AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level CHEMISTRY

Paper 3

Time allowed: 2 hours

Materials

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.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or 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.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
Section B	
TOTAL	

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 write outside the box

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

Section A

Answer **all** questions in this section.

0 1 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 Define the term enthalpy of lattice dissociation.

[2 marks]

0 1 . 2 The enthalpy of solution for ammonium nitrate is the enthalpy change for the reaction shown.

$$NH_4NO_3(s) + aq \rightarrow NH_4^+(aq) + NO_3^-(aq) \quad \Delta H = +26\,kJ\,mol^{-1}$$

Table 1

	$NH_4^+(g)$	$NO_3^-(g)$
Enthalpy of hydration $\Delta_{hyd}H$ / 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 ►

Do not write outside the box

0 1 . 3 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 cm^3 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 NH_4NO_3 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 $J K^{-1} g^{-1}$

Assume that the density of the solution = 1.00 $g\,cm^{-3}$

[3 marks]

Enthalpy of solution _____ kJ mol^{-1}

Do not write outside the box

0 1 . 4 The uncertainty in each of the temperature readings from the thermometer used in this experiment is ±0.1°C

Calculate the percentage uncertainty in the temperature change in this experiment.

[1 mark]

Percentage uncertainty _____

0 1 . 5 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 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 kJ mol^{-1}

[1 mark]

_____

_____

Question 1 continues on the next page

Do not write outside the box

0 1 . 7 **Table 3** shows some entropy data at 298 K

Table 3

	Entropy S / J K^{-1} mol^{-1}
$NH_4NO_3(s)$	151
$NH_4^+(aq)$	113
$NO_3^-(aq)$	146

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

$$NH_4NO_3(s) + aq \rightarrow NH_4^+(aq) + NO_3^-(aq) \quad \Delta H = +26 \text{ kJ mol}^{-1}$$

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 _____

_____

_____

Do not write outside the box

0 1 . 8 Ammonium nitrate decomposes as shown.

$$NH_4NO_3(s) \rightarrow N_2(g) + \frac{1}{2}O_2(g) + 2H_2O(g) \quad \Delta H = +123 \text{ kJ mol}^{-1}$$

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

Calculate the temperature at which this reaction becomes feasible.

[2 marks]

Temperature _____ K

18

Turn over for the next question

Do not write outside the box

0 2 Tschermigite is a hydrated, water-soluble mineral, with relative formula mass of 453.2

The formula of tschermigite can be represented as $M.xH_2O$, 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 tschermigite and the value of x in $M.xH_2O$

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

[6 marks]

Do not write outside the box

6

Turn over ►

Do not write outside the box

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 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 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 _____

_____

_____

Do not write outside the box

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 _____

_____

_____

0 3 . 6 Draw 3D representations of enantiomers **D** and **E** to show how their structures are related.

[2 marks]

Question 3 continues on the next page

Do not write outside the box

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 _____

_____

_____

_____

_____

15

Do not write outside the box

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

0 4 Hydrogen peroxide solution decomposes to form water and oxygen.

$$2\,H_2O_2(aq) \rightarrow 2\,H_2O(l) + O_2(g)$$

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.

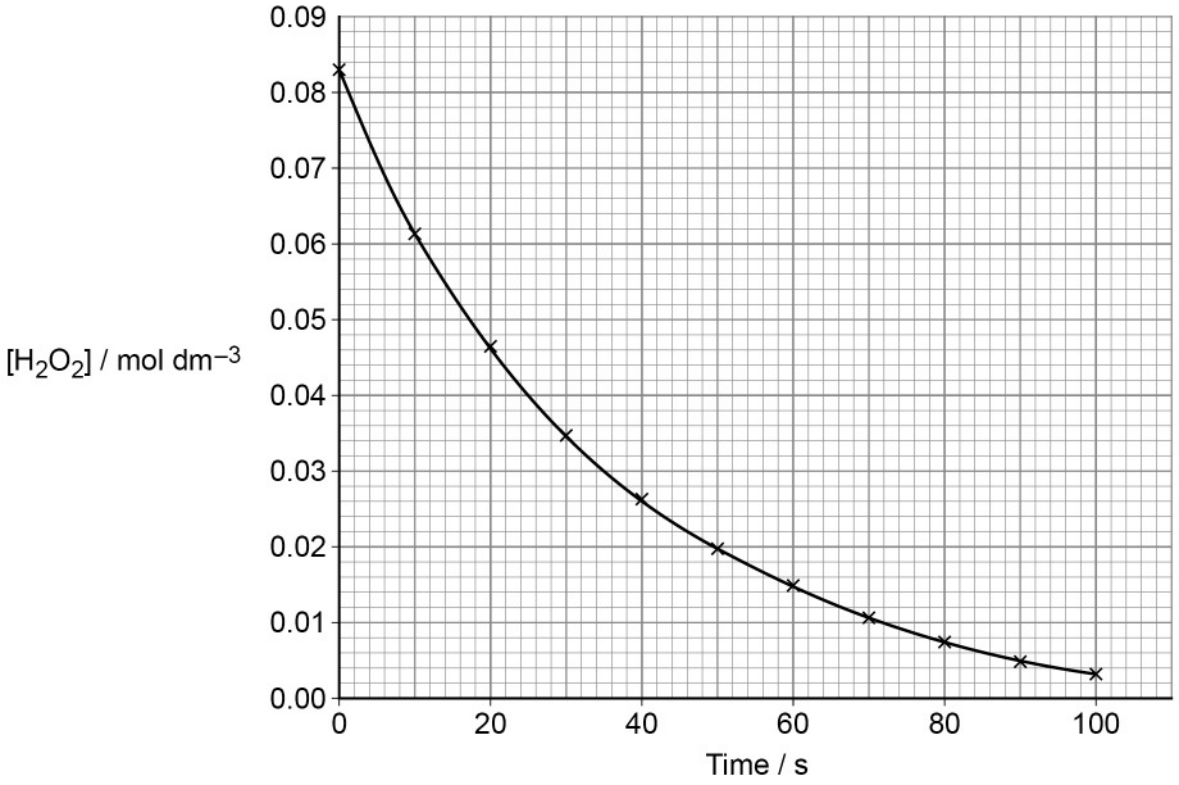
0 4 . 1 Explain why the reaction is fastest at the start.

[2 marks]

Do not write outside the box

0 4 . 2 The graph in **Figure 1** shows how the concentration of hydrogen peroxide changes with time in this experiment.

Figure 1



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 _____ mol dm^{-3} s^{-1}

Question 4 continues on the next page

Do not write outside the box

0 4 . 3 The concentration of hydrogen peroxide solution at time *t* during the experiment can be calculated using this expression.

$$[H_2O_2]_t = [H_2O_2]_{initial}\left(\frac{V_{max} - V_t}{V_{max}}\right)$$

$[H_2O_2]_t$ = concentration of hydrogen peroxide solution at time *t* / mol dm^{-3}

$[H_2O_2]_{initial}$ = concentration of hydrogen peroxide solution at the start / mol dm^{-3}

V_{max} = total volume of oxygen gas collected during the whole experiment / cm^3

V_t = volume of oxygen gas collected at time *t* / cm^3

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

Use **Figure 1** and the expression to calculate $[H_2O_2]_t$ when 20 cm^3 of oxygen has been collected.

[2 marks]

$[H_2O_2]_t$ _____ mol dm^{-3}

Do not write outside the box

Table 5 shows data from a similar experiment.

Table 5

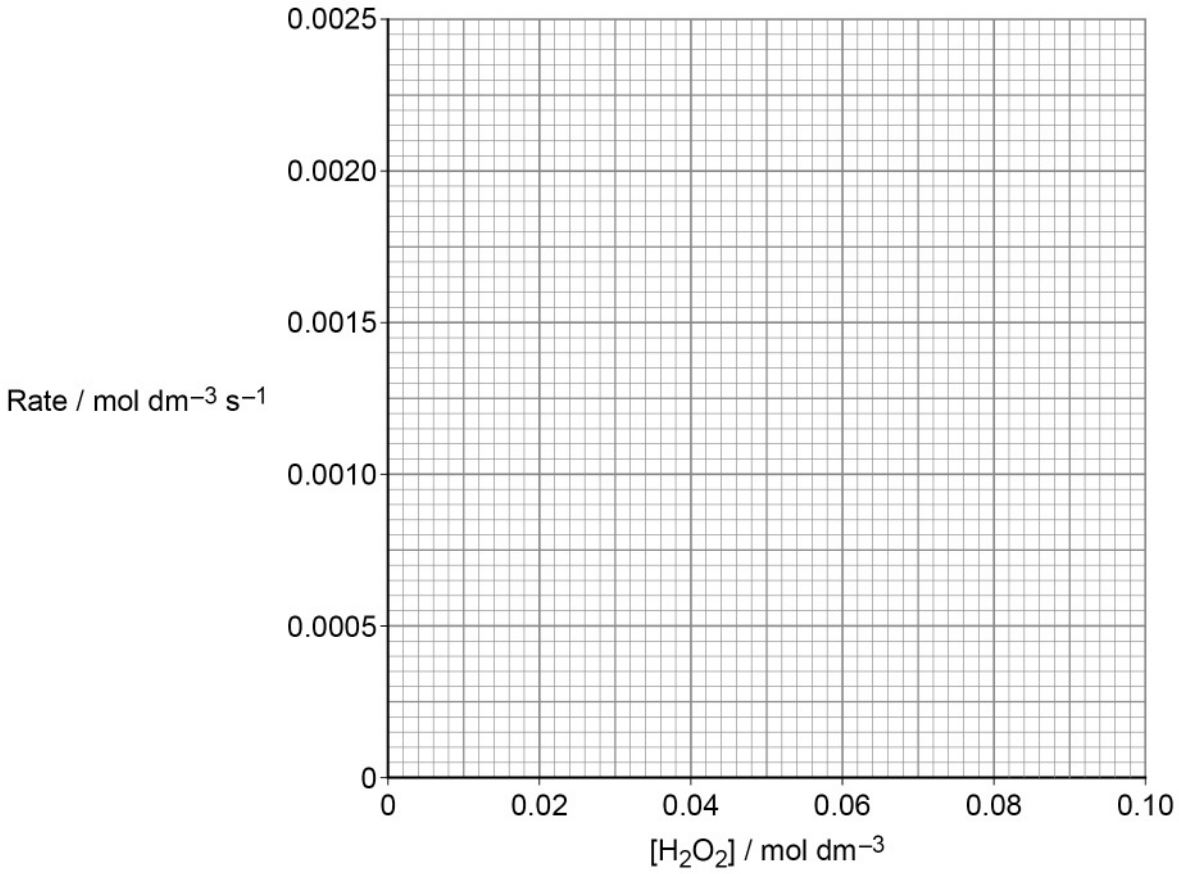
[H_2O_2] / mol dm^{-3}	0.02	0.03	0.05	0.07	0.09
Rate / mol dm^{-3} s^{-1}	0.00049	0.00073	0.00124	0.00168	0.00219

0 4 . 4 Plot the data from **Table 5** on the grid in **Figure 2**.

Draw a line of best fit.

[2 marks]

Figure 2



0 4 . 5 Use **Figure 2** 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 _____

_____

_____

10

Turn over ►

Do not write outside the box

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

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

$$2\,MnO_4^- + 5\,C_2O_4^{2-} + 16\,H^+ \rightarrow 2\,Mn^{2+} + 10\,CO_2 + 8\,H_2O$$

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]

Do not write outside the box

0 5 . 3 The reaction between peroxodisulfate ions and iodide ions in aqueous solution can be catalysed by Co^{2+} ions.

$$S_2O_8^{2-} + 2\,I^- \rightarrow 2\,SO_4^{2-} + I_2$$

Table 6 gives relevant standard electrode potentials.

Table 6

Electrode half-equation	$E^{\ominus}$ / V
$S_2O_8^{2-}(aq) + 2\,e^- \rightarrow 2\,SO_4^{2-}(aq)$	+2.01
$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$	+1.82
$I_2(aq) + 2\,e^- \rightarrow 2\,I^-(aq)$	+0.54

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

[3 marks]

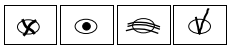
11

Do not write outside the box

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 ⬭

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 cm^3 of 1.00 mol dm^{-3} NaOH (aq) for neutralisation.

Which could be the formula of the acid?

[1 mark]

A HCOOH ⬭

B CH_3COOH ⬭

C HOOCCOOH ⬭

D $HOOCCH_2COOH$ ⬭

Do not write outside the box

0 8 Which substance has **no** delocalised electrons?

[1 mark]

A graphite ⬭

B methylbenzene ⬭

C poly(propene) ⬭

D sodium ⬭

0 9 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 $K_2Cr_2O_7$ is +7 ⬭

C Fluorine in F_2O is –1 ⬭

D Hydrogen in NaH is +1 ⬭

Do not write outside the box

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.

$$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s) \qquad E^\ominus = -0.76\ V$$
$$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s) \qquad E^\ominus = -0.13\ V$$

Which is a correct statement about this cell?

$$Zn(s)\left|Zn^{2+}(aq)\right\|Pb^{2+}(aq)\left|Pb(s)\right.$$

[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. ⬭

1 3 Which can **not** function as a Brønsted-Lowry acid?

[1 mark]

A CH_3COO^- ⬭

B HCO_3^- ⬭

C H_3O^+ ⬭

D NH_4^+ ⬭

Do not write outside the box

1 4 A strong acid H_2X dissociates in aqueous solution.

$$H_2X(aq) \rightarrow 2\,H^+(aq) + X^{2-}(aq)$$

What is the pH of a 0.020 mol dm^{-3} solution of this acid?

[1 mark]

A 1.00 ⬭

B 1.40 ⬭

C 1.70 ⬭

D 2.00 ⬭

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 CH_3COOH ⬭

C NH_3 and HCl ⬭

D NH_4Cl and KCl ⬭

1 6 Which ionisation needs less energy than this process?

$$Mg(g) \rightarrow Mg^+(g) + e^-$$

[1 mark]

A $Al(g) \rightarrow Al^+(g) + e^-$ ⬭

B $Ar(g) \rightarrow Ar^+(g) + e^-$ ⬭

C $Be(g) \rightarrow Be^+(g) + e^-$ ⬭

D $Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$ ⬭

Do not write outside the box

1 7 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 $[Ag(NO_3)_2]^-$ ⬭

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 ⬭

1 9 Which pair of reagents reacts to form a tetrahedral complex?

[1 mark]

A $CoCl_2(aq)$ and concentrated $NH_3(aq)$ ⬭

B $CuSO_4(aq)$ and concentrated $NH_3(aq)$ ⬭

C $CuSO_4(aq)$ and sodium ethanedioate(aq) ⬭

D $FeCl_3(aq)$ and concentrated HCl(aq) ⬭

Do not write outside the box

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 ⬭

2 1 The reaction between vanadium(IV) ions and manganate(VII) ions in acidic solution can be represented by the equation

$$5\,V^{4+} + MnO_4^- + 8\,H^+ \rightarrow 5\,V^{5+} + Mn^{2+} + 4\,H_2O$$

What volume, in dm^3, of 0.020 mol dm^{-3} $KMnO_4$ 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 ⬭

Do not write outside the box

2 3 Which compound is formed from bromoethane in a nucleophilic substitution reaction?

[1 mark]

A CH_3CN ⬭

B $CH_3CH_2NH_2$ ⬭

C $CH_2=CH_2$ ⬭

D $CH_3CH_2OSO_2OH$ ⬭

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 $K_2Cr_2O_7$ 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. ⬭

2 5 Which compound is an isomer of ethyl ethanoate?

[1 mark]

A butyl methanoate ⬭

B methyl propanoate ⬭

C methyl butanoate ⬭

D propanoic acid ⬭

Do not write outside the box

2 6 Which compound is an amide?

[1 mark]

A $CH_3CH_2CH_2CN$ ⬭

B $CH_3CONHCH_2CH_3$ ⬭

C $CH_3COOCH_2CH_3$ ⬭

D $CH_3NHCH_2CH_2CH_3$ ⬭

2 7 Suberoyl chloride, $ClOC(CH_2)_6COCl$, is commonly used in the manufacture of polymers.

Which compound can form a polymer with suberoyl chloride?

[1 mark]

A $H_2NCH_2CH_2NH_2$ ⬭

B $ClOCCH_2COCl$ ⬭

C $CH_3CH_2CONH_2$ ⬭

D $HOOCCH_2COOH$ ⬭

2 8 Which polymer is **not** hydrolysed when heated with aqueous alkali?

[1 mark]

A Kevlar ⬭

B Nylon 6,6 ⬭

C Poly(propene) ⬭

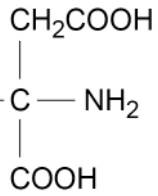
D Terylene ⬭

Do not write outside the box

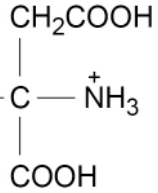
2 9 Which is the main species present in an aqueous solution of aspartic acid at pH = 14?

[1 mark]

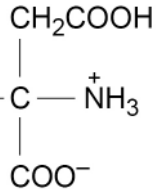
A



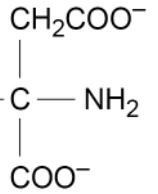
B



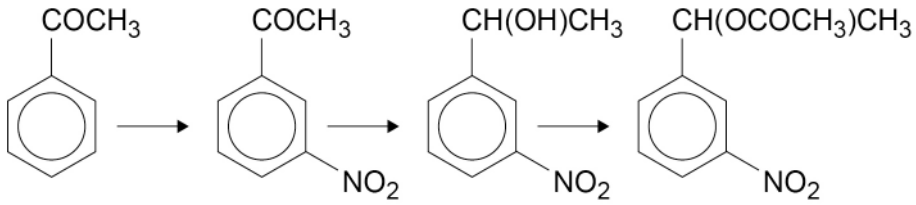
C



D



3 0



Which type of reaction is **not** involved in this reaction sequence?

[1 mark]

A esterification

B hydrolysis

C nitration

D reduction

Do not write outside the box

3 1 Which pair of reagents does **not** produce ethanol?

[1 mark]

A CH_3CH_2Br and NaOH(aq) ⬭

B CH_3COOCH_3 and NaOH(aq) ⬭

C $HCOOCH_2CH_3$ and NaOH(aq) ⬭

D CH_3CHO and $NaBH_4$(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 ⬭

3 3 Which statement about $HOCH_2CH(NH_2)COOH$ 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. ⬭

Do not write outside the box

3 4 Which compound can be dehydrated to form an alkene?

[1 mark]

A CH_3CHO ⬭

B CH_3COOH ⬭

C CH_3CH_2OH ⬭

D CH_3COOCH_3 ⬭

3 5 Which compound is **not** a 2-aminocarboxylic acid?

[1 mark]

A $CH_3CH(NH_2)COOH$ ⬭

B $CH_3CH(NH_2)CH_2COOH$ ⬭

C $CH_3CH_2CH(NH_2)COOH$ ⬭

D $(CH_3)_2CHCH(NH_2)COOH$ ⬭

30

END OF QUESTIONS

Do not write outside the box

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Do not write outside the box

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Copyright information

For confidentiality purposes, all acknowledgements of third-party copyright material are published in a separate booklet. This booklet is published after each live examination series and is available for free download from www.aqa.org.uk.

Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and AQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team.

Copyright © 2022 AQA and its licensors. All rights reserved.