

A



**Surname** \_\_\_\_\_

**Other Names** \_\_\_\_\_

**Centre Number** \_\_\_\_\_

**Candidate Number** \_\_\_\_\_

**Candidate Signature** \_\_\_\_\_

**I declare this is my own work.**

**A-level**

**CHEMISTRY**

**Paper 3**

**7405/3**

**Wednesday 17 June 2020      Morning**

**Time allowed: 2 hours**

**At the top of the page, write your surname and other names, your centre number, your candidate number and add your signature.**

**[Turn over]**



J U N 2 0 7 4 0 5 3 0 1

**For this paper you must have:**

- **the Periodic Table/Data Booklet, provided as an insert (enclosed)**
- **a ruler with millimetre measurements**
- **a scientific calculator, which you are expected to use where appropriate.**

## **INSTRUCTIONS**

- **Use black ink or black ball-point pen.**
- **Answer ALL questions.**
- **You must answer the questions in the spaces provided. Do not write on blank pages.**
- **If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).**
- **All working must be shown.**



- **Do all rough work in this book. Cross through any work you do not want to be marked.**

## **INFORMATION**

- **The marks for questions are shown in brackets.**
- **The maximum mark for this paper is 90.**

## **ADVICE**

- **You are advised to spend 70 minutes on SECTION A and 50 minutes on SECTION B.**

**DO NOT TURN OVER UNTIL TOLD TO DO SO**



**SECTION A**

**Answer ALL questions in this section.**

**0 1**

**This question is about emissions of oxides of nitrogen from petrol and diesel engines.**

**0 1 . 1**

**Explain how oxides of nitrogen are formed in engines. [2 marks]**

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01.2

**State why it is desirable to decrease emissions of oxides of nitrogen from vehicles. [1 mark]**

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**[Turn over]**



**01.3**

**Modern diesel vehicles use diesel exhaust fluids, such as AdBlue, to decrease emissions of oxides of nitrogen.**

**AdBlue reacts with water in the hot exhaust gases to form ammonia.**

**In the presence of a catalyst the ammonia reacts with oxides of nitrogen to form nitrogen and water.**

**Give the oxidation state of nitrogen in each of  $\text{NO}_2$ ,  $\text{NH}_3$  and  $\text{N}_2$**

**On the opposite page, complete the equation for the reaction between  $\text{NO}_2$  and  $\text{NH}_3$  [2 marks]**



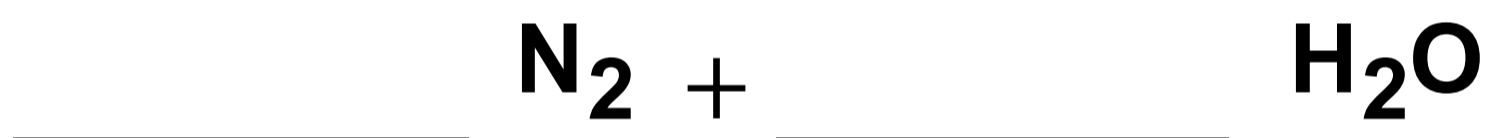
**Oxidation state of nitrogen in**

**NO<sub>2</sub>** \_\_\_\_\_

**NH<sub>3</sub>** \_\_\_\_\_

**N<sub>2</sub>** \_\_\_\_\_

**Equation**



**[Turn over]**



**01.4**

**Petrol vehicles have a catalytic converter which decreases emissions of oxides of nitrogen.**

**Platinum in the catalytic converter acts as a heterogeneous catalyst.**

**State the meaning of the term heterogeneous catalyst. [2 marks]**

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**01.5**

**Some carbon particulates are also formed in both diesel and petrol vehicles.**

**Explain why carbon particulates are formed. [1 mark]**

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**[Turn over]**

8



**0 2**

**This question is about oxides.**

**0 2 . 1**

**Sodium oxide forms a solution with a higher pH than magnesium oxide when equal amounts, in moles, of each oxide are added separately to equal volumes of water.**

**State why both oxides form alkaline solutions.**

**Suggest why sodium oxide forms a solution with a higher pH than the solution formed from magnesium oxide.**  
**[2 marks]**

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0 2 . 2

**Give an equation for the reaction between phosphorus(V) oxide and water. [1 mark]**

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**[Turn over]**



**02.3**

**In the Contact process, sulfur(IV) oxide is converted into sulfur(VI) oxide using vanadium(V) oxide as a catalyst.**

**Give TWO equations to show how the vanadium(V) oxide acts as a catalyst in this process. [2 marks]**

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

\_\_\_\_\_

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

\_\_\_\_\_

5





**The iron content of iron tablets can be determined by colorimetry.**

**Method:**

- **Dissolve a tablet in sulfuric acid.**
- **Oxidise all the iron from the tablet to  $\text{Fe}^{3+}(\text{aq})$ .**
- **Convert the  $\text{Fe}^{3+}(\text{aq})$  into a complex that absorbs light of wavelength 490 nm**
- **Make the solution up to 250 cm<sup>3</sup>**
- **Measure the absorbance of light at 490 nm with a colorimeter.**
- **Use a calibration graph to find the concentration of the iron(III) complex.**



**03.2**

**Calculate the energy, in J, gained by each excited electron in the absorption at 490 nm**

**Speed of light,  $c = 3.00 \times 10^8 \text{ m s}^{-1}$**

**Planck constant,  $h = 6.63 \times 10^{-34} \text{ J s}$**

**[3 marks]**

**Energy gained by each electron**

**J**

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**[Turn over]**







0	3	.	4
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The concentration of iron(III) in the solution is  $4.66 \times 10^{-3} \text{ mol dm}^{-3}$

Calculate the mass, in mg, of iron in the tablet used to make the  $250 \text{ cm}^3$  of solution. [2 marks]

Mass of iron in the tablet

\_\_\_\_\_ mg

[Turn over]



**0 4**

**Cisplatin,  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ , is used as an anti-cancer drug.**

**0 4 . 1**

**Cisplatin works by causing the death of rapidly dividing cells.**

**Name the process that is prevented by cisplatin during cell division. [1 mark]**

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**After cisplatin enters a cell, one of the chloride ligands is replaced by a water molecule to form a complex ion, B.**



0	4	.	2
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**Give the equation for this reaction.**  
**[2 marks]**

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**[Turn over]**



04.3

**When the complex ion B reacts with DNA, the water molecule is replaced as a bond forms between platinum and a nitrogen atom in a guanine nucleotide.**

**The remaining chloride ligand is also replaced as a bond forms between platinum and a nitrogen atom in another guanine nucleotide.**

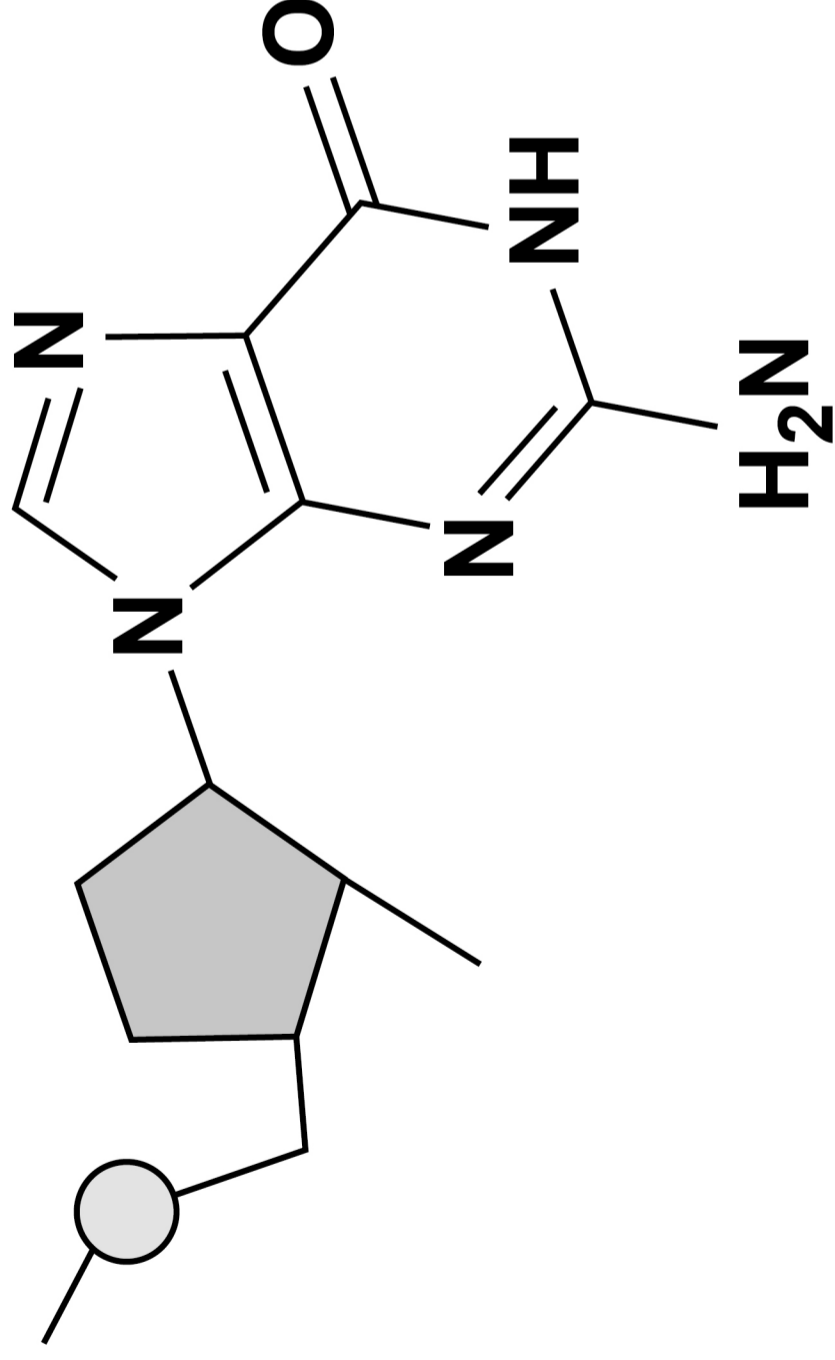
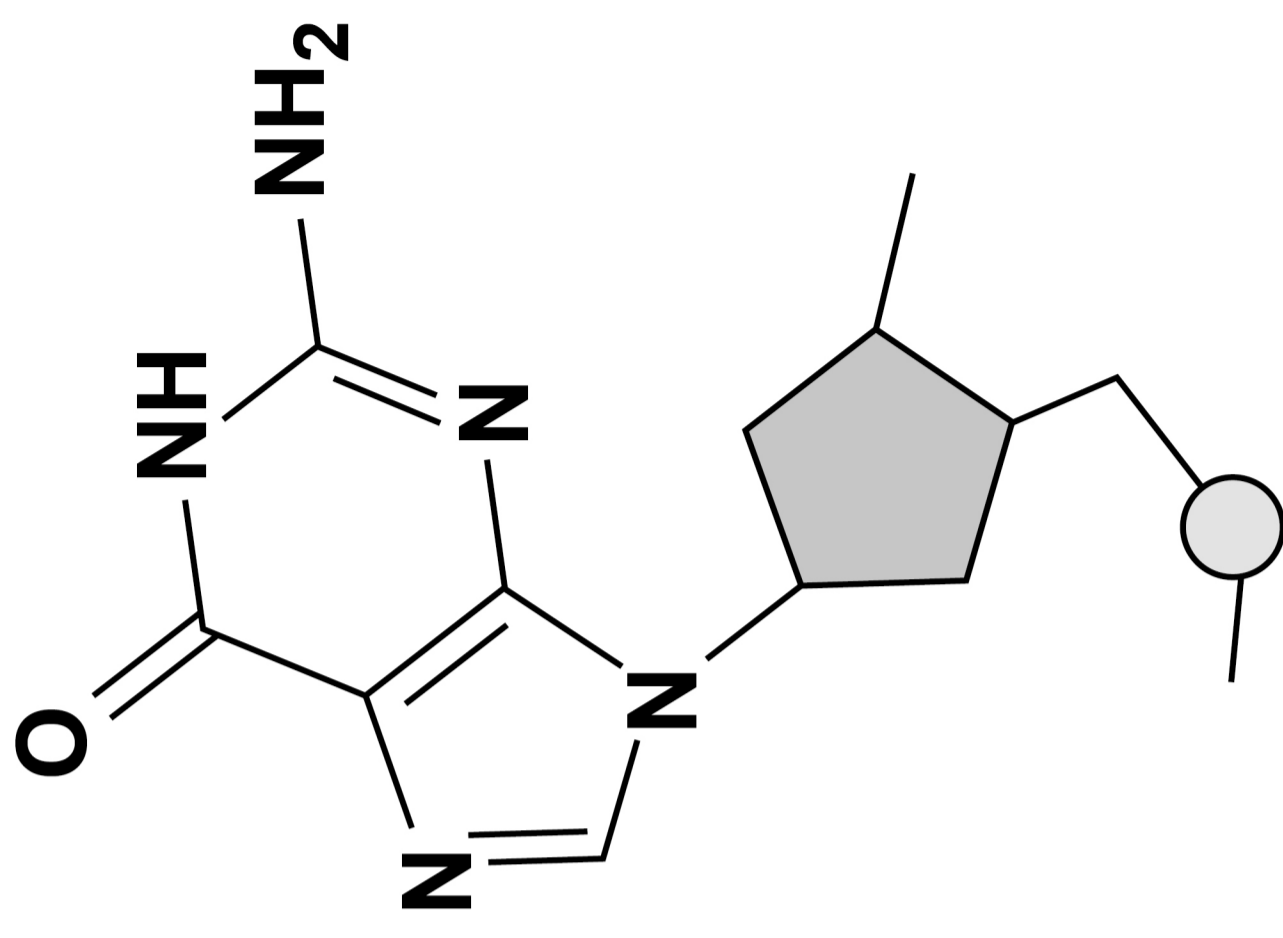
**20**

**FIGURE 1, on the opposite page, represents two adjacent guanine nucleotides in DNA.**

**Complete FIGURE 1 to show how the platinum complex forms a cross-link between the guanine nucleotides. [2 marks]**

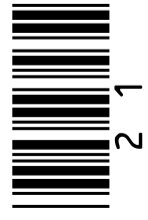


**FIGURE 1**



**21**

**[Turn over]**



**An experiment is done to investigate the rate of reaction in Question 04.2.**

**0 4 . 4**

**During the experiment the concentration of cisplatin is measured at one-minute intervals.**

**Explain how graphical methods can be used to process the measured results, to confirm that the reaction is first order.  
[3 marks]**

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**[Turn over]**



In another experiment, the effect of temperature on the rate of the reaction in Question 04.2 is investigated.

TABLE 1 shows the results.

TABLE 1

Temperature $T / \text{K}$	$\frac{1}{T} / \text{K}^{-1}$	Rate constant $k / \text{s}^{-1}$	$\ln k$
293	0.00341	$1.97 \times 10^{-8}$	-17.7
303	0.003330	$8.61 \times 10^{-8}$	-16.3
313	0.00319	$3.43 \times 10^{-7}$	-14.9
318		$6.63 \times 10^{-7}$	
323	0.00310	$1.26 \times 10^{-6}$	-13.6

0 4 . 5

Complete TABLE 1. [2 marks]





**04.6**

The Arrhenius equation can be written in the form

$$\ln k = \frac{-E_a}{RT} + \ln A$$

Use the data in TABLE 1 to plot a graph of  $\ln k$  against  $\frac{1}{T}$  on the grid in FIGURE 2, on page 27.

Calculate the activation energy,  $E_a$ , in  $\text{kJ mol}^{-1}$

The gas constant,  $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$   
[5 marks]

[Turn over]



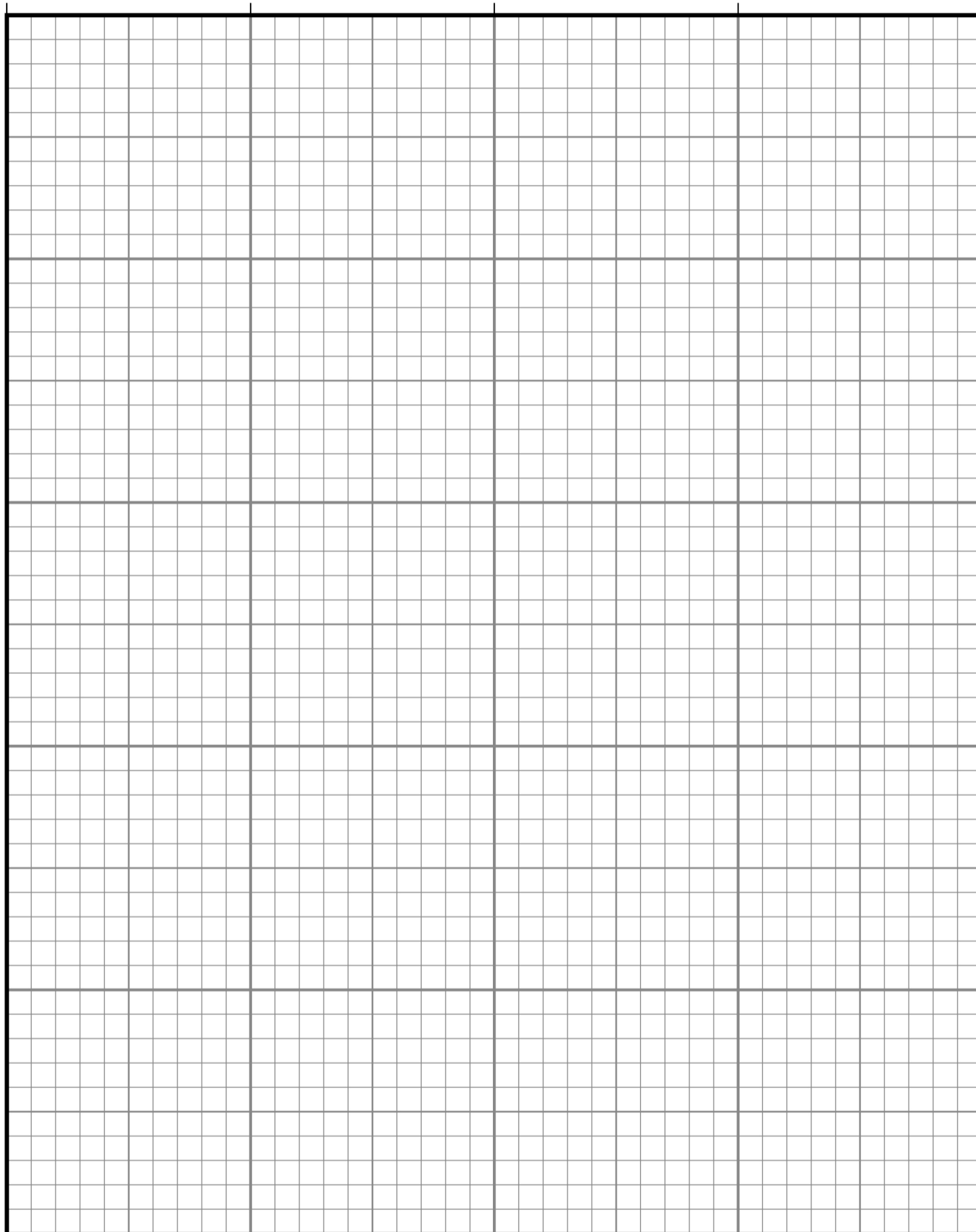
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## FIGURE 2

$$\frac{1}{T} / \text{K}^{-1}$$

0.00310 0.00320 0.00330 0.00340 0.00350

 $\ln k$  $E_a$  \_\_\_\_\_  $\text{kJ mol}^{-1}$ 

2 7

[Turn over]

15

0	5
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**A bomb calorimeter can be used for accurate determination of the heat change during combustion of a fuel.**

**A bomb calorimeter is a container of fixed volume that withstands the change in pressure during the reaction.**

**The fuel is mixed with pure oxygen in the calorimeter, ignited and the temperature change is recorded.**

**The total heat capacity ( $C_{cal}$ ) of the calorimeter is calculated using a fuel for which the heat change is known.**

**In an experiment to calculate  $C_{cal}$ , 2.00 g of hexane ( $M_r = 86.0$ ) is ignited.**

**A temperature change ( $\Delta T$ ) of 12.4 °C is recorded.**



Under the conditions of the experiment, 1.00 mol of hexane releases 4154 kJ of energy when combusted.

0 5 . 1

The heat energy released in the calorimeter,  $q = C_{\text{cal}} \Delta T$

Calculate the heat capacity ( $C_{\text{cal}}$ ) in  $\text{kJ K}^{-1}$  [3 marks]

$C_{\text{cal}}$  \_\_\_\_\_  $\text{kJ K}^{-1}$

[Turn over]



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**05.2**

When the experiment is repeated with 2.00 g of octane ( $M_r = 114.0$ ) the temperature change recorded is 12.2 °C

Calculate the heat change, in  $\text{kJ mol}^{-1}$ , for octane in this combustion reaction.

If you were unable to calculate a value for  $C_{\text{cal}}$  in Question 05.1, use  $6.52 \text{ kJ K}^{-1}$  (this is NOT the correct value). [2 marks]

Heat change \_\_\_\_\_  $\text{kJ mol}^{-1}$

[Turn over]



**05.3**

**State why the heat change calculated from the bomb calorimeter experiment is NOT an enthalpy change. [1 mark]**

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**05.4**

**The thermometer used to measure the temperature change of 12.2 °C in Question 05.2 has an uncertainty of  $\pm 0.1$  °C in each reading.**

**Calculate the percentage uncertainty in this use of the thermometer.**





**Suggest ONE change to this experiment that decreases the percentage uncertainty while using the same thermometer.**  
**[2 marks]**

**Percentage uncertainty** \_\_\_\_\_  
**Change** \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**[Turn over]**

8



0	6
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**Standard electrode potentials are measured by comparison with the standard hydrogen electrode.**

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**State the substances and conditions needed in a standard hydrogen electrode.  
[3 marks]**

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**It is difficult to ensure consistency with the setup of a standard hydrogen electrode. A  $\text{Cu}^{2+}(\text{aq}) / \text{Cu}(\text{s})$  electrode ( $E^\ominus = +0.34 \text{ V}$ ) can be used as a secondary standard.**

**A student does an experiment to measure the standard electrode potential for the  $\text{TiO}^{2+}(\text{aq}) / \text{Ti}(\text{s})$  electrode using the  $\text{Cu}^{2+}(\text{aq}) / \text{Cu}(\text{s})$  electrode as a secondary standard.**

**A suitable solution containing the acidified  $\text{TiO}^{2+}(\text{aq})$  ion is formed when titanium(IV) oxysulfate ( $\text{TiOSO}_4$ ) is dissolved in  $0.50 \text{ mol dm}^{-3}$  sulfuric acid to make  $50 \text{ cm}^3$  of solution.**

**[Turn over]**



**06.2**

**Describe an experiment the student does to show that the standard electrode potential for the  $\text{TiO}^{2+}(\text{aq}) / \text{Ti}(\text{s})$  electrode is  $-0.88 \text{ V}$**

**The student is provided with:**

- the  $\text{Cu}^{2+}(\text{aq}) / \text{Cu}(\text{s})$  electrode set up ready to use**
- solid titanium(IV) oxysulfate ( $M_r = 159.9$ )**
- $0.50 \text{ mol dm}^{-3}$  sulfuric acid**
- a strip of titanium**
- laboratory apparatus and chemicals.**

**Your answer should include details of:**

- how to prepare the solution of acidified  $\text{TiO}^{2+}(\text{aq})$**
- how to connect the electrodes**
- measurements taken**















0	6	.	3
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**Give the half-equation for the electrode reaction in the  $\text{TiO}^{2+}$  (aq) / Ti(s) electrode in acidic conditions. [1 mark]**

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**[Turn over]**



06.4

**TABLE 2 shows some electrode potential data.**

**TABLE 2**

<b>Electrode reaction</b>	<b><math>E^\ominus / \text{V}</math></b>
<b><math>2 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightarrow \text{H}_2(\text{g})</math></b>	<b>0.00</b>
<b><math>\text{Cu}^{2+}(\text{aq}) + 2 \text{e}^- \rightarrow \text{Cu}(\text{s})</math></b>	<b>+0.34</b>
<b><math>\text{NO}_3^-(\text{aq}) + 4 \text{H}^+(\text{aq}) + 3 \text{e}^- \rightarrow \text{NO}(\text{g}) + 2 \text{H}_2\text{O}(\text{l})</math></b>	<b>+0.96</b>

**Use the data in TABLE 2 to explain why copper does NOT react with most acids but does react with nitric acid.**

**Give an equation for the reaction between copper and nitric acid. [3 marks]**



**Explanation**

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**Equation**

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**[Turn over]**

13



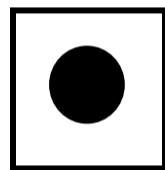
**SECTION B**

**Answer ALL questions in this section.**

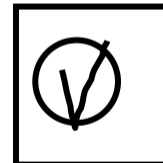
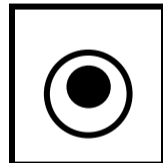
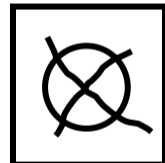
**Only ONE answer per question is allowed.**

**For each question completely fill in the circle alongside the appropriate answer.**

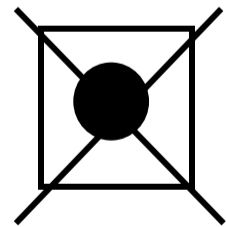
**CORRECT METHOD**



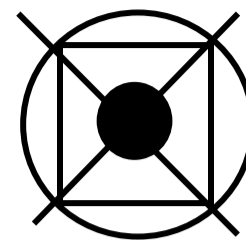
**WRONG METHODS**



**If you want to change your answer you must cross out your original answer as shown.**



**If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.**



**You may do your working in the blank space around each question but this will not be marked. Do NOT use additional sheets for this working.**

**[Turn over]**



0	7
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When heated, a sample of potassium chlorate(V) ( $\text{KClO}_3$ ) produced  $67.2 \text{ cm}^3$  of oxygen, measured at 298 K and 110 kPa



What is the amount, in moles, of potassium chlorate(V) that has decomposed?

The gas constant,

$$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1} \quad [1 \text{ mark}]$$

A  $9.95 \times 10^{-4}$

B  $1.99 \times 10^{-3}$

C  $2.99 \times 10^{-3}$

D  $4.48 \times 10^{-3}$





0	8
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**Which has a bond angle of  $109.5^\circ$ ?  
[1 mark]**

**A C (diamond)**

**B C (graphite)**

**C  $\text{NH}_2^-$**

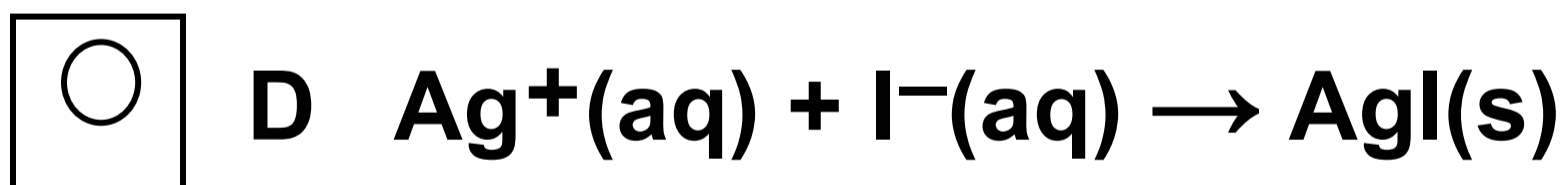
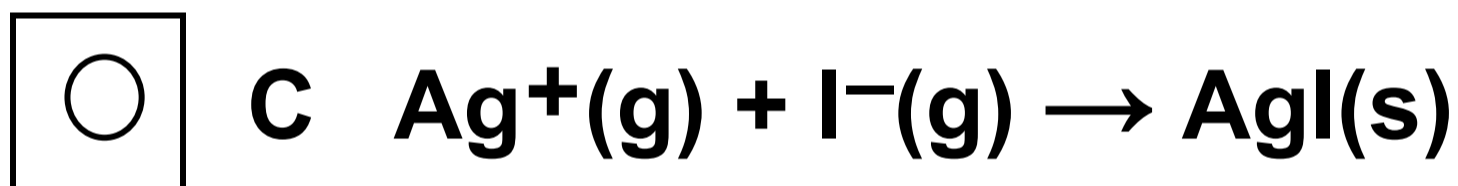
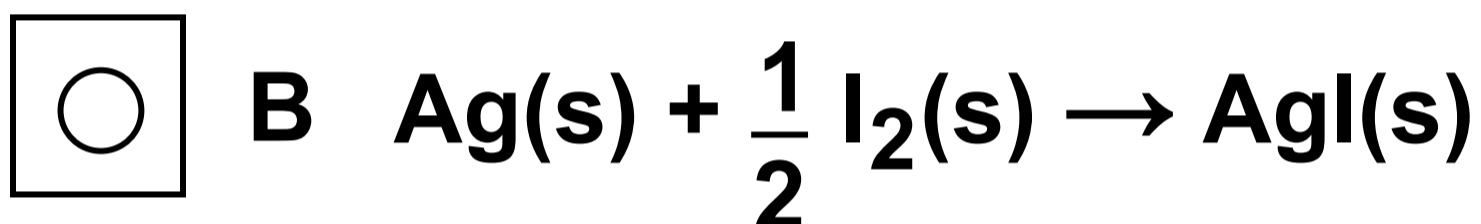
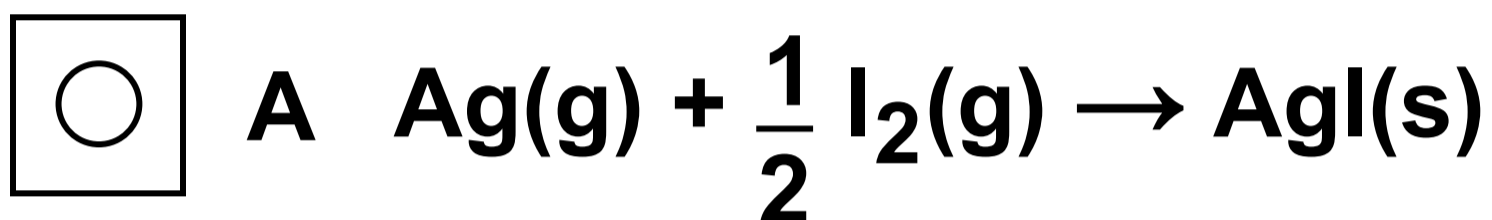
**D  $\text{NH}_3$**

**[Turn over]**



09

Which reaction has an enthalpy change equal to the standard enthalpy of formation of silver iodide? [1 mark]



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**[Turn over]**



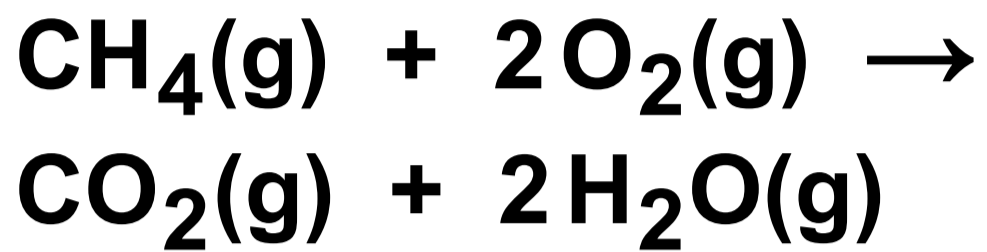
1	0
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Some bond enthalpies are given.

Bond	C–H	O–H	O=O	C=O
Bond enthalpy/ kJ mol <sup>-1</sup>	412	463	496	743



Which is the enthalpy change of this reaction in  $\text{kJ mol}^{-1}$ ?



[1 mark]

**A +698**

**B +228**

**C -228**

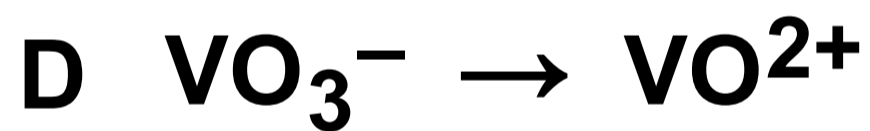
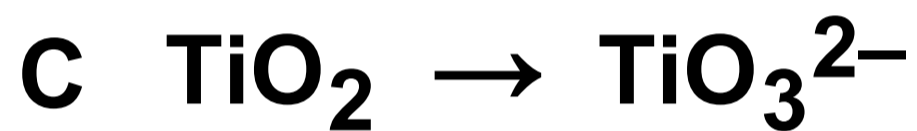
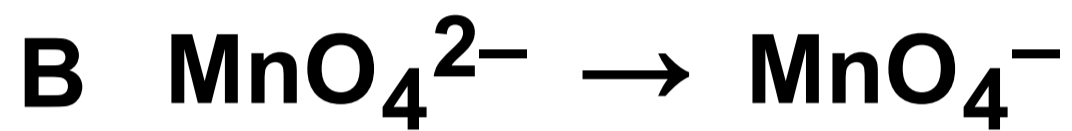
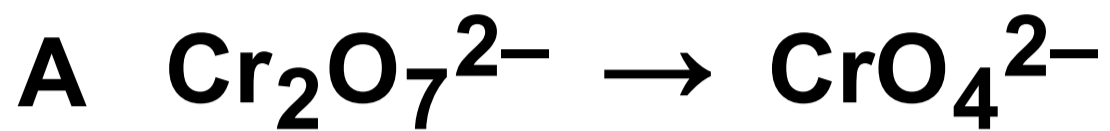
**D -698**

[Turn over]



1	1
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In which conversion is the metal reduced? [1 mark]



1	2
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The rate expression for the reaction between X and Y is

$$\text{rate} = k [\text{X}]^2 [\text{Y}]$$

Which statement is correct? [1 mark]

**A** The rate constant has units  $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$

**B** The rate of the reaction is halved if the concentration of X is halved and the concentration of Y is doubled.

**C** The rate increases by a factor of 16 if the concentration of X is tripled and the concentration of Y is doubled.

**D** The rate constant is independent of temperature.



[Turn over]

1	3
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**Which statement about pH is correct?**  
**[1 mark]**

- A** The pH of a weak base is independent of temperature.
- B** At temperatures above 298 K, the pH of pure water is less than 7.
- C** The pH of  $2.0 \text{ mol dm}^{-3}$  nitric acid is approximately 0.30
- D** The pH of  $0.10 \text{ mol dm}^{-3}$  sulfuric acid is greater than that of  $0.10 \text{ mol dm}^{-3}$  hydrochloric acid.





1	4
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A  $0.10 \text{ mol dm}^{-3}$  aqueous solution of an acid is added slowly to  $25 \text{ cm}^3$  of a  $0.10 \text{ mol dm}^{-3}$  aqueous solution of a base.

Which acid–base pair has the highest pH at the equivalence point? [1 mark]

**A**  $\text{CH}_3\text{COOH}$  and  $\text{NaOH}$

**B**  $\text{CH}_3\text{COOH}$  and  $\text{NH}_3$

**C**  $\text{HCl}$  and  $\text{NaOH}$

**D**  $\text{HCl}$  and  $\text{NH}_3$

[Turn over]



1	5
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**In the test for a halide ion in aqueous solution, dilute nitric acid is added before the addition of silver nitrate solution.**

**Why is nitric acid added? [1 mark]**

**A It increases the concentration of nitrate ions.**

**B It prevents the precipitation of silver compounds other than halides.**

**C It prevents the silver nitrate being precipitated.**

**D It provides the acidic solution required for precipitation.**



1	6
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**Which shows the major product(s) formed when chlorine reacts with cold, dilute, aqueous sodium hydroxide?  
[1 mark]**

**A NaCl only**

**B NaClO only**

**C NaCl and NaClO**

**D NaCl and NaClO<sub>3</sub>**

**[Turn over]**



1	7
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**Which shows the electron configuration of an atom of a transition metal?**  
**[1 mark]**

**A** [Ar] 4s<sup>2</sup>3d<sup>0</sup>

**B** [Ar] 4s<sup>2</sup>3d<sup>8</sup>

**C** [Ar] 4s<sup>2</sup>3d<sup>10</sup>

**D** [Ar] 4s<sup>2</sup>3d<sup>10</sup>4p<sup>1</sup>



1	8
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**Which will NOT act as a ligand in the formation of a complex ion? [1 mark]**

**A**  $\text{CH}_4$

**B**  $\text{CO}$

**C**  $\text{H}_2\text{O}$

**D**  $\text{NH}_3$

**[Turn over]**



19

Which shows the correct oxidation state and co-ordination number of cobalt in  $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$ ? [1 mark]

		oxidation state	co-ordination number
<input type="radio"/>	A	+2	5
<input type="radio"/>	B	+2	6
<input type="radio"/>	C	+3	5
<input type="radio"/>	D	+3	6



2	0
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**Which statement is NOT correct?**  
**[1 mark]**

- A**  $\text{CuCl}_4^{2-}$  is square planar.
- B**  $\text{NH}_4^+$  is tetrahedral.
- C**  $[\text{Co}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]^{2+}$  is octahedral.
- D**  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$  is octahedral.

**[Turn over]**



2	1
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**Which compound decolourises acidified potassium manganate(VII) solution? [1 mark]**

**A  $\text{Al}_2(\text{SO}_4)_3$**

**B  $\text{CuSO}_4$**

**C  $\text{FeSO}_4$**

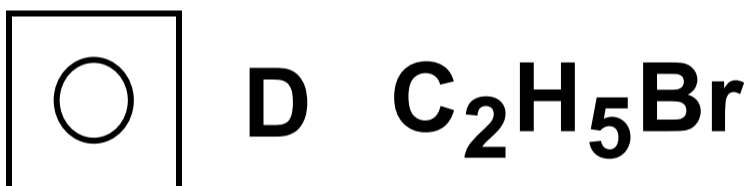
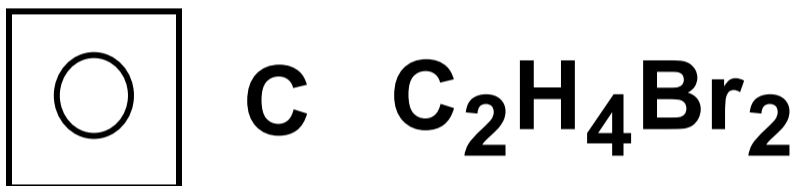
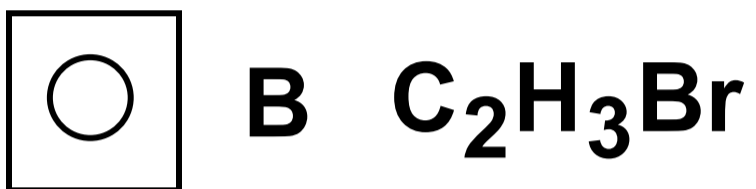
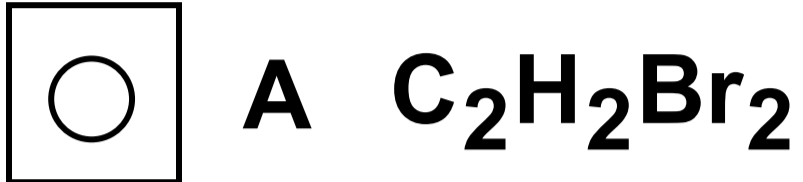
**D  $\text{Fe}_2(\text{SO}_4)_3$**





2	2
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Which has *E-Z* isomers? [1 mark]

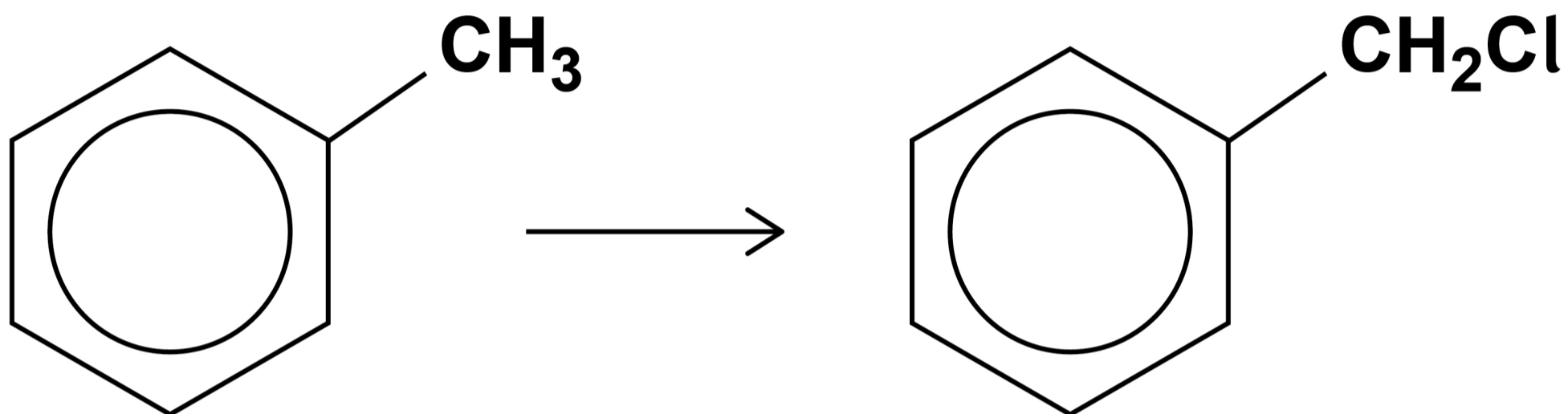


[Turn over]



2	3
---	---

**Which is the mechanism for this conversion?**



**[1 mark]**

**A Addition-elimination**

**B Electrophilic substitution**

**C Free-radical substitution**

**D Nucleophilic substitution**

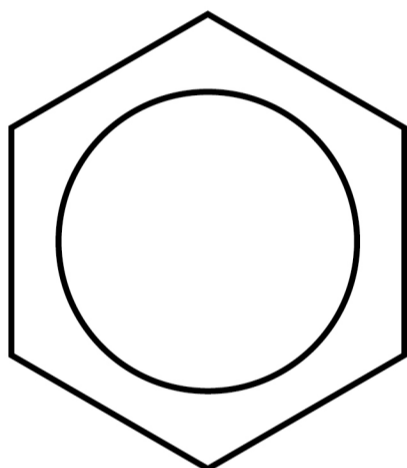


2	4
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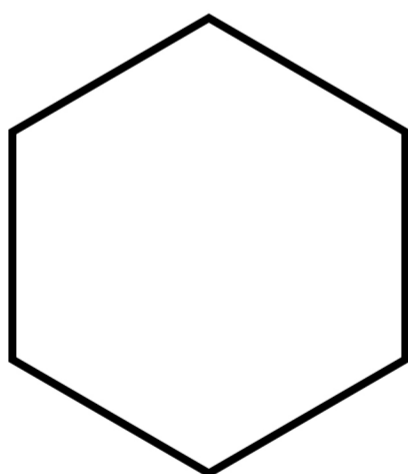
**Which compound decolourises bromine water in the absence of sunlight?**  
**[1 mark]**

**A**  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$

**B**



**C**



**D**  $\text{CH}_3\text{CH}_2\text{CHCH}_2$

**[Turn over]**



2	5
---	---

**Which compound reacts to form a ketone when warmed with an acidified solution of potassium dichromate(VI)?**  
[1 mark]

**A**  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$

**B**  $(\text{CH}_3)_2\text{CHOH}$

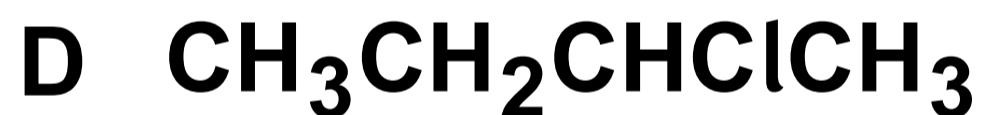
**C**  $\text{CH}_3\text{CH}_2\text{CHO}$

**D**  $(\text{CH}_3)_2\text{CHCOOH}$



2	6
---	---

Which does NOT contain an asymmetric carbon atom? [1 mark]

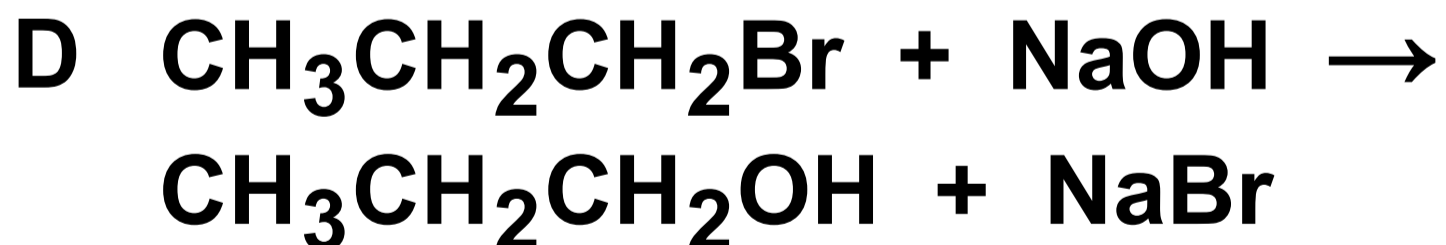
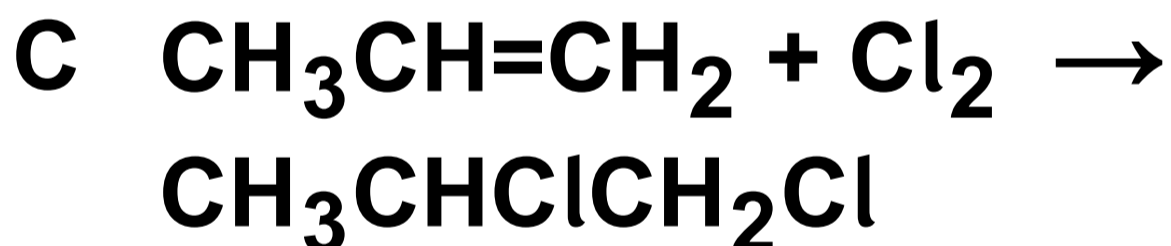
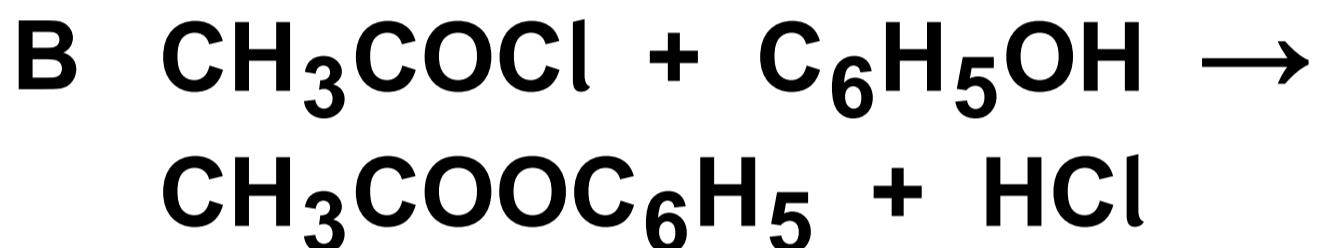
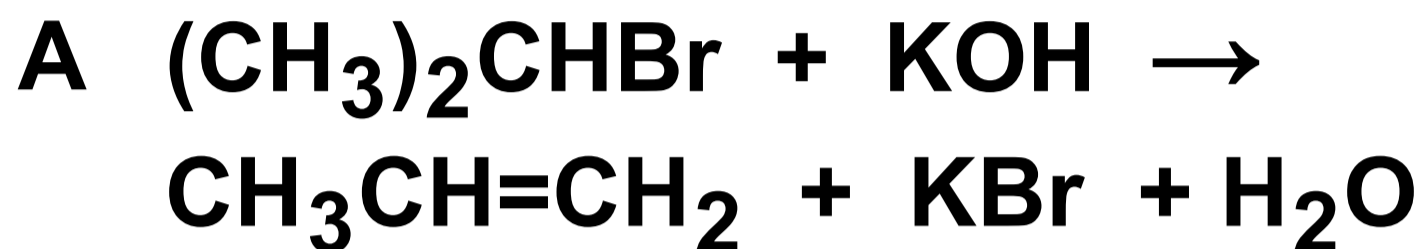


[Turn over]



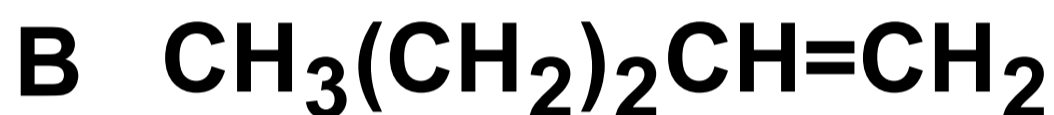
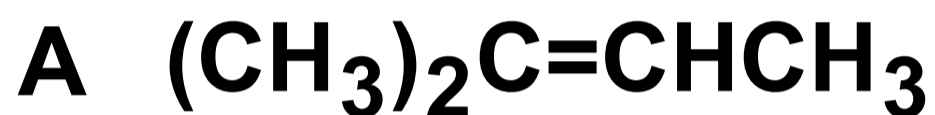
27

Which reaction involves addition-elimination? [1 mark]



2	8
---	---

**Which compound reacts with hydrogen bromide to give 2-bromo-3-methylbutane as the major product? [1 mark]**



**[Turn over]**



2	9
---	---

Which forms a polymer with  $\text{ClOC}(\text{CH}_2)_8\text{COCl}$ ? [1 mark]

**A**  $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$

**B**  $(\text{CH}_3\text{CO})_2\text{O}$

**C**  $\text{CH}_3\text{CH}_2\text{CONH}_2$

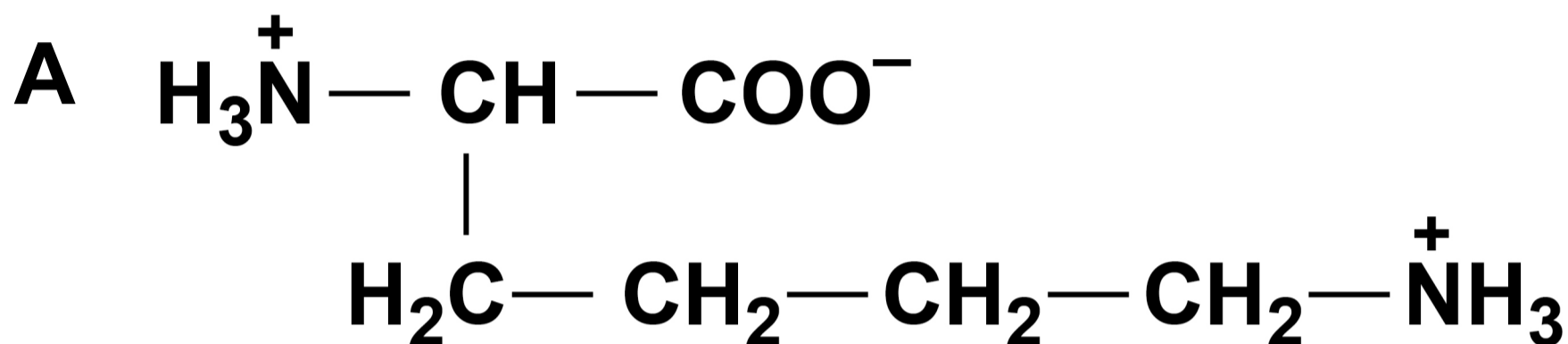
**D**  $\text{NH}_2\text{CH}_2\text{COOH}$

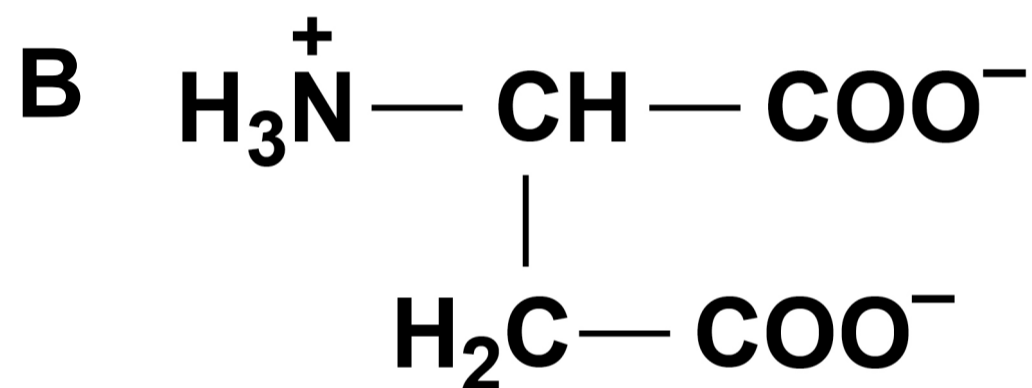


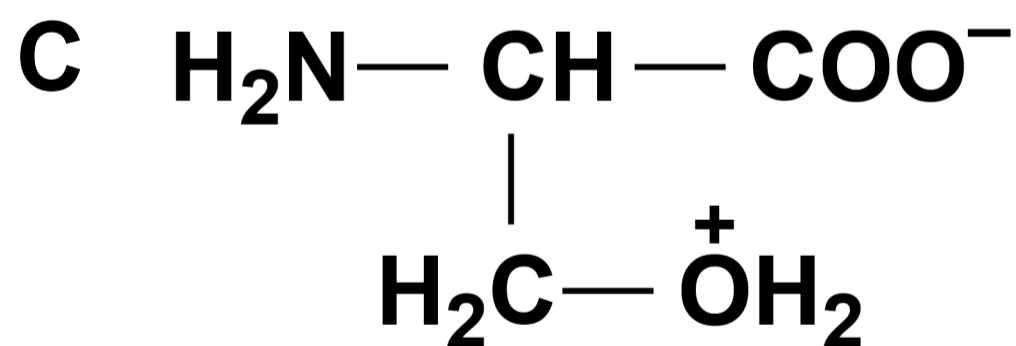


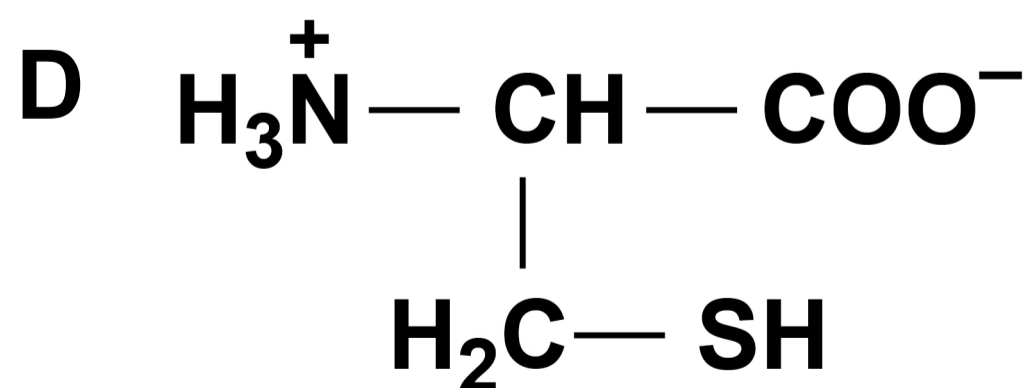
30

Which structure shows the zwitterion of an amino acid? [1 mark]







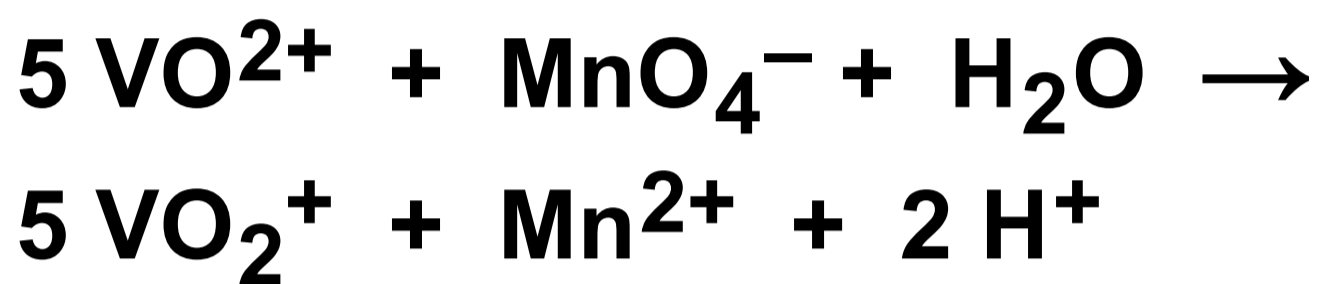


[Turn over]



3	1
---	---

What is the minimum volume, in  $\text{cm}^3$ , of  $0.02 \text{ mol dm}^{-3}$   $\text{KMnO}_4$  solution needed to oxidise  $0.01 \text{ mol}$  of  $\text{VO}^{2+}$ ?



[1 mark]

A 10

B 50

C 100

D 200



3	2
---	---

Which is the concentration of NaOH(aq), in mol dm<sup>-3</sup>, that has pH = 14.30?

$K_w = 1.00 \times 10^{-14}$  mol<sup>2</sup> dm<sup>-6</sup> at 25 °C  
[1 mark]

A -1.16

B  $5.01 \times 10^{-15}$

C  $2.00 \times 10^{14}$

D 2.00

[Turn over]



3	3
---	---

**What are the units of the rate constant for a third order reaction?**  
**[1 mark]**

**A**  $\text{mol dm}^{-3} \text{s}^{-1}$

**B**  $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$

**C**  $\text{mol}^2 \text{dm}^{-6} \text{s}^{-1}$

**D**  $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$



3	4
---	---

**What is the pH of  $0.015 \text{ mol dm}^{-3}$  sulfuric acid? [1 mark]**

**A     $-1.82$**

**B     $-1.52$**

**C     $1.52$**

**D     $1.82$**

**[Turn over]**



3	5
---	---

**Which compound is formed when phenyl benzenecarboxylate is hydrolysed under acidic conditions?**  
[1 mark]

**A  $C_6H_5CH_2OH$**

**B  $C_6H_5CHO$**

**C  $C_6H_5COCH_3$**

**D  $C_6H_5COOH$**



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**[Turn over]**



3	6
---	---

**A student rinsed the apparatus before starting an acid-base titration.**

**The results of the titration showed that the volume of acid added from the burette was larger than expected.**

**Which is a possible reason for this?  
[1 mark]**

**A The conical flask was rinsed with water before the titration.**

**B The walls of the conical flask were rinsed with water during the titration.**

**C The pipette was rinsed only with water.**

**D The burette was rinsed only with water.**

**END OF QUESTIONS**











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Question	Mark
1	
2	
3	
4	
5	
6	
Section B	
<b>TOTAL</b>	

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