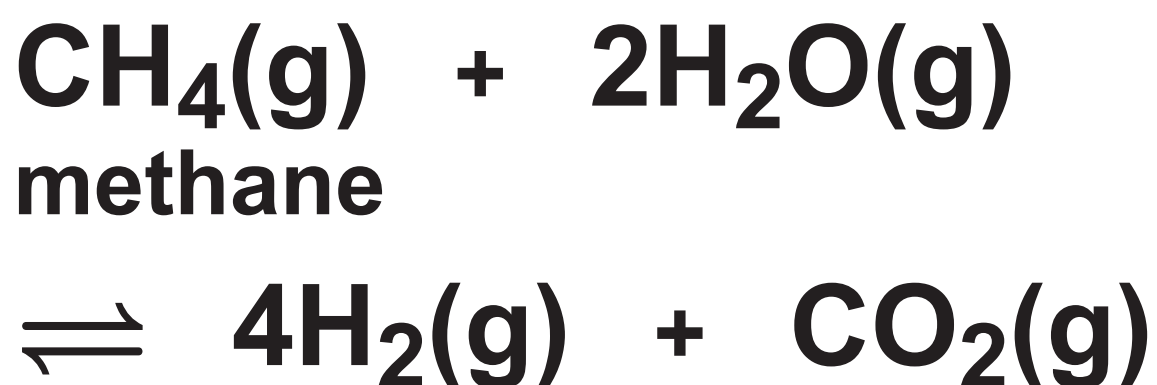
**(Total for Question 9 = 13 marks)**

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**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.**

**(continued on the next page)**

**10(a) continued.**

- (i) Describe the effect of the catalyst on the rate of attainment of equilibrium and on the equilibrium yield of products. (2 marks)**

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**(continued on the next page)**

**Turn over**

**10(a) continued.**

**\*(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 marks)**

**Answer space continues on the next 5 pages.**

**Turn over**

10(a)(ii) continued.

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**10(a)(ii) continued.**

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10(a)(ii) continued.

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10(a)(ii) continued.

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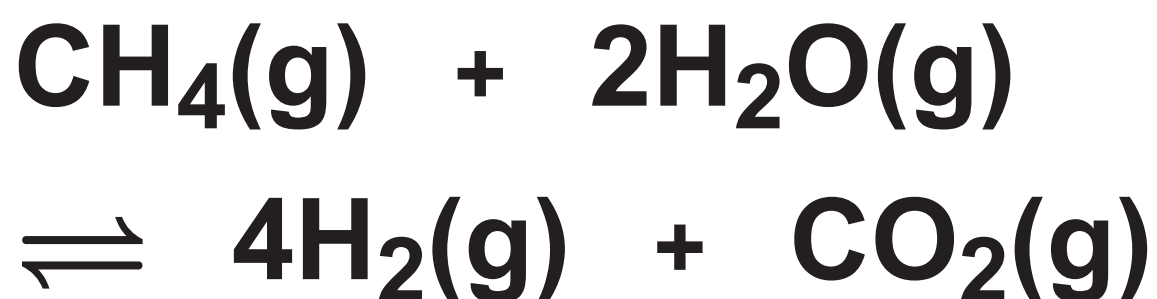
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**10(a)(ii) continued.**

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**(b) Using the equation for the reaction**



**calculate the maximum volume of products, in  $\text{dm}^3$ , that could be formed by the complete reaction of  $650 \text{ dm}^3$  of methane.**

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

**Answer space continues on the next page.**

**10(b) continued.**

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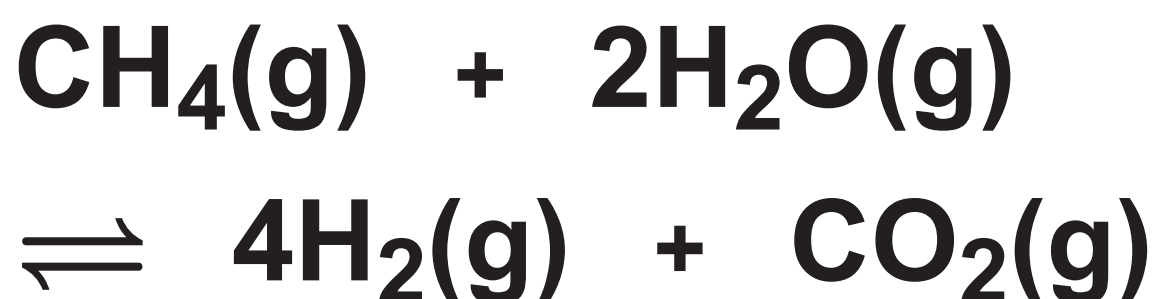
**maximum volume  
of products = \_\_\_\_\_ dm<sup>3</sup>**

**(continued on the next page)**

**Turn over**

**10 continued.**

**(c) Using the same equation for the reaction**



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

**(relative formula mass: CO<sub>2</sub> = 44;  
1 mol of any gas at room temperature and pressure occupies 24 dm<sup>3</sup>)  
(3 marks)**

**Answer space continues on the next page.**

**10(c) continued.**

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**mass of  
carbon dioxide = \_\_\_\_\_ g**

**(Total for Question 10 = 13 marks)**

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**TOTAL FOR PAPER = 100 MARKS  
END OF PAPER**