

Surname _____

Other Names _____

Centre Number _____

Candidate Number _____

Candidate Signature _____

I declare this is my own work.

A-level

CHEMISTRY

Paper 3

7405/3

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]



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
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A value for enthalpy of solution can be determined in two ways:

- **from a cycle, using lattice enthalpy and enthalpies of hydration**
- **from the results of a calorimetry experiment.**

0	1	.	1
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Define the term enthalpy of lattice dissociation.
[2 marks]



01.2

The enthalpy of solution for ammonium nitrate is the enthalpy change for the reaction shown.



$$\Delta H = +26 \text{ kJ mol}^{-1}$$

TABLE 1

	$\text{NH}_4^+(\text{g})$	$\text{NO}_3^-(\text{g})$
Enthalpy of hydration $\Delta_{\text{hyd}}H$ / kJ mol^{-1}	-307	-314

Draw a suitably labelled cycle and use it, with data from TABLE 1, to calculate the enthalpy of lattice dissociation for ammonium nitrate. [3 marks]

Enthalpy of lattice dissociation

kJ mol⁻¹

[Turn over]



0	1	.	3
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A student does an experiment to determine a value for the enthalpy of solution for ammonium nitrate.

The student uses this method.

- Measure 25.0 cm³ of distilled water in a measuring cylinder.
- Pour the water into a beaker.
- Record the temperature of the water in the beaker.
- Add 4.00 g of solid NH₄NO₃ to the water in the beaker.
- Stir the solution and record the lowest temperature reached.

TABLE 2 shows the student's results.

TABLE 2

Initial temperature / °C	20.2
Lowest temperature / °C	12.2



Calculate the enthalpy of solution, in kJ mol^{-1} , for ammonium nitrate in this experiment.

Assume that the specific heat capacity of the solution, $c = 4.18 \text{ J K}^{-1} \text{ g}^{-1}$

Assume that the density of the solution = 1.00 g cm^{-3}
[3 marks]

Enthalpy of solution _____ kJ mol^{-1}

[Turn over]



0	1	.	4
---	---	---	---

The uncertainty in each of the temperature readings from the thermometer used in this experiment is $\pm 0.1^{\circ}\text{C}$

Calculate the percentage uncertainty in the temperature change in this experiment. [1 mark]

Percentage uncertainty _____

0	1	.	5
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Suggest a change to the student's method, using the same apparatus, that would reduce the percentage uncertainty in the temperature change.

Give a reason for your answer. [2 marks]

Change _____



Reason _____

0 1 . 6

Another student obtained a value of $+15 \text{ kJ mol}^{-1}$ using the same method.

Suggest the main reason for the difference between this experimental value for the enthalpy of solution and the correct value of $+26 \text{ kJ mol}^{-1}$
[1 mark]

[Turn over]



01.7

TABLE 3 shows some entropy data at 298 K

TABLE 3

	Entropy $S / \text{J K}^{-1} \text{mol}^{-1}$
$\text{NH}_4\text{NO}_3(\text{s})$	151
$\text{NH}_4^+(\text{aq})$	113
$\text{NO}_3^-(\text{aq})$	146

Calculate a value for the Gibbs free-energy change (ΔG), at 298 K, for the reaction when ammonium nitrate dissolves in water.



$$\Delta H = +26 \text{ kJ mol}^{-1}$$

Use data from TABLE 3 and the value of ΔH from the equation.

Assume for the solvent, water, that the entropy change, $\Delta S = 0$

Explain what the calculated value of ΔG indicates about the feasibility of this reaction at 298 K
[4 marks]



ΔG _____ kJ mol^{-1}

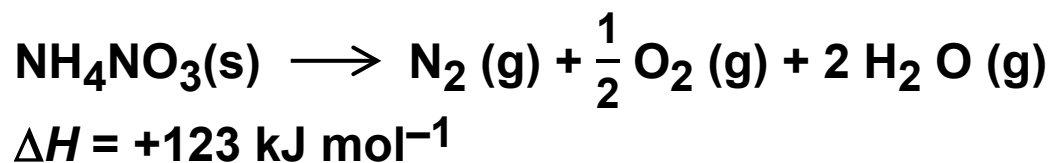
Explanation _____

[Turn over]



0	1	.	8
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Ammonium nitrate decomposes as shown.



The entropy change (ΔS) for this reaction
is $+144 \text{ J K}^{-1} \text{ mol}^{-1}$

Calculate the temperature at which this reaction
becomes feasible. [2 marks]

Temperature _____ K



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[Turn over]



02

Tschemmigite is a hydrated, water-soluble mineral, with relative formula mass of 453.2

The formula of tschemmigite can be represented as $M \cdot x H_2O$, where M represents all the ions present.

TABLE 4 shows its composition by mass.

TABLE 4

Element	% by mass
N	3.09
H	6.18
Al	5.96
S	14.16
O	70.61

In an analysis, it is found that the mineral contains the ions NH_4^+ , Al^{3+} and SO_4^{2-}

Calculate the empirical formula of tschemmigite and the value of x in $M \cdot xH_2O$

Describe the tests, with their results, including ionic equations, that would confirm the identities of the ions present. [6 marks]





[illegible]

6



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[Turn over]



0	3
---	---

Under suitable conditions, 2-bromobutane reacts with sodium hydroxide to produce a mixture of five products, A, B, C, D and E.

Products A, B and C are alkenes.

A is a structural isomer of B and C.

A does not exhibit stereoisomerism.

B and C are a pair of stereoisomers.

Products D and E are alcohols.

D and E are a pair of enantiomers.

0	3	.	1
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Give the names of the TWO concurrent mechanisms responsible for the formation of the alkenes and the alcohols. [2 marks]

Mechanism to form alkenes

Mechanism to form alcohols



0	3	.	2
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Define the term stereoisomers. [2 marks]

0	3	.	3
---	---	---	---

Deduce the name of isomer A.

**Explain why A does NOT exhibit stereoisomerism.
[2 marks]**

Name _____

Explanation _____

[Turn over]



0	3	.	4
---	---	---	---

Outline the mechanism for the reaction of 2-bromobutane with sodium hydroxide to form alkene A. [3 marks]

0	3	.	5
---	---	---	---

Deduce the name of isomer B and the name of isomer C.

Explain the origin of the stereoisomerism in B and C. [2 marks]

Names _____



Explanation _____

03.6

Draw 3D representations of enantiomers D and E to show how their structures are related. [2 marks]

[Turn over]



0	3	.	7
---	---	---	---

A student compares the rates of hydrolysis of 1-chlorobutane, 1-bromobutane and 1-iodobutane.

The suggested method is:

- **add equal volumes of the three halogenoalkanes to separate test tubes**
- **add equal volumes of aqueous silver nitrate to each test tube**
- **record the time taken for a precipitate to appear in each test tube.**

State and explain the order in which precipitates appear. [2 marks]

Order in which precipitates appear



Explanation

[Turn over]

15



0	4
---	---

Hydrogen peroxide solution decomposes to form water and oxygen.



The reaction is catalysed by manganese(IV) oxide.

A student determines the order of this reaction with respect to hydrogen peroxide. The student uses a continuous monitoring method in the experiment.

The student places hydrogen peroxide solution in a conical flask with the catalyst and uses a gas syringe to collect the oxygen formed. The student records the volume of oxygen every 10 seconds for 100 seconds.

0	4	.	1
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Explain why the reaction is fastest at the start.
[2 marks]

[Turn over]

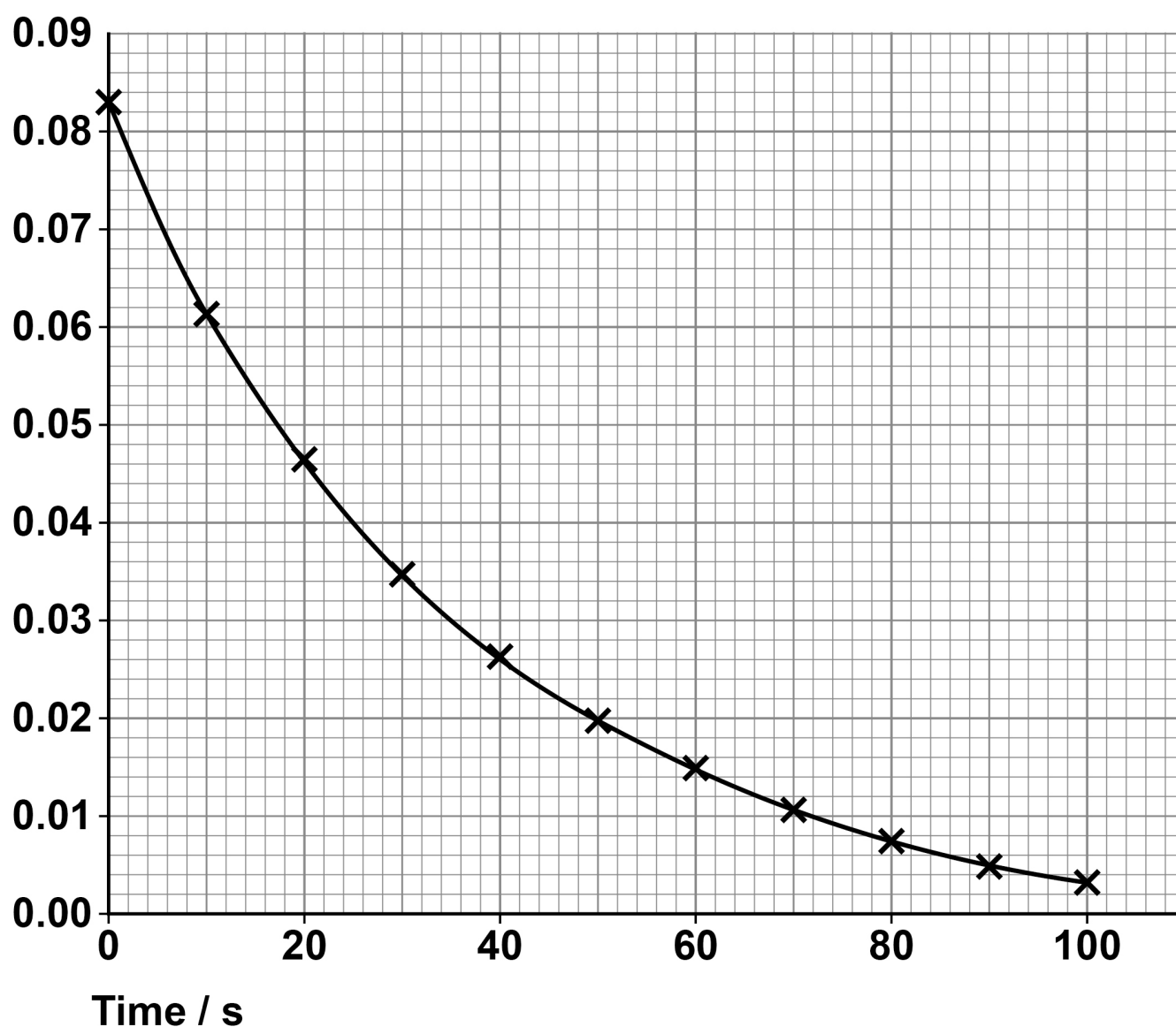


04.2

The graph in FIGURE 1 shows how the concentration of hydrogen peroxide changes with time in this experiment.

FIGURE 1

$[\text{H}_2\text{O}_2] / \text{mol dm}^{-3}$



Tangents to the curve in FIGURE 1 can be used to determine rates of reaction.

Draw a tangent to the curve when the concentration of hydrogen peroxide solution is 0.05 mol dm^{-3}

Use your tangent to calculate the gradient of the curve at this point. [2 marks]

Gradient _____ $\text{mol dm}^{-3} \text{ s}^{-1}$

[Turn over]



04.3

The concentration of hydrogen peroxide solution at time t during the experiment can be calculated using this expression.

$$[\text{H}_2\text{O}_2]_t = [\text{H}_2\text{O}_2]_{\text{initial}} \left(\frac{V_{\text{max}} - V_t}{V_{\text{max}}} \right)$$

$[\text{H}_2\text{O}_2]_t$ = concentration of hydrogen peroxide solution at time t / mol dm⁻³

$[\text{H}_2\text{O}_2]_{\text{initial}}$ = concentration of hydrogen peroxide solution at the start / mol dm⁻³

V_{max} = total volume of oxygen gas collected during the whole experiment / cm³

V_t = volume of oxygen gas collected at time t / cm³

In this experiment, $V_{\text{max}} = 100 \text{ cm}^3$

Use FIGURE 1, on page 28, and the expression to calculate $[\text{H}_2\text{O}_2]_t$ when 20 cm³ of oxygen has been collected. [2 marks]



$[\text{H}_2\text{O}_2]_t$ _____ mol dm^{-3}

[Turn over]





TABLE 5 shows data from a similar experiment.

TABLE 5

$[\text{H}_2\text{O}_2] / \text{mol dm}^{-3}$	0.02	0.03	0.05	0.07	0.09
Rate / $\text{mol dm}^{-3} \text{ s}^{-1}$	0.00049	0.00073	0.00124	0.00168	0.00219

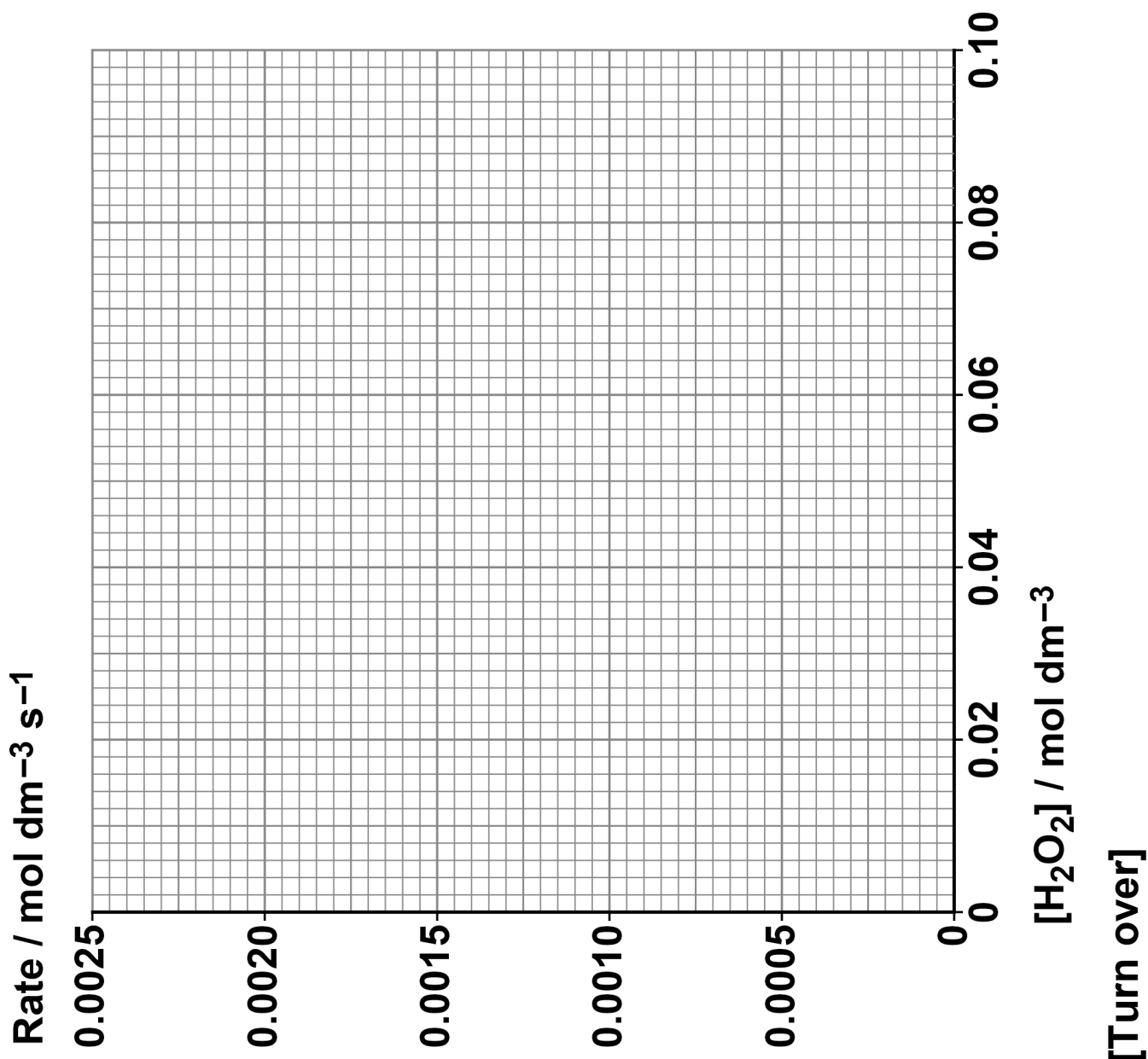
0 4 . 4

Plot the data from TABLE 5 on the grid in FIGURE 2, on the opposite page.

Draw a line of best fit. [2 marks]



FIGURE 2



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0 4 . 5

Use FIGURE 2, on page 33, to determine the order of reaction with respect to H_2O_2

State how the graph shows this order. [2 marks]

Order

How the graph shows this order

[Turn over]

0	5
---	---

This question is about catalysis.

0	5	.	1
---	---	---	---

Zeolites are used as heterogeneous catalysts in the catalytic cracking of alkanes.

Tetradecane ($C_{14}H_{30}$) can be cracked to form octane and a cycloalkane.

Give an equation for this reaction.

State the meaning of the term heterogeneous.

[2 marks]

Equation

Heterogeneous



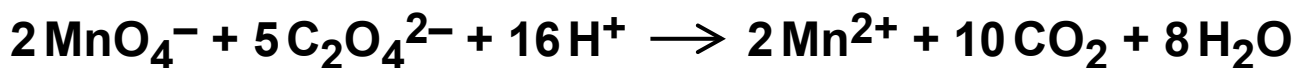
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[Turn over]



0	5	.	2
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A student determines the concentration of ethanedioate ions in an acidified solution by titration with potassium manganate(VII) solution.



The mixture is warmed before the addition of potassium manganate(VII) solution because the reaction is slow at first. When more potassium manganate(VII) solution is added, the mixture goes colourless quickly due to the presence of an autocatalyst.

Explain the meaning of the term autocatalyst.

Explain, using equations where appropriate, why the reaction is slow at first and then goes quickly.

[6 marks]



05.3

The reaction between peroxodisulfate ions and iodide ions in aqueous solution can be catalysed by Co^{2+} ions.

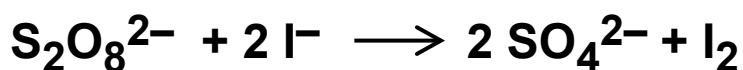


TABLE 6 gives relevant standard electrode potentials.

TABLE 6

Electrode half-equation	E^\ominus / V
$\text{S}_2\text{O}_8^{2-}(\text{aq}) + 2 \text{e}^- \longrightarrow 2 \text{SO}_4^{2-}(\text{aq})$	+2.01
$\text{Co}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Co}^{2+}(\text{aq})$	+1.82
$\text{I}_2(\text{aq}) + 2 \text{e}^- \longrightarrow 2 \text{I}^-(\text{aq})$	+0.54



Use the electrode potential data to suggest how Co^{2+} catalyses the reaction. [3 marks]

[illegible]

[Turn over]

11



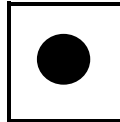
SECTION B

Answer ALL questions in this section.

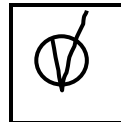
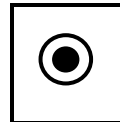
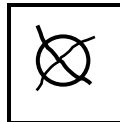
Only ONE answer per question is allowed.

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

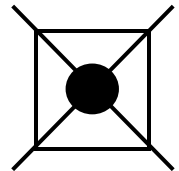
CORRECT METHOD



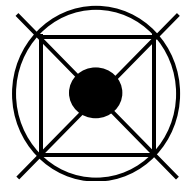
WRONG METHODS



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.**



0	6
---	---

Which atom in the ground state contains at least one unpaired p electron? [1 mark]

☐

A Na

☐

B Ne

☐

C O

☐

D Sc

[Turn over]



0	7
---	---

Complete combustion of 0.0100 mol of an organic acid produced 0.0200 mol of carbon dioxide.

The same amount of the acid required 20 cm³ of 1.00 mol dm⁻³ NaOH (aq) for neutralisation.

Which could be the formula of the acid? [1 mark]

☐

A HCOOH

☐

B CH₃COOH

☐

C HOCCOOH

☐

D HOOCCH₂COOH



0	8
---	---

Which substance has NO delocalised electrons?
[1 mark]

☐

A graphite

☐

B methylbenzene

☐

C poly(propene)

☐

D sodium

[Turn over]



09

Consider the change that occurs in the shape of the curve for the distribution of molecular energies in a gas when the temperature of the gas is increased.

Which is a correct statement about the gas molecules at a higher temperature? [1 mark]

☐

A There are more molecules with any given energy.

☐

B There are more molecules with the mean energy.

☐

C There are more molecules with the most probable energy.

☐

D There is an increase in the most probable energy of the molecules.

1	0
---	---

Which of these oxidation states is correct? [1 mark]

☐

A Chlorine in Cl_2 is -1

☐

B Chromium in $\text{K}_2\text{Cr}_2\text{O}_7$ is $+7$

☐

C Fluorine in F_2O is -1

☐

D Hydrogen in NaH is $+1$

[Turn over]



1	1
---	---

Which change to a hydrogen electrode has NO effect on the electrode potential? [1 mark]

☐

A the concentration of the hydrogen ions

☐

B the pressure of the hydrogen

☐

C the surface area of the platinum electrode

☐

D the temperature of the acid

1	2
---	---

Some electrode potential data are shown.



Which is a correct statement about this cell?



[1 mark]

☐

A Electrons travel in the external circuit from zinc to lead.

☐

B The concentration of lead(II) ions increases.

☐

C The maximum EMF of the cell is 0.89 V

☐

D Zinc is deposited.

[Turn over]



13

Which can NOT function as a Brønsted-Lowry acid?
[1 mark]

☐

A CH_3COO^-

☐

B HCO_3^-

☐

C H_3O^+

☐

D NH_4^+



1	4
---	---

A strong acid H_2X dissociates in aqueous solution.



What is the pH of a $0.020 \text{ mol dm}^{-3}$ solution of this acid? [1 mark]

☐

A 1.00

☐

B 1.40

☐

C 1.70

☐

D 2.00

[Turn over]



1	5
---	---

Equal volumes of two solutions, each with the same concentration, are mixed together at 298 K

Which two solutions, when mixed, form a solution with a pH >7? [1 mark]

☐

A HCOOH and HCOOK

☐

B KOH and CH₃COOH

☐

C NH₃ and HCl

☐

D NH₄Cl and KCl

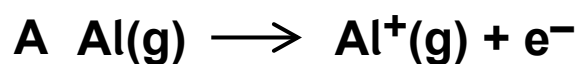
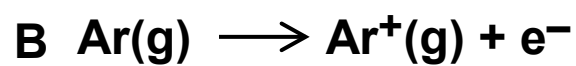
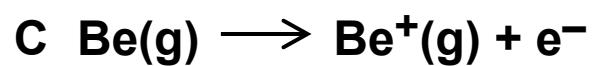
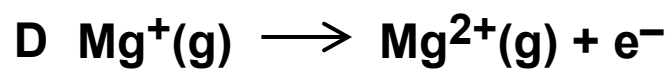


1	6
---	---

Which ionisation needs less energy than this process?



[1 mark]

☐☐☐☐

[Turn over]



17

Which statement is correct about the Group 1 elements? [1 mark]

☐

A The Cs^+ ion has a more negative enthalpy of hydration than the Rb^+ ion.

☐

B The enthalpy of atomisation for potassium is greater than the enthalpy of atomisation for sodium.

☐

C The melting point of potassium is higher than the melting point of sodium.

☐

D The second ionisation energy of rubidium is lower than the second ionisation energy of lithium.



1	8
---	---

A test for chloride ions in aqueous solution involves adding dilute nitric acid followed by aqueous silver nitrate.

What is the reason for adding the nitric acid? [1 mark]

☐

A To convert AgNO_3 into $[\text{Ag}(\text{NO}_3)_2]^-$

☐

B To decrease the solubility of silver chloride

☐

C To increase the pH of the solution

☐

D To prevent the precipitation of other silver compounds

[Turn over]



19

Which pair of reagents reacts to form a tetrahedral complex? [1 mark]

☐

A $\text{CoCl}_2(\text{aq})$ and concentrated $\text{NH}_3(\text{aq})$

☐

B $\text{CuSO}_4(\text{aq})$ and concentrated $\text{NH}_3(\text{aq})$

☐

C $\text{CuSO}_4(\text{aq})$ and sodium ethanedioate(aq)

☐

D $\text{FeCl}_3(\text{aq})$ and concentrated $\text{HCl}(\text{aq})$



2	0
---	---

Cobalt(II) chloride solution changes colour when an excess of concentrated hydrochloric acid is added.

What type of reaction takes place? [1 mark]

☐

A hydrolysis

☐

B ligand substitution

☐

C precipitation

☐

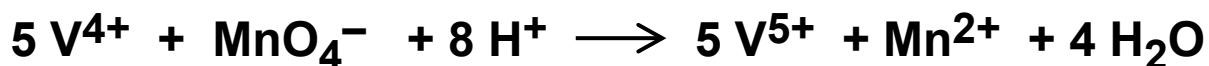
D redox

[Turn over]



2	1
---	---

The reaction between vanadium(IV) ions and manganate(VII) ions in acidic solution can be represented by the equation



What volume, in dm^3 , of $0.020 \text{ mol dm}^{-3} \text{KMnO}_4$ is needed to oxidise 0.10 mol of vanadium(IV) ions completely? [1 mark]

☐

A 0.10

☐

B 0.50

☐

C 1.0

☐

D 5.0



2	2
---	---

2-Bromopropane reacts with bromine to form 2,2-dibromopropane.

What is the name of the mechanism of this reaction?
[1 mark]

☐

A Electrophilic addition

☐

B Elimination

☐

C Free-radical substitution

☐

D Nucleophilic substitution

[Turn over]



2	3
---	---

Which compound is formed from bromoethane in a nucleophilic substitution reaction? [1 mark]

☐

A CH_3CN

☐

B $\text{CH}_3\text{CH}_2\text{NH}_2$

☐

C $\text{CH}_2=\text{CH}_2$

☐

D $\text{CH}_3\text{CH}_2\text{OSO}_2\text{OH}$



2	4
---	---

Which statement is NOT correct for both primary and secondary alcohols? [1 mark]

☐

A They are easily oxidised to carboxylic acids by acidified $\text{K}_2\text{Cr}_2\text{O}_7$ solution.

☐

B They can be formed from bromoalkanes by hydrolysis.

☐

C They form esters with carboxylic acids.

☐

D They show hydrogen bonding in the liquid state.

[Turn over]



2	5
---	---

Which compound is an isomer of ethyl ethanoate?
[1 mark]

☐

A butyl methanoate

☐

B methyl propanoate

☐

C methyl butanoate

☐

D propanoic acid



2	6
---	---

Which compound is an amide? [1 mark]

☐

A $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN}$

☐

B $\text{CH}_3\text{CONHCH}_2\text{CH}_3$

☐

C $\text{CH}_3\text{COOCH}_2\text{CH}_3$

☐

D $\text{CH}_3\text{NHCH}_2\text{CH}_2\text{CH}_3$

[Turn over]



2	7
---	---

Suberoyl chloride, $\text{ClOC}(\text{CH}_2)_6\text{COCl}$, is commonly used in the manufacture of polymers.

Which compound can form a polymer with suberoyl chloride? [1 mark]

☐

A $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$

☐

B $\text{ClOCCH}_2\text{COCl}$

☐

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

☐

D $\text{HOOCCH}_2\text{COOH}$



2	8
---	---

Which polymer is NOT hydrolysed when heated with aqueous alkali? [1 mark]

☐

A Kevlar

☐

B Nylon 6,6

☐

C Poly(propene)

☐

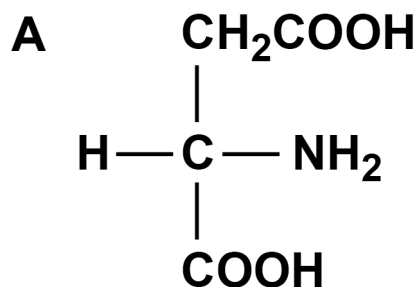
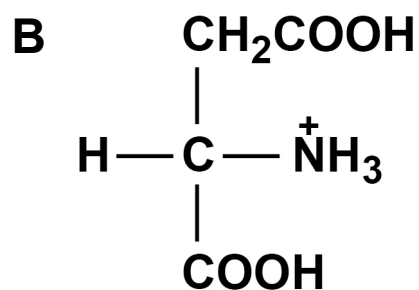
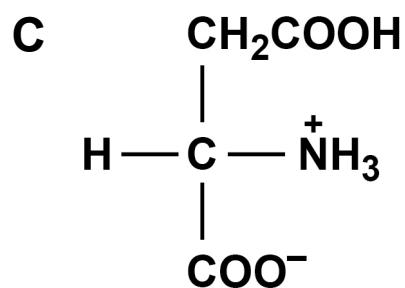
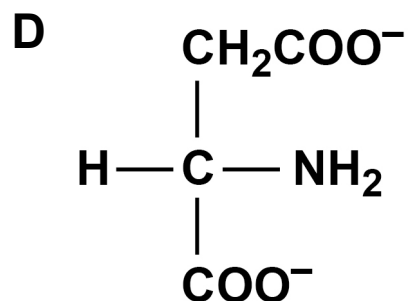
D Terylene

[Turn over]

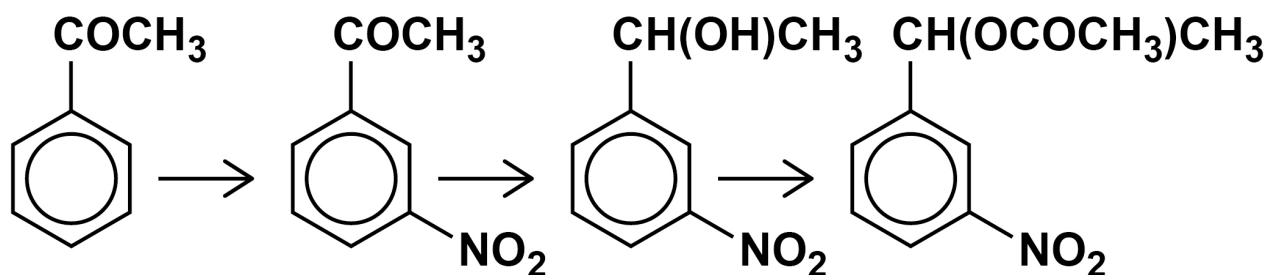


29

Which is the main species present in an aqueous solution of aspartic acid at pH = 14? [1 mark]

☐

☐

☐

☐


3	0
---	---



Which type of reaction is NOT involved in this reaction sequence? [1 mark]

☐

A esterification

☐

B hydrolysis

☐

C nitration

☐

D reduction

[Turn over]



3	1
---	---

Which pair of reagents does NOT produce ethanol?
[1 mark]

☐

A $\text{CH}_3\text{CH}_2\text{Br}$ and NaOH(aq)

☐

B $\text{CH}_3\text{COOCH}_3$ and NaOH(aq)

☐

C $\text{HCOOCH}_2\text{CH}_3$ and NaOH(aq)

☐

D CH_3CHO and $\text{NaBH}_4\text{(aq)}$



3	2
---	---

Which type of interaction between polypeptide chains is mainly responsible for maintaining the secondary structure of a protein in the form of an alpha helix?
[1 mark]

☐

A covalent bonds

☐

B hydrogen bonds

☐

C ionic interactions

☐

D van der Waals forces

[Turn over]



3	3
---	---

Which statement about $\text{HOCH}_2\text{CH}(\text{NH}_2)\text{COOH}$ is correct? [1 mark]

☐

A It decolourises bromine water.

☐

B It is a component of DNA.

☐

C It is insoluble in water.

☐

D It reacts with hydrochloric acid.



3	4
---	---

Which compound can be dehydrated to form an alkene? [1 mark]

☐

A CH_3CHO

☐

B CH_3COOH

☐

C $\text{CH}_3\text{CH}_2\text{OH}$

☐

D $\text{CH}_3\text{COOCH}_3$

[Turn over]



3	5
---	---

Which compound is NOT a 2-aminocarboxylic acid?
[1 mark]

☐

A $\text{CH}_3\text{CH}(\text{NH}_2)\text{COOH}$

☐

B $\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_2\text{COOH}$

☐

C $\text{CH}_3\text{CH}_2\text{CH}(\text{NH}_2)\text{COOH}$

☐

D $(\text{CH}_3)_2\text{CHCH}(\text{NH}_2)\text{COOH}$

END OF QUESTIONS

30



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Additional page, if required.

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Question	Mark
1	
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Section B	
TOTAL	

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