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A Level Chemistry

Sample Assessment Materials

Pearson Edexcel Level 3 Advanced GCE in Chemistry (9CH0)

First teaching from September 2015

First certification from 2017 | Issue 1

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Pearson Edexcel Level 3 Advanced GCE in Chemistry (9CH0)

Sample Assessment Materials

First certification 2017

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Contents

Introduction

The Pearson Edexcel Level 3 Advanced GCE in Chemistry is designed for use in schools and colleges. It is part of a suite of GCE qualifications offered by Pearson.

These sample assessment materials have been developed to support this qualification and will be used as the benchmark to develop the assessment students will take.

General marking guidance

- All candidates must receive the same treatment. Examiners must mark the last candidate in exactly the same way as they mark the first.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than be penalised for omissions.
- Examiners should mark according to the mark scheme – not according to their perception of where the grade boundaries may lie.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification/indicative content will not be exhaustive.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, a senior examiner must be consulted before a mark is given.
- Crossed-out work should be marked **unless** the candidate has replaced it with an alternative response.

Write your name here

Surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number | | | | | |

Candidate Number | | | | |

Chemistry

Advanced

Paper 1: Advanced Inorganic and Physical Chemistry

Sample Assessment Materials for first teaching September 2015

Time: 1 hour 45 minutes

Paper Reference **9CH0/01**

You must have:
Data Booklet
Scientific calculator, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- For questions marked with an *****, marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

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.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

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S 4 7 5 5 3 A 0 1 2 8

PEARSON

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 ☒.

1 This question is about the bonding and structure of molecules.

(a) Which element exists as discrete molecules in its solid state?

(1)

☒ **A** aluminium

☒ **B** iodine

☒ **C** silicon

☒ **D** sodium

(b) Which compound has non-polar molecules?

(1)

☒ **A** ammonia

☒ **B** carbon dioxide

☒ **C** hydrogen sulfide

☒ **D** water

(c) Which is the best reason for why the boiling temperature of HF is much higher than that of HCl?

(1)

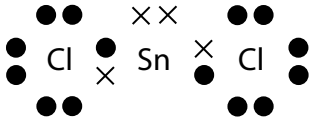
☒ **A** the instantaneous dipole-induced dipole (London) forces are stronger in HF

☒ **B** HF molecules have a smaller mass

☒ **C** there are intermolecular hydrogen bonds in HF

☒ **D** HF molecules have fewer electrons

(d) The dot-and-cross diagram for a molecule of tin(II) chloride, $SnCl_2$, in the gaseous state is:



(i) Using the electron-pair repulsion theory, explain the shape of this molecule.

(2)

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.....

.....

.....

(ii) Predict a value for the Cl—Sn—Cl bond angle.

Justify your answer.

(2)

.....

.....

.....

.....

(Total for Question 1 = 7 marks)

2 This question is about energy changes involved in the formation of ionic compounds.

(a) What is the order of increasing first ionisation energy for the elements beryllium, helium and lithium?

(1)

☒ **A** lithium < helium < beryllium

☒ **B** beryllium < lithium < helium

☒ **C** helium < beryllium < lithium

☒ **D** lithium < beryllium < helium

(b) The **second** ionisation energy of calcium has a magnitude of 1150 kJ mol^{-1}.

Which of the following represents the **second** ionisation energy of calcium?

(1)

☒ **A** $Ca(g) \rightarrow Ca^{2+}(g) + 2e^-$ $\Delta H^{\ominus} = +1150$ kJ mol^{-1}

☒ **B** $Ca^+(g) \rightarrow Ca^{2+}(g) + e^-$ $\Delta H^{\ominus} = +1150$ kJ mol^{-1}

☒ **C** $Ca(g) \rightarrow Ca^{2+}(g) + 2e^-$ $\Delta H^{\ominus} = -1150$ kJ mol^{-1}

☒ **D** $Ca^+(g) \rightarrow Ca^{2+}(g) + e^-$ $\Delta H^{\ominus} = -1150$ kJ mol^{-1}

(c) The formation of potassium ions can be represented by the equation

$$K(s) \rightarrow K^+(g) + e^-$$

Which statement corresponds to the energy change for this process?

(1)

☒ **A** the first electron affinity of potassium

☒ **B** the first ionisation energy of potassium

☒ **C** the sum of the enthalpy change of atomisation of potassium and the first electron affinity of potassium

☒ **D** the sum of the enthalpy change of atomisation of potassium and the first ionisation energy of potassium

(d) The table shows the ionic radius and charge of each of six ions.

Ion	D^+	E^+	G^{2+}	X^-	Y^-	Z^{2-}
Ionic radius / nm	0.14	0.18	0.15	0.14	0.18	0.15

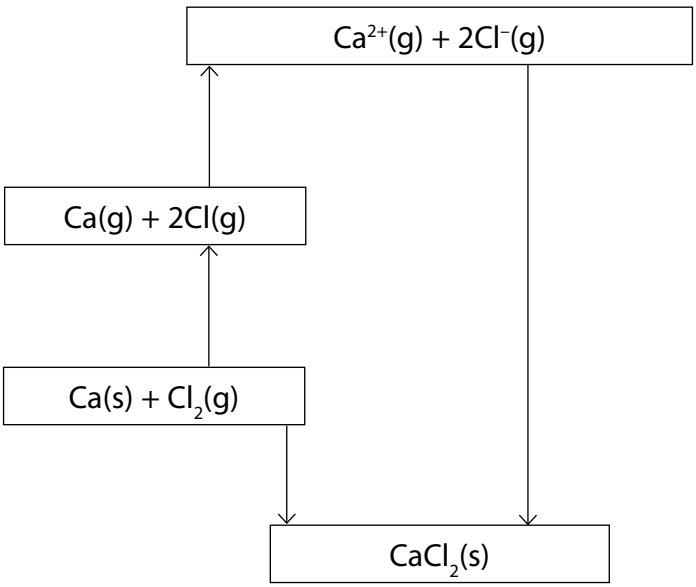
The ionic solids DX, EY and GZ have the same lattice structure.

Deduce the order of magnitude of their lattice energies, giving the most exothermic first.

Justify your answer.

(3)

(e) The diagram shows a Born-Haber cycle for calcium chloride, $CaCl_2$.



	kJ mol^{-1}
Enthalpy of formation of $CaCl_2(s)$	–796
Lattice energy of $CaCl_2(s)$	–2258
Enthalpy of atomisation of $Ca(s) \rightarrow Ca(g)$	178
Enthalpy of atomisation of $\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$	122
First ionisation energy of Ca(g)	590
Electron affinity of Cl(g)	–349

Calculate the second ionisation energy of calcium, in kJ mol^{-1}.

(2)

(Total for Question 2 = 8 marks)

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3 Vanadium is a transition metal that forms ions with several oxidation numbers. Four of these ions are shown in the table.

Formula of ion	Oxidation number of vanadium	Colour of ion
V^{2+}	+2	violet
V^{3+}	+3	green
VO^{2+}	+4	blue
VO_2^+	+5	yellow

(a) Complete the electronic configuration for the vanadium atom and the V^{3+} ion.

(2)

V $1s^2\ 2s^2\ 2p^6\ 3s^2$ .....

V^{3+} $1s^2\ 2s^2\ 2p^6\ 3s^2$ .....

(b) The table shows the standard electrode (redox) potentials, $E^{\ominus}$, for some half-cell reactions.

Redox system	Half-cell reaction	$E^{\ominus}$ / V
1	$V^{2+}(aq) + 2e^- \rightleftharpoons V(s)$	−1.20
2	$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	−0.26
3	$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
4	$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+1.00
5	$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightleftharpoons SO_2(g) + 2H_2O(l)$	+0.17

(i) Explain, using information from the table, the colour changes that take place when SO_2 gas is bubbled slowly through an acidified solution containing VO_2^+ ions.

Equations are not required.

(3)

(ii) Explain, using information in the table, whether the disproportionation of $V^{2+}(aq)$ into $V^{3+}(aq)$ and V(s) is feasible under standard conditions.

(2)

(Total for Question 3 = 7 marks)

4 Aqueous copper(II) sulfate reacts with an excess of aqueous ammonia to give a dark blue solution.

The dark blue solution contains the octahedral complex ion, $[Cu(NH_3)_x(H_2O)_y]^{2+}$.

The formula of this complex ion is determined by colorimetry, using this method:

- Make up six different mixtures of 1.00 mol dm^{-3} aqueous ammonia and 0.500 mol dm^{-3} aqueous copper(II) sulfate and water.
- Filter the mixtures to remove any precipitate that forms.
- The filtrate is a dark blue solution that contains the complex ion, $[Cu(NH_3)_x(H_2O)_y]^{2+}$.
- Place the dark blue solution into a colorimeter and measure the absorbance of the solution.

The table shows the absorbance of each mixture.

	Mixture					
	1	**2**	**3**	**4**	**5**	**6**
Volume of 0.500 mol dm^{-3} $CuSO_4(aq)$ / cm^3	5.00	5.00	5.00	5.00	5.00	5.00
Volume of 1.00 mol dm^{-3} $NH_3(aq)$ / cm^3	3.00	6.00	9.00	12.00	15.00	18.00
Volume of $H_2O(l)$ / cm^3	17.00	14.00	11.00	8.00	5.00	2.00
Absorbance	0.25	0.50	0.76	0.84	0.84	0.84

(a) Plot a graph of absorbance against volume of $NH_3(aq)$ on the grid opposite.

Draw a straight line of best fit through the first three points and another straight line of best fit through the last three points. Extend both lines so that they cross.

(2)

(b) (i) Use the graph to determine the smallest volume of 1.00 mol dm^{-3} $NH_3(aq)$ required to completely react with 5.00 cm^3 of 0.500 mol dm^{-3} of $CuSO_4$ solution.

(1)

(ii) Calculate the amount, in moles, of $CuSO_4$ in 5.00 cm^3 of 0.500 mol dm^{-3} solution.

(1)

(iii) Calculate the amount of NH_3, in moles, present in the volume of $NH_3(aq)$ in (b)(ii).

(1)

(iv) Deduce the values of x and y in the formula of the complex ion $[Cu(NH_3)_x(H_2O)_y]^{2+}$.

(1)

x = ... y = ...

(c) The precipitate formed when some of the mixtures are made is copper(II) hydroxide.

Write an ionic equation to show the formation of copper(II) hydroxide from its ions. Include state symbols.

(2)

(Total for Question 4 = 8 marks)

5 Chlorine and bromine are elements in Group 7 of the Periodic Table.

Both elements exist in a number of different oxidation numbers and therefore are involved in many redox reactions.

(a) Write an equation for the reaction between chlorine and cold, dilute aqueous sodium hydroxide. State symbols are not required.

(1)

(b) Chlorine dioxide reacts with cold, dilute aqueous sodium hydroxide.

The ionic equation for the reaction is:

$$2ClO_2(aq) + 2OH^-(aq) \rightarrow ClO_2^-(aq) + ClO_3^-(aq) + H_2O(l)$$

Using oxidation numbers, explain why the chlorine in ClO_2 has undergone disproportionation.

(3)

(c) Chloride ions (Cl^-) can be oxidised to chlorine molecules (Cl_2) by manganate(VII) ions.

A dilute solution containing manganate(VII) ions (MnO_4^-) and an excess of dilute sulfuric acid is added to the solution containing chloride ions.

As the manganate(VII) ion solution is added, it changes from purple to colourless.

(i) The formula of the manganese species that is formed during this reaction is

(1)

☒ **A** $Mn^{2+}(aq)$

☒ **B** $Mn^{3+}(aq)$

☒ **C** $Mn^{4+}(aq)$

☒ **D** $MnO_4^{2-}(aq)$

(ii) Using oxidation numbers, deduce the molar ratio of MnO_4^- to Cl^- that would appear in the balanced chemical equation for the reaction.

(2)

(d) Potassium bromide reacts with concentrated sulfuric acid. Three of the products of the reaction are hydrogen bromide, bromine and sulfur dioxide.

(i) Explain why the hydrogen bromide, which is a colourless gas, appears as misty fumes when it makes contact with moist air.

(2)

(ii) State the type of reaction that occurs in the formation of sulfur dioxide.

(1)

(Total for Question 5 = 10 marks)

6 Sodium can form three oxides:

sodium oxide, Na_2O

sodium peroxide, Na_2O_2

sodium superoxide, NaO_2

It has been suggested that sodium superoxide could be used in spacecraft to regenerate oxygen.

Oxygen needs to be replaced in a spacecraft because an astronaut oxidises glucose, according to the equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Sodium superoxide can regenerate oxygen according to the equation:

$$4NaO_2 + 2CO_2 \rightarrow 2Na_2CO_3 + 3O_2$$

In order to maintain the correct percentage of oxygen in the air, any excess carbon dioxide could be removed by using sodium oxide.

$$Na_2O + CO_2 \rightarrow Na_2CO_3$$

(a) Calculate the mass of sodium oxide that would be required to remove the excess carbon dioxide when exactly 880 g of sodium superoxide is reacted per day.

You can assume that an astronaut oxidises 2 mol of glucose each day.

(4)

(b) Using a dot-and-cross diagram, explain why the superoxide ion, O—O^-, is a radical.

(2)

(c) A 0.403 g sample of sodium peroxide was reacted with water:

$$Na_2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_2$$

The hydrogen peroxide produced was determined by titration with a solution containing cerium(IV) ions. In this reaction the hydrogen peroxide is converted into oxygen.

$$H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$$

The hydrogen peroxide solution reacted with exactly 24.85 cm^3 of a 0.420 mol dm^{-3} solution of cerium(IV) ions, Ce^{4+}.

Deduce the formula of the cerium ion present in the final solution. Support your answer with a calculation.

(4)

(Total for Question 6 = 10 marks)

7 The following reversible reaction is used in industry to make methanol, CH_3OH:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -91 \text{ kJ mol}^{-1}$$

(a) Which change would affect both the value of the equilibrium constant, K_c, and the proportion of methanol present in an equilibrium mixture of the three gases?

(1)

- ☒ **A** adding a catalyst
- ☒ **B** changing the temperature
- ☒ **C** increasing the concentration of carbon monoxide
- ☒ **D** increasing the pressure

(b) The expression for the equilibrium constant, K_c, for this reaction is

$$K_c = \frac{[CH_3OH(g)]}{[CO(g)][H_2(g)]^2}$$

0.200 mol of CO(g) and 0.400 mol of $H_2(g)$ are mixed in a sealed container of volume 1.2 dm^3 at a temperature of 500 K and a pressure of 100 atmospheres and allowed to reach equilibrium.

The equilibrium mixture is found to contain 0.086 mol of $CH_3OH(g)$.

(i) Calculate K_c for this reaction. Give your answer to an appropriate number of significant figures and state the units.

(5)

(ii) The equilibrium mixture of CO(g), H_2(g) and CH_3OH(g) is heated in the same sealed container to a temperature higher than 500 K. Since the gas volume remains the same, the increased temperature results in an increase in pressure.

Explain why it is difficult to predict the effect on the yield of CH_3OH.

(3)

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(Total for Question 7 = 9 marks)

8 Acids can be classified as weak or strong acids.

(a) A mixture of concentrated sulfuric and nitric acids is used in the nitration of benzene.

The following equilibrium is set up:

$$H_2SO_4 + HNO_3 \rightleftharpoons H_2NO_3^+ + HSO_4^-$$

Which statement about this equilibrium is correct?

(1)

☒ **A** HNO_3 and $H_2NO_3^+$ are a conjugate acid-base pair

☒ **B** the nitric acid acts as an acid

☒ **C** the nitric acid acts as an oxidising agent

☒ **D** the sulfuric acid acts as a dehydrating agent

(b) Sulfuric acid ionises in two stages.

Stage 1: $H_2SO_4(aq) \rightarrow H^+(aq) + HSO_4^-(aq)$

Stage 2: $HSO_4^-(aq) \rightleftharpoons H^+(aq) + SO_4^{2-}(aq)$

(i) Explain, with reference to the equations, why the HSO_4^- ion is classified as a weak acid.

(2)

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(ii) A 0.100 mol dm^{-3} solution of sulfuric acid has a pH of 0.97.

Calculate the concentration of hydrogen ions in this solution.

(1)

(c) Ethanoic acid, CH_3COOH, is a weak acid.

A student prepares 600 cm^3 of a buffer solution by mixing 400 cm^3 of 0.500 mol dm^{-3} ethanoic acid solution with 200 cm^3 of 0.500 mol dm^{-3} sodium ethanoate solution, CH_3COONa.

Calculate the pH of the buffer solution produced.

(K_a for ethanoic acid = 1.74×10^{-5} mol dm^{-3})

(4)

(Total for Question 8 = 8 marks)

9 Prussian Blue, $[Fe_4[Fe(CN)_6]_3]$, is a dark blue pigment used in painting and dyeing.

It was discovered around 1700 AD in the German state of Prussia.

Prussian Blue is formed when an iron(III) salt is added to a solution containing the complex ion $[Fe(CN)_6]^{4-}$.

The cyanide ion has the formula CN^-.

(a) (i) The oxidation number of Fe in the $[Fe(CN)_6]^{4-}$ ion is

(1)

☒ **A** +2

☒ **B** +3

☒ **C** +4

☒ **D** +6

(ii) Draw a diagram to show the shape of a $[Fe(CN)_6]^{4-}$ ion, using the structure CN^- to represent a cyanide ligand and showing how the cyanide ligands bond to the central iron ion.

(2)

(b) A solution containing $[Fe(CN)_6]^{3-}$ ions can be made from $[Fe(H_2O)_6]^{2+}$ ions in two steps as shown:

Step 1 $[Fe(H_2O)_6]^{2+}(aq) + 6CN^-(aq) \rightleftharpoons [Fe(CN)_6]^{4-}(aq) + 6H_2O(l)$

Step 2 $2[Fe(CN)_6]^{4-}(aq) + Cl_2(aq) \rightarrow 2[Fe(CN)_6]^{3-}(aq) + 2Cl^-(aq)$

Name the type of reaction taking place in each of Steps 1 and 2.

(2)

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(c) In a separate reaction, aqueous sodium hydroxide was added to a solution containing iron(II) sulfate. A green precipitate formed that turned brown on standing in air.

Identify the green precipitate and explain why it turns brown on standing in air.

(3)

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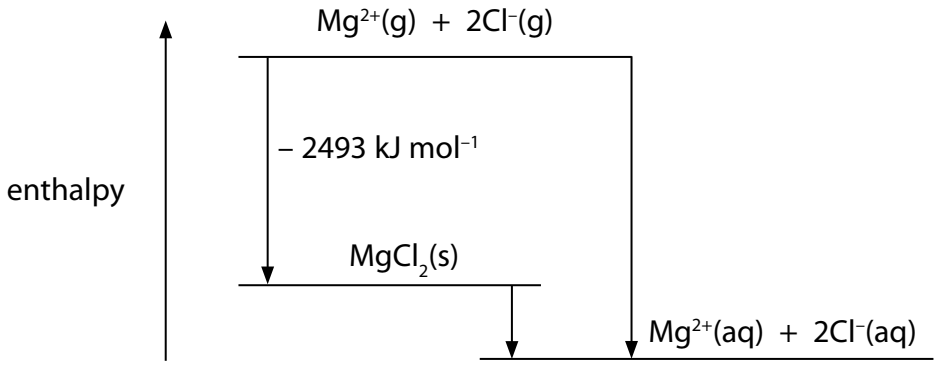
(Total for Question 9 = 8 marks)

10 This question is about some Group 2 compounds.

(a) Explain the trend in the thermal stability of carbonates in Group 2.

(3)

(b) Magnesium chloride is soluble in water. The enthalpy level diagram for the dissolving of magnesium chloride is



The enthalpy changes of hydration of the ions are:

Mg^{2+} $-1920\ kJ\ mol^{-1}$

Cl^- $-364\ kJ\ mol^{-1}$

Calculate the enthalpy change of solution, $\Delta H_{solution}$, of $MgCl_2(s)$ in $kJ\ mol^{-1}$.

(2)

(c) The table shows some data relating to the dissolving of magnesium sulfate, $MgSO_4$, in water at 298 K.

$\Delta H^{\ominus}_{solution}$ / kJ mol^{-1}	$\Delta S^{\ominus}_{system}$ / J K^{-1} mol^{-1}
–87	–210

(i) Explain why the dissolving of magnesium sulfate in water is exothermic by considering the enthalpy changes involved.

(2)

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(ii) Use the data in the table to calculate $\Delta G^{\ominus}$ when magnesium sulfate dissolves in water at 298 K. State the significance of your answer.

(2)

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*(d) The table shows some data relating to the dissolving of barium sulfate and calcium sulfate in water at 298 K.

Salt	$\Delta H^{\ominus}_{solution}$ / kJ mol^{-1}	$T\Delta S^{\ominus}_{system}$ / kJ mol^{-1}
$BaSO_4$	+19	–31
$CaSO_4$	– 18	–43

Comment on the relative solubility in water of barium sulfate and calcium sulfate at 298 K, using data from the table.

(6)

(Total for Question 10 = 15 marks)

TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
* Actinide series	232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

CHEMISTRY A LEVEL PAPER 1 MARK SCHEME

Question number	Answer	Additional guidance	Marks
1(a)	B		**1**
1(b)	B		**1**
1(c)	C		**1**
1(d)(i)	An explanation that makes reference to the following points: • the shape is V-shaped/bent (1) • because the three electron pairs on Sn repel one another (1)	First marking point can be awarded for a correctly-drawn diagram	**2**
1(d)(ii)	• prediction: any value between 95 and 119º (1) • justification: lone pair – bond pair repulsion is greater than bond pair – bond pair repulsion (and hence the angle is less than 120º) (1)		**2**

(Total for Question 1 = 7 marks)

Question number	Answer	Additional guidance	Marks
2(a)	D		**1**
2(b)	B		**1**
2(c)	D		**1**
2(d)	• order: GZ > DX > EY (1) Justification: • the ions in GZ have higher charges (than those in both EY and DX) (1) • the ions in DX are smaller than those in EY (1)		**3**
2(e)	• construction of balanced cycle (1) • substitution and evaluation of 2^{nd} IE (1)	Example calculation $-2258 = -590 - 2^{nd}\text{ IE} + 2(349) - 178 - 2(122) - 796$ hence 2^{nd} IE = (+) 1148 (kJ mol^{-1}) correct answer, no working scores 2 marks	**2**

(Total for Question 2 = 8 marks)

Question number	Answer	Additional guidance	Marks
3(a)	• (V) $(1s^2 2s^2 2p^6 3s^2) 3p^6 3d^3 4s^2$ (1) • (V^{3+}) $(1s^2 2s^2 2p^6 3s^2) 3p^6 3d^2$ (1)	Allow $4s^2 3d^3$	**2**
3(b)(i)	An explanation that makes reference to the following points: • $E^{\ominus}$ of redox system 5 is more negative / less positive than that of both redox systems 4 and 3 (but not than that of redox systems 2 and 1) (1) • therefore SO_2 releases electrons to / reduces VO_2^+ to VO^{2+} and then VO^{2+} to V^{3+} (1) • (yellow to) blue <u>then</u> green (1)	Accept explanations based on calculating $E^{\ominus}_{cell}$ for the reactions Accept correct use of anticlockwise rule Ignore green colour before blue	**3**
3(b)(ii)	The reaction is **<u>not</u>** feasible because: • $E^{\ominus}$ of redox system 2 is less negative than that of redox system 1 (1) • therefore V^{2+} ions in system 2 will not release electrons to the V^{2+} ions in system 1 (1)	Accept explanations based on calculating $E^{\ominus}_{cell}$ for the reactions Accept correct use of anticlockwise rule	**2**

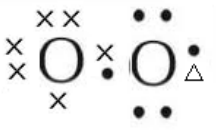
(Total for Question 3 = 7 marks)

Question number	Answer	Additional Guidance	Marks
4(a)	• axes: correct way round, labelled, suitable scale (1) • all points plotted correctly to nearest gridline AND straight line through first 3 points, straight line through last 3 points, and the two lines intersect (1)	The scale is suitable if the distance between the first point plotted and the last point plotted covers more than half of the graph paper on each axis.	**2**
4(b)(i)	10 (cm^3) (1)	Award mark for a value read correctly from the candidate's graph	**1**
4(b)(ii)	(0.005 x 0.5) = 2.5(0) x 10^{-3} / 0.0025 (mol) (1)		**1**
4(b)(iii)	(0.010 x 1.00) = 1 x 10^{-2} / 0.01 (mol) (1)	Answer to (iii) csq on (ii)	**1**
4(b)(iv)	x = 4 and y = 2 (1)	Answer to (iv) csq on (i) and (ii), but x + y must total 6	**1**
4(c)	$Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ • correctly balanced equation (1) • state symbols (1)	Allow $[Cu(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(H_2O)_4(OH)_2(s) + 2H_2O(l)$	**2**

(Total for Question 4 = 8 marks)

Question number	Answer	Additional guidance	Marks
5(a)	$Cl_2 + 2NaOH \rightarrow NaOCl + NaCl + H_2O$ (1)	Accept $Cl_2 + 2OH^- \rightarrow OCl^- + Cl^- + H_2O$ Ignore state symbols	**1**
5(b)	An explanation that makes reference to the following points: • Cl has oxidation number +4 to in ClO_2 (1) • Cl (in ClO_2) changes oxidation number to +3 (ClO_2^-) and +5 (ClO_3^-) (1) • (therefore) chlorine/it (in ClO_2) has been both oxidised and reduced (1)	Accept 4+ Accept 3+ and 5+ Allow answers in any order	**3**
5(c)(i)	A		**1**
5(c)(ii)	An answer that makes reference to the following points: • Mn changes from +7 to +2 and Cl changes from -1 to 0 (1) • therefore ratio is MnO_4^- to $5Cl^-$ /the ratio of MnO_4^- to Cl^- is 1 to 5 (1)	Accept 7+ and 2+ Accept 1–	**2**
5(d)(i)	An explanation that makes reference to the following points: • the HBr dissolves in water (in the air) (1) • and forms droplets (of hydrobromic acid) (1)		**2**
5(d)(ii)	• the (conc.) H_2SO_4 is reduced to SO_2 (1)	Accept redox	**1**

(Total for Question 5 = 10 marks)

Question number	Answer	Additional guidance	Marks
6(a)	• determines number of mol of CO_2 produced (1) • calculates number of mol NaO_2 in 880 g (1) • calculates the number of mol of CO_2 reacted with NaO_2 and hence determines the number of mol of CO_2 in excess (1) • calculation of mass of Na_2O = 248 g (1)	<u>Example of calculation</u> 2 mol glucose produces 12 mol CO_2 880 g NaO_2 = 16 mol 16 mol NaO_2 remove 8 mol CO_2 (therefore 4 mol CO_2 is excess) mass of Na_2O required is (4 x 62) = 248 g 3rd mark is csq on answers given in 1st and 2nd marks 4th mark is csq on answer given in 3rd mark Correct answer with units and no working scores 4 marks.	**4**
6(b)	An explanation that makes reference to the following points:  (1) • it is a radical because it has an unpaired electron (1)	Accept any other symbols in place of dots and crosses, including a minus sign to replace the triangle	**2**

Question number	Answer	Additional guidance	Marks
6(c)	• calculation of number of moles Na_2O_2 (= mols H_2O_2) (1) • calculation of number of moles Ce^{4+} (1) • determination of the ratio H_2O_2 : Ce^{4+} (1) • formula of cerium ion is Ce^{3+} (1)	Example of answer $n(Na_2O_2) = (0.403 \div 78.0) = 5.17 \times 10^{-3}$ $n(Ce^{4+}) = (24.85 \div 1000 \times 0.420)$ $= 1.04 \times 10^{-2}$ $n(Ce^{4+}) : n(H_2O_2) = 1.04 \times 10^{-2} : 5.17 \times 10^{-3}$ $= 2 : 1$ 1st and 2nd mark: accept answers to any significant figures, except 1s.f 3rd mark csq on answers given in 1st and 2nd marks 4th mark csq on answer given in 3rd mark	**4**

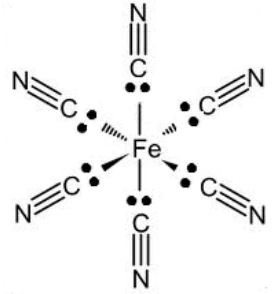
(Total for Question 6 = 10 marks)

Question number	Answer	Additional guidance	Marks
7(a)	B		**1**
7(b)(i)	• calculation of n(CO) at equilibrium and $n(H_2)$ at equilibrium (1) • converting number of moles to concentration (1) • evaluation of K_c by substitution (1) • correct answer to 3 sf (1) • units: $dm^6\ mol^{-2}$ (1)	Example of calculation n(CO) at equilibrium = 0.114 (mol) $n(H_2)$ at equilibrium = 0.228 (mol) $[CO] = 0.0950\ moldm^{-3}$, $[H_2] = 0.190\ moldm^{-3}$, $[CH_3OH] = 0.0717\ mol\ dm^{-3}$ $K_c = 0.0717 \div (0.0950 \times 0.190^2) = 20.9068\ldots..$ $= 20.9\ dm^6\ mol^{-2}$ Allow $mol^{-2}\ dm^6$ 3rd and 4th marks csq on answers given in 1st and 2nd marks Correct final answer to 3 sf with units but no working scores 5 marks	**5**
7(b)(ii)	An explanation that makes reference to the following points: • an increase in temperature shifts the equilibrium to the left (1) • an increase in pressure shifts the equilibrium to the right (1) • these changes produce opposing effects, so to predict the effect on the yield it is necessary to know the relative effects of each one (1)		**3**

(Total for Question 7 = 9 marks)

Question number	Answer	Additional guidance	Marks
8(a)	A		**1**
8(b)(i)	An explanation that makes reference to the following points: • stage 2 is an equilibrium reaction / only partial ionisation occurs (1) • therefore fewer hydrogen ions are formed (1)	Accept dissociation for ionisation	**2**
8(b)(ii)	• rearrangement of equation pH = - log $[H^+]$ and substitution to give final answer (1)	Example calculation: $[H^+] = 10^{-pH}$ $10^{-0.97} = 0.107$ (mol dm^{-3}) Allow 0.11 (mol dm^{-3}) Correct answer with no working scores 1 mark	**1**
8(c)	• rearrangement of K_a expression (1) • calculation of $[CH_3COOH]$ and $[CH_3COO^-]$ (1) • substitution, and evaluation of $[H^+]$ in the buffer solution (1) • conversion of $[H^+]$ to pH for buffer solution (1)	Example of calculation : $[H^+] = K_a \frac{[CH_3COOH]}{[CH_3COO^-]}$ $[CH_3COOH] = 0.333$ mol dm^{-3} and $[CH_3COO^-] = 0.167$ mol dm^{-3} $[H^+] = 1.74 \times 10^{-5} \times 0.333 / 0.167$ $= 3.48 \times 10^{-5}$ (mol dm^{-3}) so pH = -lg $3.48 \times 10^{-5} = 4.46$ Accept answers that use forms of the Henderson-Hasselbach equation Correct answer with no working scores 4 marks	**4**

(Total for Question 8 = 8 marks)

Question number	Answer	Additional guidance	Marks
9(a)(i)	A		**1**
9(a)(ii)	 • 3D shape correctly shown (1) • electron pairs shown OR all six bonds shown clearly to the carbons (1)	Charge and square brackets not required Allow dotted lines for the wedges going backwards Allow arrows to represent dative covalent bonds instead of electron pairs	**2**
9(b)	• step 1 – ligand substitution/ligand exchange (1) • step 2 – redox (1)	Allow reduction **and** oxidation	**2**
9(c)	• identification: green precipitate is iron(II) hydroxide (1) Explanation: • precipitate turns brown because iron(II) hydroxide is oxidised by oxygen (and water) in the air (1) • to form iron(III) hydroxide (1)	Allow $Fe(OH)_2$ / $Fe(H_2O)_4(OH)_2$ Allow $Fe(OH)_3$ / $Fe(H_2O)_3(OH)_3$	**3**

(Total for Question 9 = 8 marks)

Question number	Answer	Additional guidance	Marks
10(a)	An explanation that makes reference to the following points: • they get more stable down the group (1) • because the size of the cations increases/charge density of cations decreases (1) • and so carbonate ions are less polarised (1)		**3**
10(b)	• rearrangement of equation (1) • calculation of $\Delta H_{solution}$ (1)	Example of calculation $-2493 + \Delta H_{solution} = -1920 + (-2 \times 364)$ $\Delta H_{solution} = -155$ (kJ mol^{-1}) Correct sign must be given in final answer Correct answer and sign with no working scores 2 marks	**2**
10(c)(i)	An explanation that makes reference to the following points: • breaking the lattice is endothermic and the hydration of ions is exothermic (1) • (therefore the dissolving of magnesium sulphate is exothermic) because the enthalpy of hydration (of the ions) is greater in magnitude than the lattice energy (of $MgSO_4$) (1)		**2**
10(c)(ii)	• $\Delta G^{\ominus} = -87 - (298 \times -0.210)$ $= -24(.42)$ (kJ mol^{-1}) (1) • since ΔG is negative the process/reaction is spontaneous/feasible (1)		**2**

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Marks</th></tr>
<tr><td>*10(d)</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>6</td></tr>
</table>

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Marks</th></tr>
<tr><td>*10(d) cont.</td><td>The following table shows how the marks should be
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr>
</table>
awarded for structure and lines of reasoning.
Indicative content
($\Delta G^{\ominus}_{solution} = \Delta H^{\ominus}_{solution} - T\Delta S^{\ominus}_{system}$)
• for $BaSO_4$: $\Delta H^{\ominus}_{solution}$ and $-T\Delta S^{\ominus}_{system}$ are both positive (1)
• for $CaSO_4$: $\Delta H^{\ominus}_{solution}$ is negative and $-T\Delta S^{\ominus}_{system}$ is positive (1)
• but the magnitude of $-T\Delta S^{\ominus}_{system}$ is greater than that of $\Delta H^{\ominus}_{solution}$ (1)
• therefore $\Delta G^{\ominus}_{solution}$ for both salts is positive (1)
• when $\Delta G^{\ominus}_{solution}$ is positive the salt is only slightly soluble (1)
• $BaSO_4$ is less soluble than $CaSO_4$ because $\Delta G^{\ominus}_{solution}$ is more positive (1)</td><td></td><td></td></tr>
</table>

(Total for Question 10 = 15 marks)

Write your name here

Surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number | Candidate Number

Chemistry

Advanced

Paper 2: Advanced Organic and Physical Chemistry

Sample Assessment Materials for first teaching September 2015

Time: 1 hour 45 minutes

Paper Reference **9CH0/02**

You must have:
Data Booklet
Scientific calculator, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- For questions marked with an *, marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

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.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

S47554A

S 4 7 5 5 4 A 0 1 3 2

PEARSON

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 ☒.

1 This question is about some hydrocarbons.

(a) (i) Which isomeric alkane has the lowest boiling temperature?

(1)

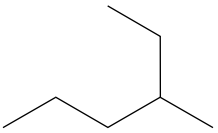
☒ **A** 2,2-dimethylbutane

☒ **B** hexane

☒ **C** 3-methylpentane

☒ **D** 2-methylpentane

(ii) What is the name of this alkane?



(1)

☒ **A** 4-ethylpentane

☒ **B** 2-ethylpentane

☒ **C** 4-methylhexane

☒ **D** 3-methylhexane

(b) Describe how the orbitals from carbon atoms interact to form the bonds in a benzene ring. You may include a labelled diagram to support your answer.

(3)

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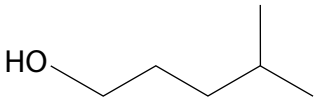
.....

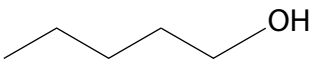
(Total for Question 1 = 5 marks)

2 The skeletal formulae of four compounds are shown.

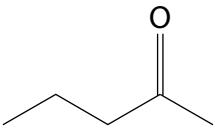
A



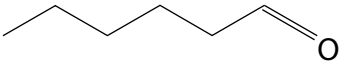
B



C



D



(a) Which compound has the molecular formula $C_6H_{14}O$?

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(b) Which compound forms a pale yellow precipitate when reacted with iodine and sodium hydroxide solution?

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(c) Which compound forms a silver mirror when reacted with Tollens' reagent?

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 2 = 3 marks)

3 This question is about amines.

(a) Amines can behave as bases.

What is meant by the term base?

(1)

.....

.....

.....

.....

(b) Which of these compounds has the highest pH when dissolved in water to form solutions of the same concentration?

(1)

☒ **A** NH_3

☒ **B** CH_3NH_2

☒ **C** $C_6H_5NH_2$

☒ **D** NH_4Cl

(c) A student wrote a statement about the mechanism of the reaction between a primary chloroalkane and an amine.

> The amine acts as a nucleophile due to its unpaired electron. It attacks the slightly positive carbon in the chloroalkane, forming an intermediate. The carbon is slightly positive as it is attached to an electropositive chlorine atom. The intermediate then loses a proton and a chloride ion, forming the product, an N-substituted amide.

Identify and correct **two** of the errors in the statement.

(2)

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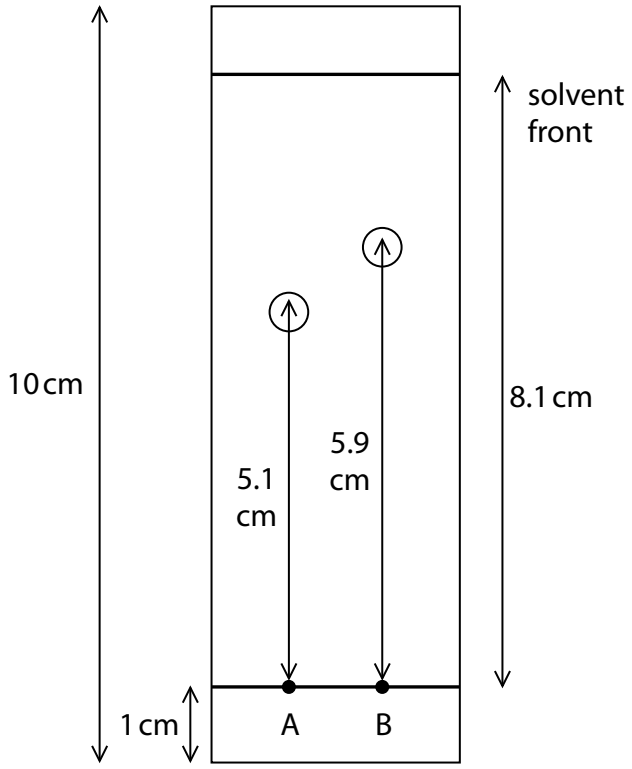
(Total for Question 3 = 4 marks)

4 This question is about the properties of amino acids and other organic compounds.

(a) A chromatogram of two amino acids, **A** and **B**, is shown.



The R_f value of amino acid A is

(1)

- ☒ **A** 0.51
- ☒ **B** 0.56
- ☒ **C** 0.63
- ☒ **D** 0.67

(b) Amino acid **B** has the structure $H_2NCH(CH_2CH(CH_3)_2)COOH$.

Predict the pH of the solution formed when it dissolves in water and justify your answer.

(2)

(c) Some data about different organic compounds is shown in the table.

Compound	Relative molecular mass	Melting temperature / ˚C
glycine (an amino acid)	75	233
butan-1-ol	74	–90
pentane	72	–130

Use information from the table to justify the types of intermolecular forces in each of these compounds.

(4)

(Total for Question 4 = 7 marks)

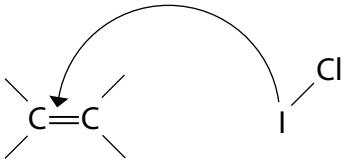
5 This question is about the chemistry of iodine compounds and hydrocarbons.

(a) Iodine monochloride (ICl) reacts with unsaturated compounds such as sunflower oil.

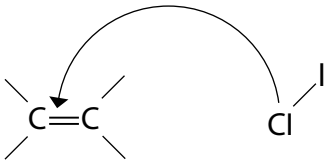
(i) Which diagram shows the first step in the mechanism of the reaction between iodine monochloride and an unsaturated compound?

(1)

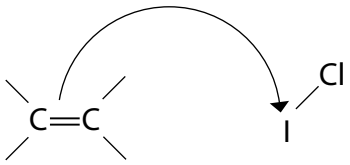
☒ **A**



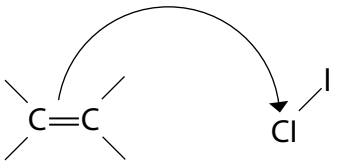
☒ **B**



☒ **C**



☒ **D**



(ii) What is the name and type of the mechanism in the overall reaction?

(1)

- ☒ **A** electrophilic substitution
- ☒ **B** nucleophilic substitution
- ☒ **C** electrophilic addition
- ☒ **D** nucleophilic addition

(b) The number of grams of iodine from iodine monochloride that reacts with 100 g of an oil or fat is known as the iodine value and is used to compare levels of unsaturation in different oils and fats.

An excess of iodine monochloride, 11.0 g, was mixed with 6.40 g of sunflower oil. The remaining unreacted iodine monochloride was treated with excess potassium iodide to liberate iodine.

$$ICl + KI \rightarrow KCl + I_2$$

The liberated iodine was titrated with sodium thiosulfate solution of concentration 0.500 mol dm^{-3}. 21.20 cm^3 of this solution was required to completely react with the liberated iodine.

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

(i) Calculate the amount, in mol, of sodium thiosulfate that reacted with the liberated iodine and hence calculate the amount (in mol) of liberated iodine.

(2)

(ii) Use your answer to (i) and the initial mass of iodine monochloride, 11.0 g, to calculate the iodine value of the oil.

(5)

(c) Sunflower oil can be hydrogenated to form solid fats such as margarine. What is the **most** appropriate catalyst for this reaction?

(1)

- ☒ **A** nickel
- ☒ **B** iron
- ☒ **C** rhodium
- ☒ **D** vanadium(V) oxide

(Total for Question 5 = 10 marks)

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6 This question is about the kinetics of chemical reactions.

(a) The rate equation for the reaction between hydrogen and nitrogen monoxide is:

$$\text{rate} = k[H_2][NO]^2$$

By what factor does the rate increase when the concentration of hydrogen is tripled and that of nitrogen monoxide is doubled?

(1)

- ☒ **A** 5
- ☒ **B** 6
- ☒ **C** 12
- ☒ **D** 18

(b) The 'initial rates' method is used to investigate the orders of reaction with respect to reactants **A**, **B** and **C**. The table shows the results obtained.

Run	Initial concentration / mol dm^{-3}			Initial rate / mol dm^{-3} s^{-1}
	A	B	C	
1	0.32	0.080	0.16	2.4×10^{-3}
2	0.64	0.080	0.16	4.8×10^{-3}
3	0.32	0.16	0.16	9.6×10^{-3}
4	0.64	0.32	0.48	0.23

(i) Deduce the orders with respect to **A** and **B**.

(2)

A .....

B .....

(ii) Deduce the order with respect to **C** and justify your answer.

(2)

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.....

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.....

.....

(iii) Give the rate equation for the reaction.

(1)

(iv) Calculate the rate constant, *k*, to an appropriate number of significant figures. Give units for your answer.

(3)

(c) A different reaction, between iodine and propanone, in the presence of hydrogen ions, has the rate equation:

$$\text{rate} = k[CH_3COCH_3][H^+]$$

(i) Give the overall order of the reaction.

(1)

(ii) Explain, in terms of collision theory, why increasing the concentration of propanone changes the rate of reaction.

(2)

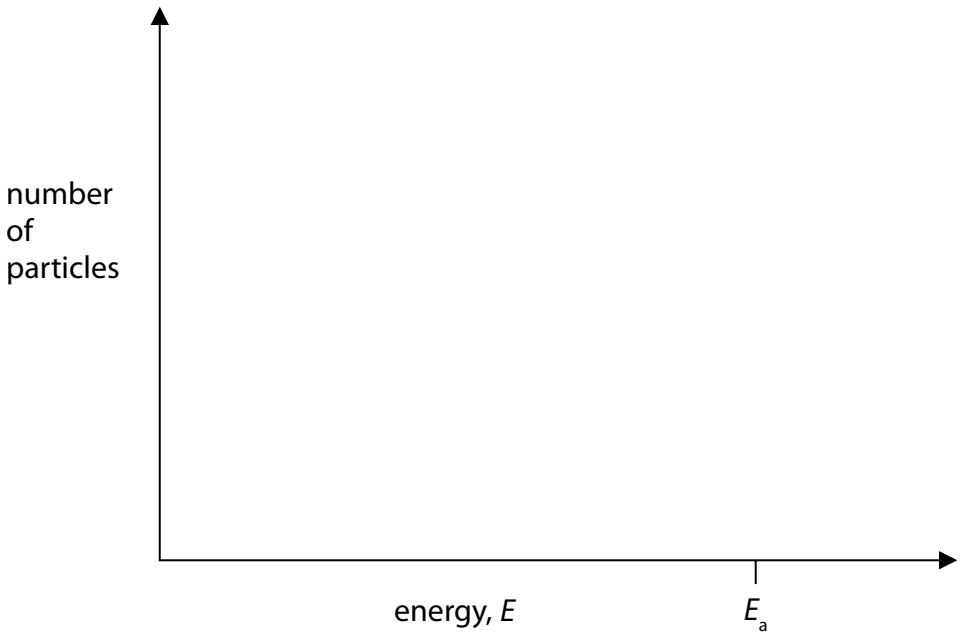
(d) Catalysts are sometimes used in reactions.

(i) Explain how a catalyst affects the rate of a reaction.

(3)

(ii) Draw and label lines on the axes to show how an increase in temperature affects the number of particles with $E > E_a$.

(2)



(Total for Question 6 = 17 marks)

7 The compound 2-phenylethyl propanoate is a synthetic oil used in some fragrances due to its rose-like aroma.

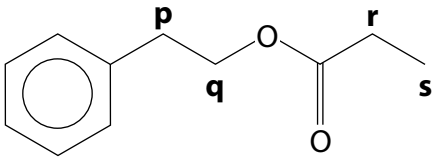
(a) Combustion analysis of 1.56 g of 2-phenylethyl propanoate, in a laboratory, produced 4.26 g of $CO_2(g)$ and 1.10 g of $H_2O(l)$.

Show that the data is consistent with the molecular formula of 2-phenylethyl propanoate, $C_{11}H_{14}O_2$.

(4)

(b) Nuclear magnetic resonance (NMR) spectroscopy can be used to determine structural formulae.

An incomplete ^{1}H NMR spectrum for 2-phenylethyl propanoate shows a peak for the hydrogen atoms attached to the benzene ring.

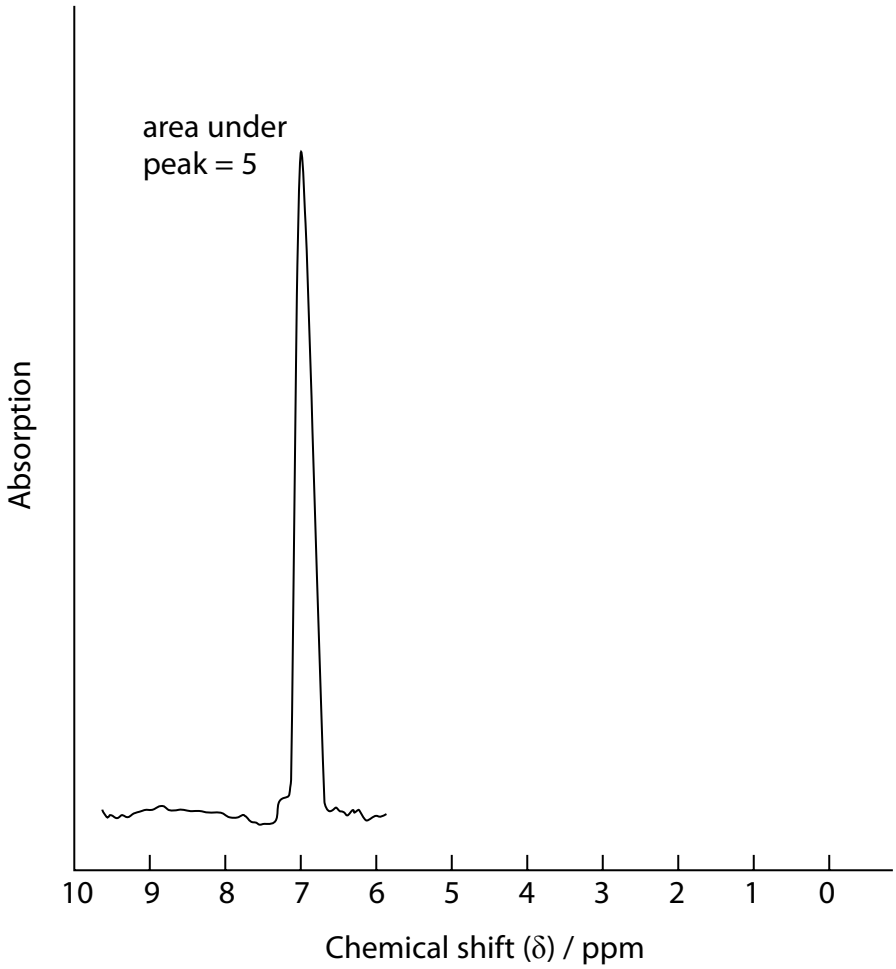


Complete the spectrum for the protons attached to the carbon atoms **p**, **q**, **r** and **s**, giving the relative areas under each peak.

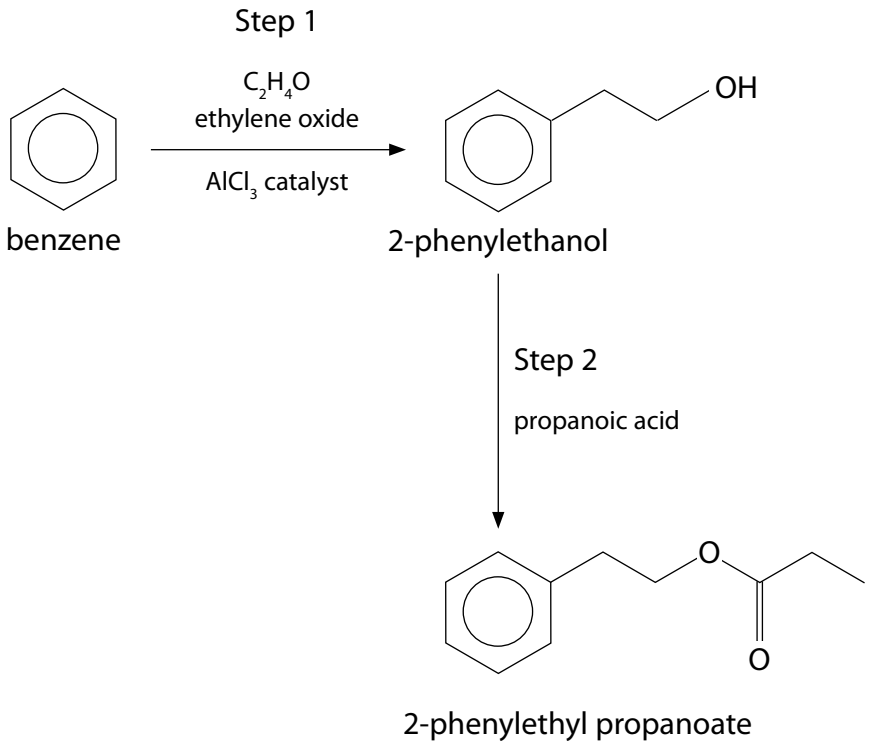
You should use the Data Booklet. Your spectrum does not have to be to scale.

(6)

Predicted spectrum:



(c) A possible synthetic route to prepare 2-phenylethyl propanoate is:



(i) The attacking species in Step 1 can be represented as $^{+}CH_2CH_2OAlCl_3^{-}$

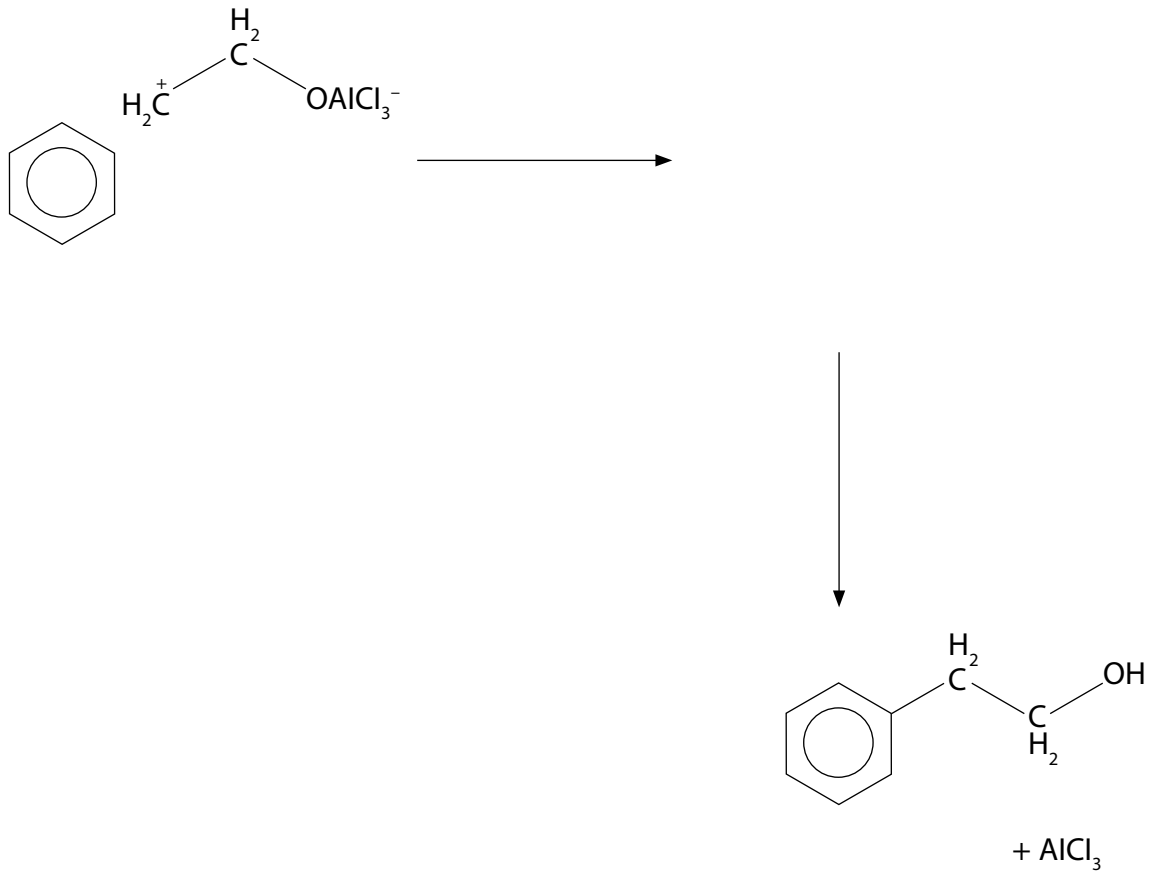
What is the mechanism in this step?

(1)

- ☒ **A** electrophilic substitution
- ☒ **B** nucleophilic substitution
- ☒ **C** electrophilic addition
- ☒ **D** nucleophilic addition

(ii) Complete the diagram, including curly arrows, to show the mechanism for the reaction to form 2-phenylethanol.

(4)



(iii) In the synthetic route, what type of reaction is Step 2?

(1)

☒ **A** hydrolysis

☒ **B** esterification

☒ **C** neutralisation

☒ **D** hydrogenation

(iv) Name a suitable catalyst for Step 2.

(1)

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(Total for Question 7 = 17 marks)

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8 Propanoic acid can be synthesised from propene, a by-product of the petrochemical industry.

(a) Complete the equation to show the formation of propene and one other hydrocarbon.

$$C_{10}H_{22} \rightarrow C_3H_6 + \text{.....}$$

(1)

(b) Propanoic acid can be synthesised from propene in 3 steps. A student proposed the following synthesis:

Step 1: propene $\rightarrow$ 1-bromopropane

Step 2: 1-bromopropane $\rightarrow$ **X**

Step 3: **X** $\rightarrow$ propanoic acid

(i) Identify **X** and give the conditions needed to carry out Step 2 and Step 3 in this synthesis.

(4)

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(ii) Explain, by considering the mechanism of the reaction, why the student's choice of reaction for Step 1 will lead to a low overall yield.

(2)

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(c) Propene is used in the manufacture of polymers.

(i) Write an equation to show the formation of poly(propene) from propene.

(2)

(ii) Describe how the chemical reaction to form the polymer nylon differs from the chemical reaction to form poly(propene).

(2)

(iii) Give **two** ways in which chemists contribute to a more sustainable use of such materials as poly(propene) and nylon.

(2)

(Total for Question 8 = 13 marks)

9 The table shows the formulae of three different halogenoalkanes and the optical activity of the products of their reaction with hydroxide ions in aqueous solution.

Reaction	Halogenoalkane reacting with hydroxide ions	Optical activity of product mixture
1	CH_3Cl	none
2	$CH_3CHBrCH_2CH_3$	significant
3	$CH_3CH_2CH_2C(Br)(CH_3)CH_2CH_3$	no significant activity

(a) Draw the mechanism for reaction **1**.

(4)

(b) The halogenoalkane in reaction **2** is 2-bromobutane.

(i) Name the halogenoalkane in reaction **3**.

(1)

.....

.....

*(ii) Both halogenoalkanes used in reaction **2** and reaction **3** were a single optical isomer.

Explain the optical activity of the product mixture for reaction **2** and reaction **3**, in terms of the reaction mechanism.

(6)

(c) Compounds containing the alkene functional group can show stereoisomerism.

(i) Draw the **two** structural isomers for an alkene that shows stereoisomerism.

(1)

(ii) Explain why stereoisomerism occurs in alkenes.

(2)

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(Total for Question 9 = 14 marks)

TOTAL FOR PAPER = 90 MARKS

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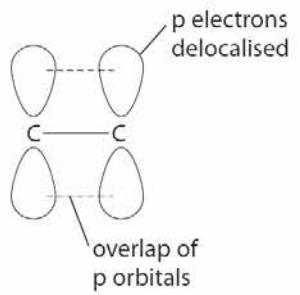
The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
* Actinide series	232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

CHEMISTRY A LEVEL PAPER 2 MARK SCHEME

Question Number	Answer	Additional Guidance	Mark
1(a)(i)	A		**1**
1(a)(ii)	D		**1**
1(b)	A description that makes reference to: • (head on) overlap between orbitals from neighbouring carbon atoms to form a sigma bond (1) • (the remaining) p orbitals overlap sideways (1) • and so electrons delocalise (around the ring) (1) Example of a possible diagram scoring 2 marks (marking points 2 and 3)  	Allow sp^2 hybrid orbitals overlap to form a sigma bond	**3**

(Total Question 1 = 5 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)	A		**1**
2(b)	C		**1**
2(c)	D		**1**

(Total Question 2 = 3 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	reacts with acids to form a salt/proton acceptor (1)	Allow electron pair donor	**1**
3(b)	B		**1**
3(c)	Any **two** of the following points: • the nucleophile does not have an unpaired electron, it has a lone pair of electrons (1) • the slightly positive carbon is not attached to an electropositive chlorine atom, it is attached to an electronegative chlorine atom (1) • the product is not an amide, it is a (secondary) amine (1)		**2**

(Total Question 3 = 4 marks)

Question Number	Answer	Additional Guidance	Mark
4(a)	C		**1**
4(b)	• Prediction: 7/neutral (1) • Justification: Amino group accepts one proton released from acid / **B** exists as a zwitterion (so it is not acidic or alkaline) (1)	Allow 6.5 to 7.5 Allow proton from acid accepted by amine	**2**
4(c)	An answer that makes reference to the following points: • pentane has the lowest melting temperature because it only has London forces (1) • butan-1-ol and glycine have (similar) London forces (due to similar number of electrons) (1) • butan-1-ol has higher / less negative melting temperature than pentane as it has hydrogen bonds (1) • glycine has the highest melting temperature as it is an ionic solid (lattice) / consists of zwitterions (1)	Accept van der Waals as alternative to London If marking points 2 and 3 are not scored then allow 1 mark for the idea that butan-1-ol has higher melting temperature (than pentane) due to stronger intermolecular forces	**4**

(Total Question 4 = 7 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)(i)	C		**1**
5(a)(ii)	C		**1**
5(b)(i)	• amount of sodium thiosulfate (1) • amount of liberated iodine (1)	Example of calculation Amount of sodium thiosulfate = 21.2/1000 x 0.500 = 0.0106 (mol) Amount of liberated iodine = 0.0106/2 = 5.3×10^{-3} /0.0053 (mol) Allow ecf from 1st to 2nd mark Correct answer with no working scores 2 marks	**2**
5(b)(ii)	• initial amount of ICl (1) • amount of ICl that reacted with oil (1) • mass of iodine in ICl (1) • expression for iodine value (1) • final iodine value (1)	Allow ecf from (b)(i) If no subtraction allow 3 max (1st, 4th and 5th marks) Example of calculation Initial amount of ICl = 11.0 /162.4 = 0.067734 (mol) Amount of ICl that reacted with oil = 0.067734 - 5.3×10^{-3} = 0.062434 (mol) Mass of iodine in ICl = 0.062434 x 126.9 =7.9229s g (with 6.4 g oil) Iodine value = 7.9229 x 100/6.4 = 123.79 / 124 Correct answer with no working scores 5 marks	**5**
5(c)	A		**1**

(Total Question 5 = 10 marks)

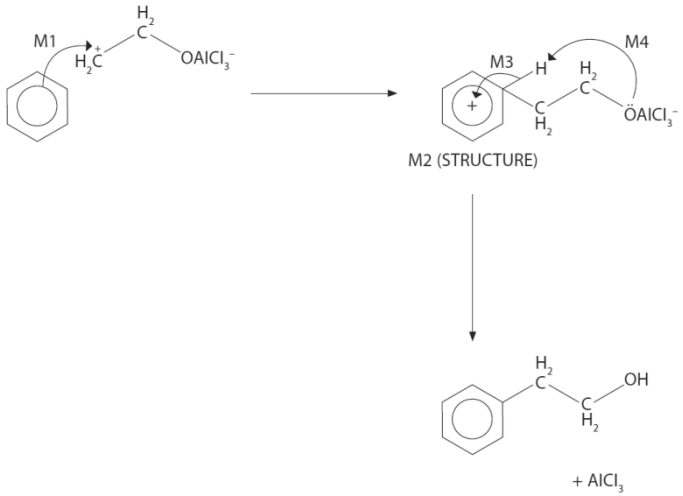
Question Number	Answer	Additional Guidance	Mark
6(a)	C		**1**
6(b)(i)	• Comparison of runs 1 and 2 to determine order wrt A = 1 (1) • Comparison of runs 1 and 3 to determine order wrt B = 2 (1)	Allow comparisons of other relevant pairs of runs	**2**
6(b)(ii)	(When comparing runs 2 and 4) • [A] constant so no effect but [B] x 4 so increases rate by 16 / to 0.0768 (1) • [C] x 3 and rate increases by 0.23 ÷ 0.0768 (= 2.99 i.e. 3), so first order with respect to C (1)	Allow comparisons of other relevant pairs of runs, e.g. runs 3 and 4	**2**
6(b)(iii)	• rate = k[A][B]^2[C] (1)		**1**
6(b)(iv)	• rearrangement of rate expression (1) • evaluation of value for k to 2.s.f (1) • units $dm^9\ mol^{-3}\ s^{-1}$ (1)	Example of calculation k = rate / [A][B]^2[C] = 7.324…. = 7.3 $dm^9\ mol^{-3}\ s^{-1}$ Allow ecf from b (iii) Allow units in any order Correct answer with no working and units to 2 sf scores 3 marks	**3**

Question Number	Answer	Additional Guidance	Mark
6(c)(i)	• 2^{nd} order (1)		**1**
6(c)(ii)	An explanation that makes reference to the following points: • rate increases because increased concentration of propanone means more propanone molecules in a given volume (1) • so more frequent collisions / greater rate of collisions / more collisions per second (1)		**2**
6(d)(i)	An explanation that makes reference to the following points: • increases the rate of reaction because it lowers the activation energy (1) • by providing alternative reaction mechanism /pathway (1) • so greater proportion of particles collide with sufficient energy (1)	Responses in terms of heterogeneous catalysis can score a maximum of 2 marks • Reactants bond onto catalyst surface (adsorption) • Increases concentration of reactant (at surface) • Products break away from catalyst surface (desorption) All 3 points scores 2 marks A combination of any 2 points scores 1 Any single point only scores 0 marks	**3**

Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	• one Maxwell-Boltzmann distribution shown drawn with appropriate shape (1) • second distribution shown with maximum lower and to right of that shown by first curve, with larger area below curve beyond E_a (1) (to score 2nd mark there must be a clear indication that the second distribution is at a higher temperature)	Curves should not cross *x*- axis	**2**

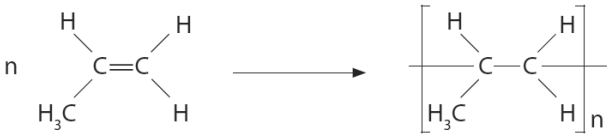
(Total Question 6 = 17 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)	• calculation of mass of C from CO_2 (1) • calculation of mass of H from H_2O (1) • subtraction to find mass of O, and evaluation of number of moles of C, H and O (1) • confirm whole number ratio (1)	<u>Example of calculation</u> Mass of C = 4.26 x 12/44 = 1.1618 g Mass of H = 1.1 x 2/18 = 0.12222 g So mass O = 1.56 – (1.1618 + 0.1222) = 0.27598 g Moles C = 1.1618/12 = 0.096817 Moles H = 0.12222/1 = 0.12222 Moles O = 0.27598/16 = 0.017249 Ratio = 5.6 : 7.1 : 1 = 11 : 14 : 2 Allow alternative correct methods	**4**
7(b)	• 4 (additional) peaks drawn (1) • Splitting marks (ignore chemical shift at this point) (2) - **p**, **q** and **s** are triplets and **r** is quartet scores 2 marks - two or three splitting patterns correctly shown scores 1 mark • area under curve (1) - total shown by candidate = (2+2+2+3) = 9 • chemical shifts (2) - Peak at 0-2 ppm due to protons on **s** - Peak at 2-3 ppm due to protons on **r** - Peak at 3-4 ppm due to protons on **q** - Peak at 1.6-2.8 ppm due to protons on **p**	Peaks can be shown as separate lines Ignore whether values are linked to correct peak All peaks at correct chemical shift score 2 marks Two or three at correct chemical shift peaks score 1 mark	**6**

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	A		**1**
7(c)(ii)	 • electron pair movement from ring to electrophile (1) • formula of intermediate ion (1) • movement of bond pair to reinstate delocalised ring (1) • movement of lone pair from oxygen to hydrogen (1)	Can show H^+ ion forming and reacting with lone pair from oxygen Can show O-Al bond breaking	**4**
7(c)(iii)	B		**1**
7(c)(iv)	• (concentrated) sulfuric acid / H_2SO_4 **or** (concentrated) hydrochloric acid/HCl (1)	Do not award dilute sulfuric acid	**1**

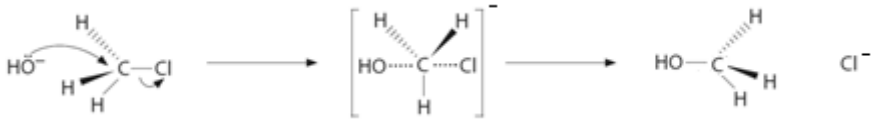
(Total Question 7 = 17 marks)

Question Number	Answer	Additional Guidance	Mark
8(a)	Any **one** from: • $C_3H_6 + C_7H_{16}$ (1) • $2C_3H_6 + C_4H_{10}$ (1) • $3C_3H_6 + CH_4$ (1)		**1**
8(b)(i)	• **X** is propan-1-ol (1) Step 2 • reaction with aqueous NaOH (and heat) (1) Step 3 • oxidation to acid using acidified $K_2Cr_2O_7$ (1) • with excess oxidising agent / heated under reflux (1)	Allow 'H^+ and $Cr_2O_7^{2-}$'	**4**
8(b)(ii)	An explanation that makes reference to **two** of the following points: • main product from reaction with HBr will be 2-bromopropane (1) • as secondary carbocation (formed in mechanism) is more stable (than primary) (1)	Allow reverse argument e.g. • 1-bromopropane is the minor product • as primary carbocation (formed in mechanism) is less stable (than secondary)	**2**

Question Number	Answer	Additional Guidance	Mark
8(c)(i)	 • formulae (1) • balancing and brackets (1)	Ignore type of brackets 2nd mark dependent on correct formulae	**2**
8(c)(ii)	A description that makes reference to: • nylon is formed by a condensation reaction / releases HCl when polymers forms (1) • nylon is formed from two different monomers (1) **OR** • poly(propene) is formed by an addition reaction / forms only one product (1) • poly(propene) is formed from only one type of monomer (1)		**2**

Question Number	Answer	Additional Guidance	Mark
8(c)(iii)	An answer that makes reference to **two** of the following points: • reprocessing of polymers into simpler compounds for use as feedstock in the chemical industry (1) • capture and use of energy from incineration (1) • sorting (Using IR) **and** recycling of polymers (1) • removal of harmful/toxic/corrosive products formed during incineration (1)		**2**

(Total Question 8 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
9(a)	 • attack by hydroxide ion on positive carbon (1) • breaking of C-Cl bond (1) • formula of transition state with correct charge (1) • 'partial' bonds to OH and Cl shown in transition state (1)	Arrow must start from O and go to C; lone pair not required Arrow from bond to Cl Ignore brackets	**4**
9(b)(i)	3-bromo-3-methylhexane (1)	Allow 3-methyl-3-bromohexane	**1**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*9(b)(ii)</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>6</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*9(b)(ii) cont.</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr>
</table>
Indicative content
• Reaction 2 forms optically active product as only one enantiomer formed (S_N2)
• as hydroxide ion can only attack on opposite side to leaving group
• which causes inversion (of configuration) of the chiral centre
• Reaction 3 product mixture shows no significant optical activity as a racemic mixture forms (S_N1)
• as intermediate is a planar carbocation,
• so can be attacked (by hydroxide ion) from either side</td><td>Could use labelled diagrams to illustrate attack of hydroxide ions in either mechanism</td><td></td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
***9(b)(ii) cont.**	**Or** • mechanism of reaction 2 is S_N2 • because single enantiomer is formed as product and is optically active • as hydroxide ion can only attack on opposite side to leaving group • reaction 3 produces a racemic mixture as product is not significantly optically active • so reaction 3 is S_N1 • as the two products rotate the plane of plane-polarised light in opposite directions		
9(c)(i)	• two correct structures (1)		**1**
9(c)(ii)	An explanation that makes reference to the following points: • in alkenes this occurs due to non-rotation of C=C bond (1) • because π-bond prevents it / π-bond above and below σ - bond (1)	Allow no free rotation around the carbon-carbon double bond	**2**

(Total Question 9 = 14 marks)

Write your name here

Surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number | | | | | |

Candidate Number | | | | |

Chemistry

Advanced

Paper 3: General and Practical Principles in Chemistry

Sample Assessment Materials for first teaching September 2015

Time: 2 hours 30 minutes

Paper Reference **9CH0/03**

You must have:
Data Booklet
Scientific calculator, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- For questions marked with an *****, marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

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.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

S47555A

S 4 7 5 5 5 A 0 1 3 6

PEARSON

Answer ALL questions.

Write your answers in the spaces provided.

1 Solid benzoic acid is usually purified by recrystallisation from hot water.
The method used is:

1 The impure solid is dissolved in the minimum volume of hot water.

2 The solution is quickly filtered.

3 The solution is allowed to cool and crystallise.

4 The crystals are filtered from the remaining solution.

5 The crystals are washed with a little cold water.

6 The crystals are left to dry.

(a) State how steps **2**, **4** and **5** remove impurities from the benzoic acid.

(3)

(b) Describe how impurities affect the melting temperature of an impure solid.

(2)

(Total for Question 1 = 5 marks)

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2 Compound **A** is a green solid containing one cation and one anion. It dissolves in water to form a green solution.

(a) Give the formulae of **two** cations which could be responsible for the green colour in the solid.

(2)

.....

(b) A student adds dilute sodium hydroxide solution, drop by drop, to an aqueous solution of **A**.
A green precipitate forms, which dissolves in excess sodium hydroxide solution to form a dark green solution.

(i) Give the formula of the cation in **A**.

(1)

.....

(ii) Give a formula for the green precipitate.

(1)

.....

(iii) Give a formula for the species present in the dark green solution.

(1)

.....

(c) The student adds a few drops of acidified potassium manganate(VII) solution to another sample of a solution of **A** in a test tube.

State the colour change that occurs.

(1)

.....

.....

(d) The student acidifies 2 cm^3 of a solution of **A** with dilute nitric acid in a test tube and then adds a few drops of aqueous silver nitrate. A white precipitate is formed.

(i) Give the formula of the anion in **A**.

(1)

.....

(ii) This test is usually followed by the addition of ammonia solution to test the solubility of the precipitate.

Explain why this procedure in not suitable to confirm the identity of the anion in **A**.

(2)

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(Total for Question 2 = 9 marks)

3 The equation for the reaction between iodine and propanone is:

$$CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + H^+(aq) + I^-(aq)$$

The kinetics of this reaction were studied.

(a) The order of the reaction with respect to iodine was determined by preparing a mixture of solutions of iodine and sulfuric acid in a conical flask. A solution of propanone was then added and a timer started. After one minute, a 10.0 cm^3 sample of the reaction mixture was removed. Further 10.0 cm^3 samples of the reaction mixture were removed at regular time intervals during the experiment.

After removal, each sample was immediately added to sodium hydrogencarbonate solution and then titrated with sodium thiosulfate solution to determine the concentration of iodine.

The table shows the volumes and initial concentrations of the substances in one experiment.

Substance	Volume / cm^3	Concentration / mol dm^{-3}
iodine	50	0.020
sulfuric acid	20	2.5
propanone	25	2.0

(i) Deduce, by calculation of the amounts used, whether propanone or iodine was in excess.

(2)

(ii) Name the piece of apparatus which is most suitable for measuring the volume of sulfuric acid.

(1)

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.....

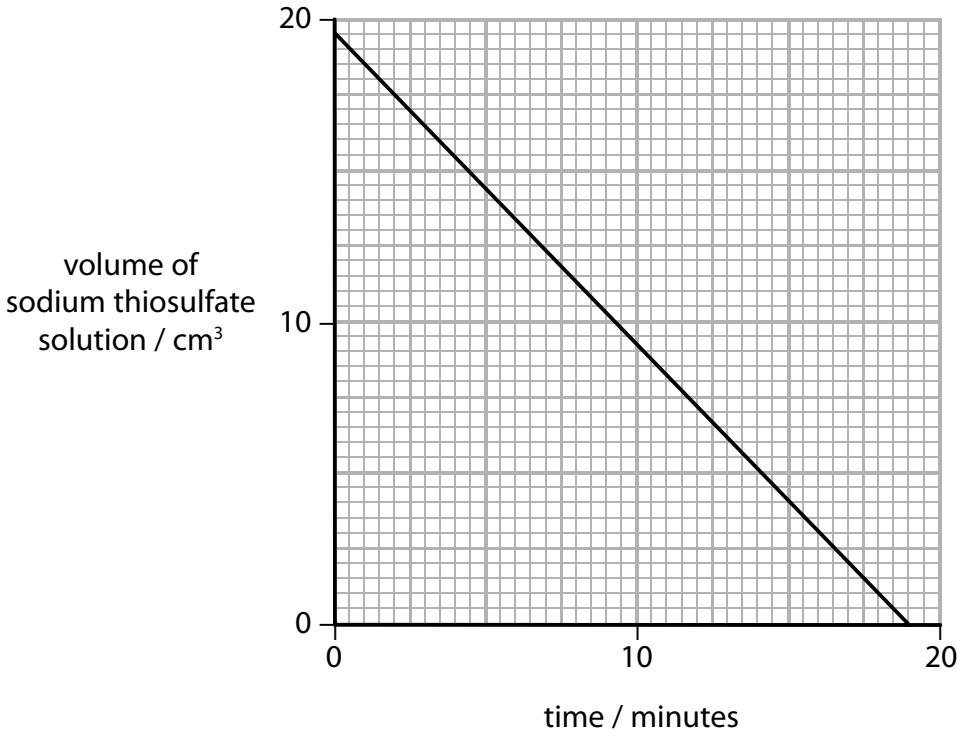
(iii) Name the piece of apparatus which is most suitable for removing the sample from the reaction mixture.

(1)

.....

.....

(b) The graph shows the results of titrating the samples of the reaction mixture.



Explain how you can deduce the order of reaction with respect to iodine from this graph.

(2)

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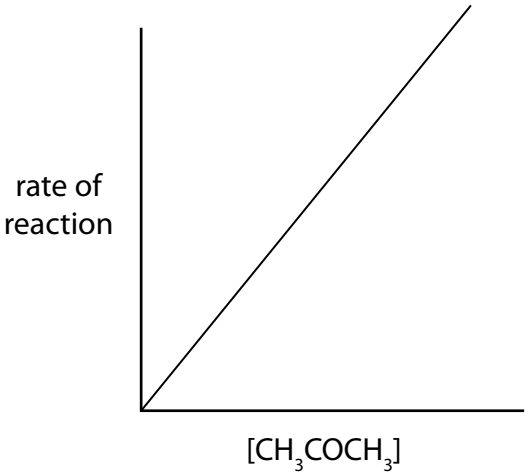
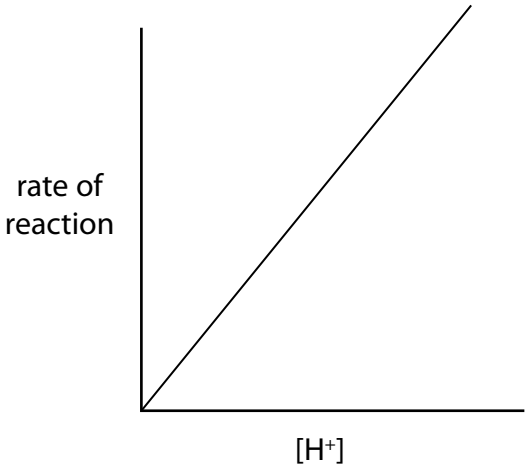
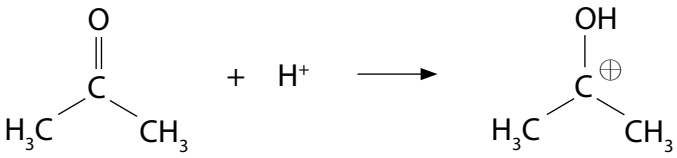
(c) These graphs were obtained in other experiments to determine the order of reaction with respect to propanone and to sulfuric acid.

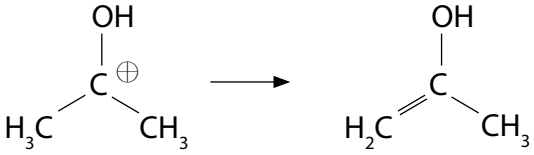


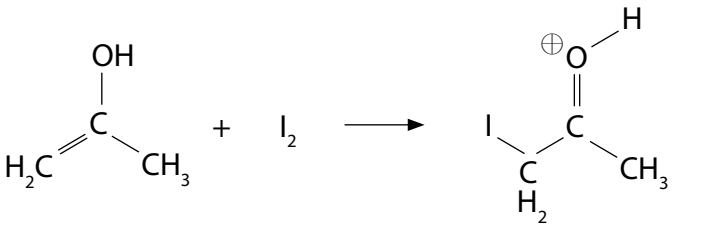


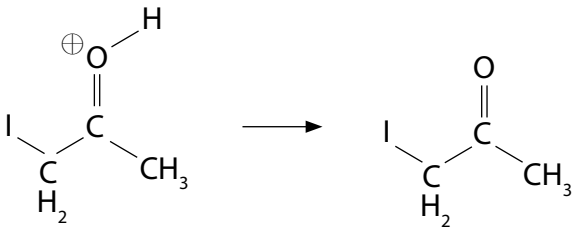
Use these graphs and your answer from part (b) to comment on whether this proposed mechanism for the reaction is correct.

(3)

step 1  fast

step 2  slow

step 3  fast

step 4  fast

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(Total for Question 3 = 9 marks)

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4 This question is about the effect of changes in temperature on reactions.

(a) An experiment to determine the activation energy for the reaction between magnesium and hydrochloric acid was carried out. The time taken for 0.100 g of magnesium to react completely when added to 20.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid was recorded at different temperatures. A summary of the processed data is shown.

Temperature / K	$\frac{1}{T}$ / K^{-1}	ln *k*
283	3.53×10^{-3}	−4.80
299	3.34×10^{-3}	−3.56
311	3.22×10^{-3}	−3.00
322	3.11×10^{-3}	−2.25
329	3.04×10^{-3}	−1.79

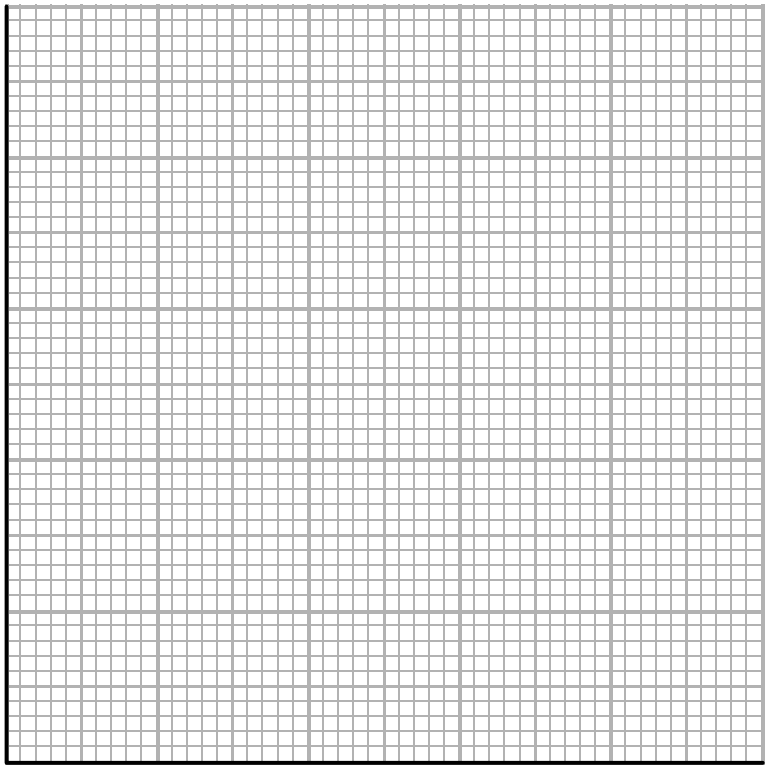
The activation energy, E_a, of the reaction can be found using the equation:

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

Use this data to plot a graph of ln *k* against $\frac{1}{T}$ and hence determine the activation energy in kJ mol^{-1}.

(4)

ln *k*



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

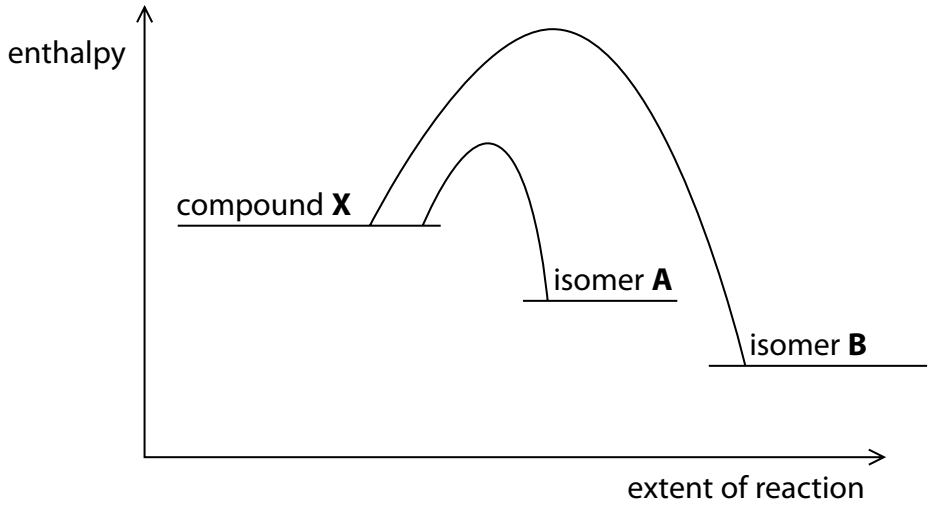
Activation energy = ... kJ mol^{-1}

*(b) In the study of a different reaction, a compound **X** reacted reversibly with concentrated sulfuric acid to form two isomers, **A** and **B**.

$$\text{compound } \mathbf{X} + H_2SO_4(\text{conc.}) \rightleftharpoons \text{isomer } \mathbf{A} + \text{isomer } \mathbf{B}$$

At 40 °C, approximately 95% of the product was isomer **A**. At 160 °C, the product contained approximately 85% of isomer **B**.

The diagram shows the reaction profiles for the formation of the two isomers.



Use the information to comment on the different yields of isomer **A** and isomer **B** at different temperatures.

(6)

(Total for Question 4 = 10 marks)

5 Ammonia is produced industrially by reacting nitrogen and hydrogen.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} = -92.0 \text{ kJ mol}^{-1}$$

A temperature in the range of 673 to 773 K is used.

The standard entropies, $S^{\ominus}$, of $N_2(g)$, $H_2(g)$ and $NH_3(g)$ at 298 K are given in the table.

substance	$N_2(g)$	$H_2(g)$	$NH_3(g)$
$S^{\ominus}$ **/ J K^{-1} mol^{-1}**	192	131	193

(a) Show that this reaction is feasible at 298 K by calculating $\Delta G^{\ominus}$ in kJ mol^{-1}. Give your answer to an appropriate number of significant figures.

(5)

(b) Explain, in terms of entropy, why this reaction is not feasible at very high temperatures.

(2)

(c) Nitrogen and hydrogen were reacted together at 673 K and 200 atm pressure in a closed vessel.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

The reaction mixture was allowed to reach equilibrium. The number of moles of each gas at equilibrium were found to be:

$N_2(g)$ 2.88 $H_2(g)$ 8.64 $NH_3(g)$ 6.48

Calculate the value of K_p at 673 K, giving appropriate units.

(5)

(Total for Question 5 = 12 marks)

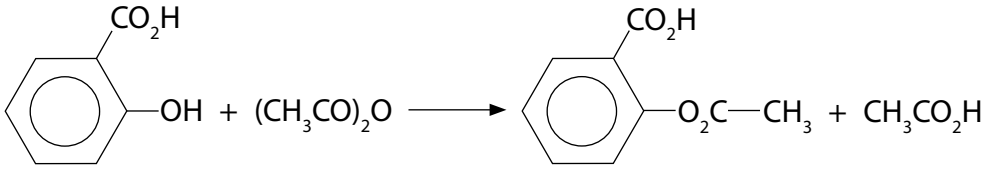
6 This question is about the chemistry of the alcohol functional group.

(a) Ethanol and water mix together readily because of the formation of hydrogen bonds between the molecules.

Devise an experiment to estimate the strength of this interaction including how you would process the data collected.

(6)

(b) The painkiller aspirin can be synthesised by the reaction between 2-hydroxybenzoic acid, which contains a hydroxyl group, and ethanoic anhydride, using concentrated phosphoric acid as a catalyst. The reagents are heated under reflux, then the excess ethanoic anhydride is removed by reacting it with water.



2–hydroxybenzoic acid | ethanoic anhydride | aspirin

(i) The percentage yield for this synthesis is 65%.

Calculate the mass of aspirin you would obtain using 2.0 g of 2-hydroxybenzoic acid.

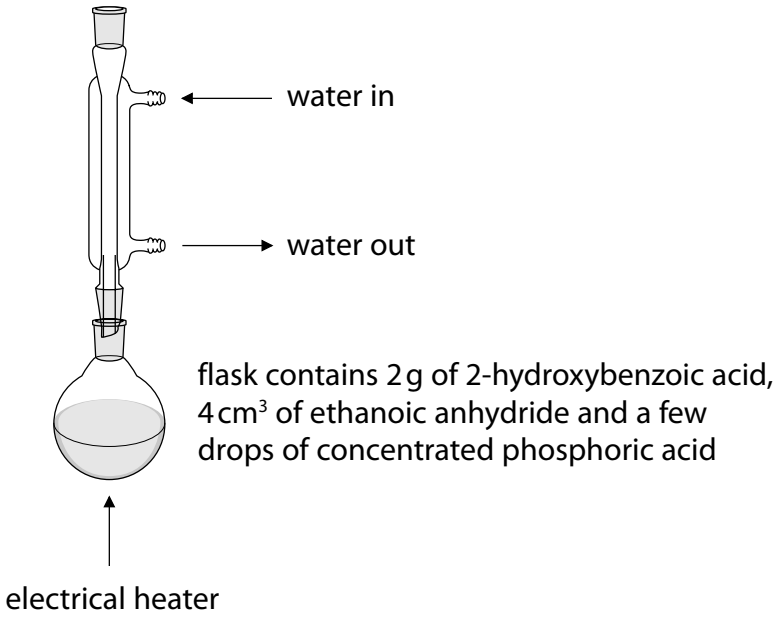
(3)

(ii) The diagram shows a proposed set-up of apparatus used for the stage of the synthesis that requires heating under reflux.

Identify **three** improvements that should be made to this set-up. Give a reason for each improvement made.

You may assume suitable clamps are used.

(6)



(Total for Question 6 = 15 marks)

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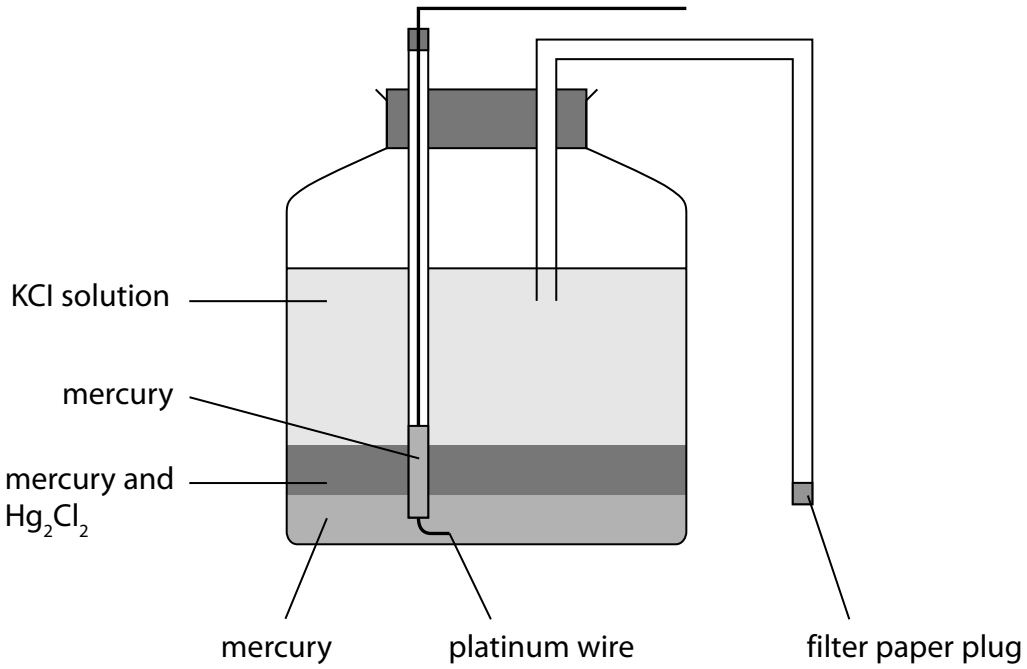
7 The diagram shows a calomel electrode, which can be used for measuring standard electrode potentials.



(a) (i) State a solution that could be used in the side arm to act as the salt bridge.

(1)

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.....

(ii) Explain the purpose of the salt bridge.

(2)

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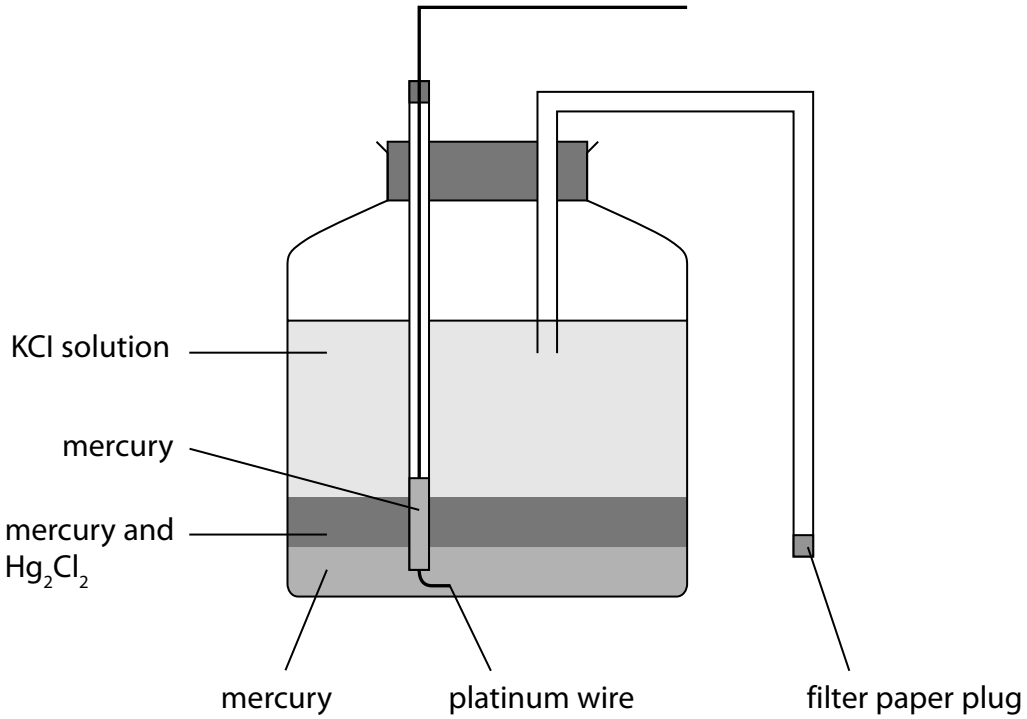
(b) A calomel electrode can be used to measure the standard electromotive force (emf), $E^{\ominus}_{cell}$ of the cell:

$$Pt|[2Hg(l) + 2Cl^{-}(aq)],Hg_2Cl_2(s)::Ag^{+}(aq)|Ag(s)$$



(i) Complete the diagram above by drawing a suitable silver half-cell including the appropriate electric circuit.

(3)

(ii) State the concentration of the solution in the silver half-cell and a suitable experimental condition.

(2)

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(c) (i) Use the Data Booklet to calculate the standard emf of the cell in b(i), given:

$$Pt|[2Hg(l) + 2Cl^-(aq)],Hg_2Cl_2(s) \quad E^\ominus = +0.27\ V$$

(2)

(ii) The emf of the cell shown below is:

$$Pt|[2Hg(l) + 2Cl^-(aq)],Hg_2Cl_2(s) :: [Fe^{3+}(aq),Fe^{2+}(aq)]|Pt \quad E^\ominus_{cell} = +0.50\ V$$

Use this value to calculate the standard emf of the following cell:

$$Pt[Fe^{2+}(aq),Fe^{3+}(aq)] :: Ag^+(aq)|Ag(s)$$

(1)

(iii) Write the overall equation for the cell reaction when current is being drawn.

(1)

(iv) Calculate the numerical value of the equilibrium constant for this reaction at 298 K using $\Delta G^\ominus = -2892\ J\ mol^{-1}$ and the relationship $\Delta G^\ominus = -RT\ln K$.

(2)

(Total for Question 7 = 14 marks)

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8 Cinnamon is a spice that is extracted from the bark of the cinnamon tree.

It is extracted by crushing the soft bark with water, and then steam distilling the mixture to produce cinnamon oil.

(a) The steam distillate is washed with saturated sodium chloride solution and the oil separated and dried.

(i) Draw a diagram of the apparatus you would use to separate the oil, labelling the oil.

[Densities: cinnamon oil 1.050 g cm^{-3}; sodium chloride solution 1.122 g cm^{-3}]

(2)

(ii) Give the name of a chemical that could be used to dry the oil.

(1)

.....

.....

(iii) State the change in appearance of the oil when it is being dried.

(1)

.....

.....

(b) Compound **Q** is the main component of cinnamon oil. Some chemical tests are carried out to try to find the structure of **Q**.

The results of each test are given in parts (i) to (iii).

Deduce from the results of each test what functional group may be present in **Q**.

(i) **Q** decolourises both bromine water and acidified potassium manganate(VII).

(1)

.....

.....

(ii) **Q** gives a yellow precipitate with 2,4-dinitrophenylhydrazine.

(1)

.....

.....

(iii) **Q** forms a red precipitate when boiled with either Benedict's or Fehling's solution.

(1)

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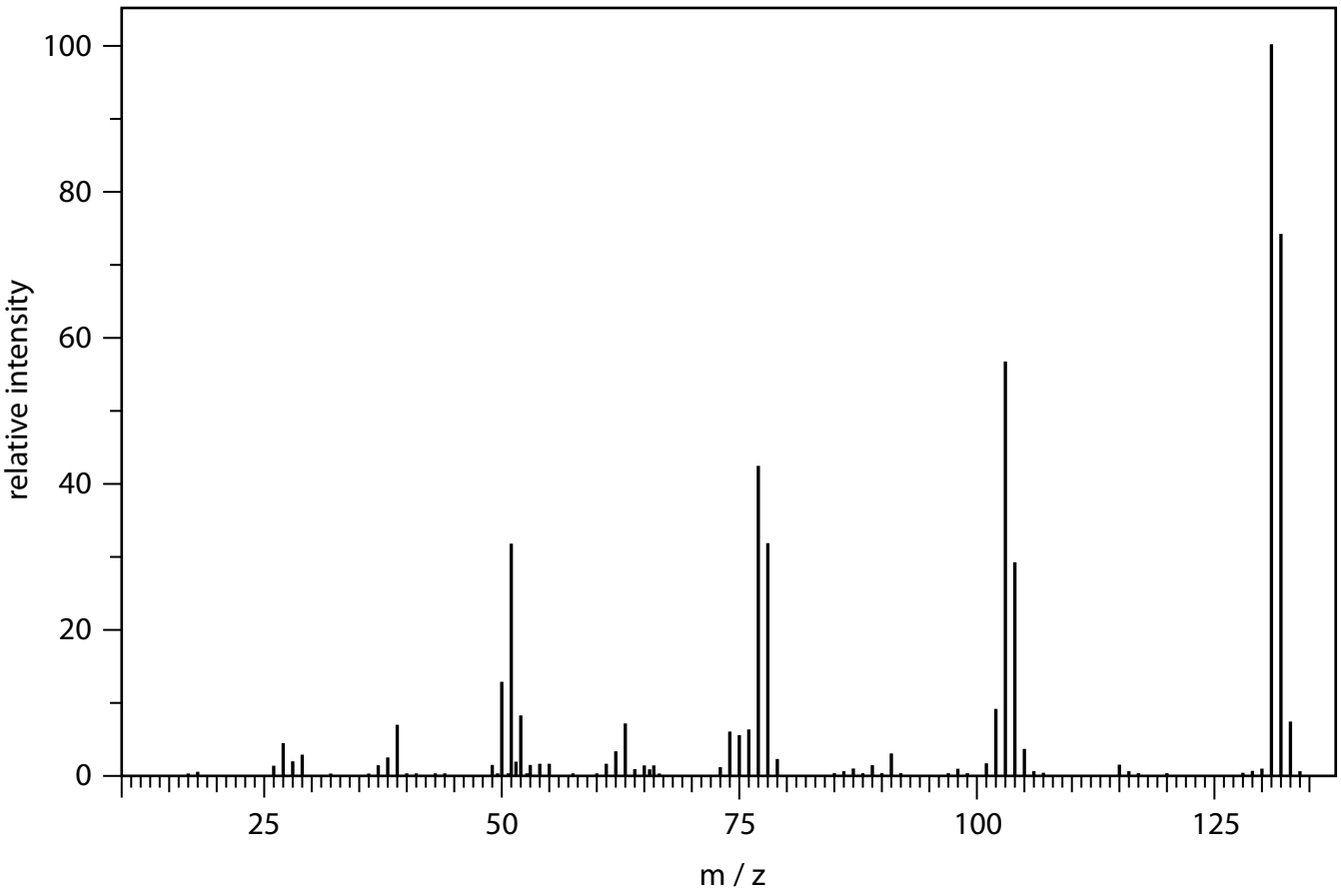
(c) **Q** has the empirical formula C_9H_8O and its mass spectrum is shown.



(i) Predict the identity of the fragment ions causing the peaks at 77 and 103.

(2)

m/z	formula of fragment ion
77	
103	

(ii) Deduce **two** possible displayed formulae for **Q**.

(2)

(iii) The peak at m/z = 132 in the mass spectrum of **Q** is the molecular ion peak. The mass spectrum also shows a peak at m/z = 133.

Give a reason why the peak at m/z = 133 occurs.

(1)

.....

.....

(d) Compound **Q** can be converted into cinnamic acid which contains a carboxylic acid functional group and is a monobasic acid.

1.78 g of cinnamic acid is reacted with 250 cm^3 of 0.500 mol dm^{-3} NaOH.

25.0 cm^3 of the resulting solution was titrated with 0.400 mol dm^{-3} HCl.

28.25 cm^3 was needed for complete neutralisation.

Calculate the M_r of cinnamic acid, giving your answer to one decimal place.

(5)

(Total for Question 8 = 17 marks)

9 Brass is an alloy of copper and zinc.

(a) (i) Explain why copper is classified as a transition element but zinc is not.

(2)

(ii) Brass has a structure similar to that of metallic copper, but with zinc ions replacing some copper ions in the lattice.

Explain why brass is malleable whereas a crystal of sodium chloride is not.

(3)

(b) A sample of brass was weighed on a balance, reading to two decimal places. The mass of the sample was recorded as 5.00 g.

This sample of brass was reacted with excess concentrated nitric acid and the resulting solution was made up to 250 cm^3 in a volumetric flask using distilled water.

25.0 cm^3 portions were taken from this solution using a pipette. Each portion was neutralised by adding sodium carbonate solution; and excess potassium iodide solution was then added. The liberated iodine was titrated with 0.250 mol dm^{-3} sodium thiosulfate solution, using a freshly prepared solution of starch as indicator.

The mean titre was 22.70 cm^3.

(i) Use the equation for the reaction to give two observations when nitric acid reacts with copper.

$$Cu(s) + 2NO_3^-(aq) + 4H^+(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$$

(2)

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(ii) Complete the equation for the reaction between iodine and thiosulfate ions. Include state symbols.

(1)

$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow$

(iii) Copper(II) ions react with iodide ions to form iodine.

$$2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$$

Calculate the percentage by mass of copper in the brass. Give your answer to an appropriate number of significant figures.

(5)

(iv) A student wants to identify the piece of apparatus that contributes most to measurement uncertainties in this experiment, so that the procedure can be modified.

The percentage measurement uncertainty is marked on the pipette as ±0.24%, and on the volumetric flask as ±0.08%.

By using appropriate calculations for the other apparatus used, deduce the **most** significant source of measurement uncertainty in this procedure.

(2)

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(Total for Question 9 = 15 marks)

10

Benzene

Benzene was first discovered by Michael Faraday in London in 1825. He identified it by distilling a liquid obtained from condensing a gas produced by heating whale oil.

In 1834, Mitscherlich discovered the same liquid could be obtained by heating benzoic acid with lime.

Benzene is now produced from petroleum. Petroleum is fractionally distilled and benzene is obtained from the hexane in the naphtha fraction.

Hexane is heated to about 770 K. It then passes to a reactor where it reacts to form cyclohexane and hydrogen. The cyclohexane is then dehydrogenated to form benzene. Other aromatic products like methylbenzene and dimethylbenzenes are also produced. The aromatic products are separated by further distillation.

Benzene is the starting compound for a large number of useful chemicals and materials. For example it is used to make the polymer, poly(phenylethene).

(a) Write an equation for the reaction between benzoic acid and lime, calcium oxide. State symbols are not required.

(1)

(b) Deduce, with references to oxidation numbers, what has happened to the carbon in the conversion of cyclohexane to benzene.

(2)

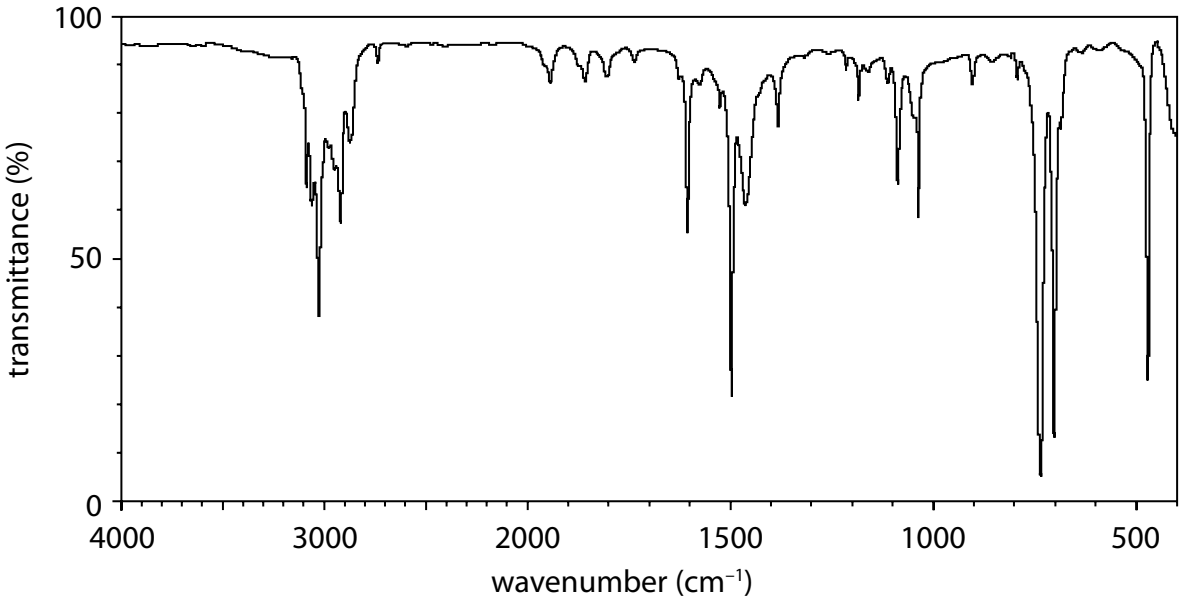
(c) The infrared spectra of benzene and methylbenzene are shown.

Identify which infrared spectrum is that of methylbenzene.

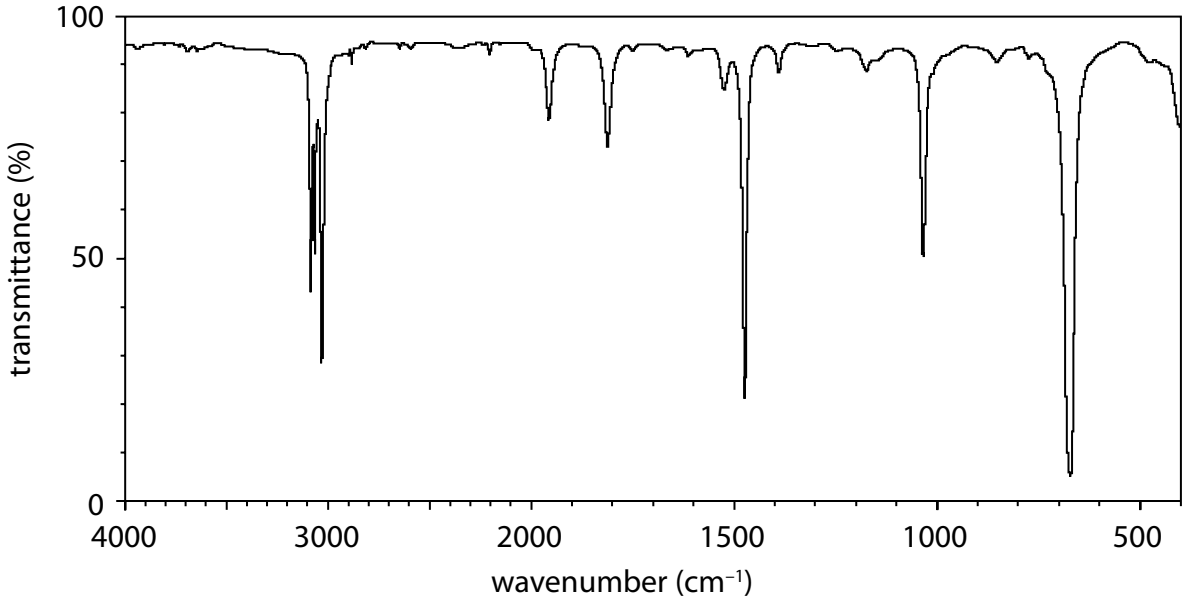
Justify your answer by identifying **one** distinguishing feature in your chosen spectrum.

(2)

Spectrum 1



Spectrum 2

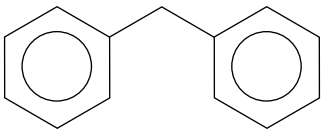


(d) Phenlyethene is used to make the polymer poly(phenylethene).

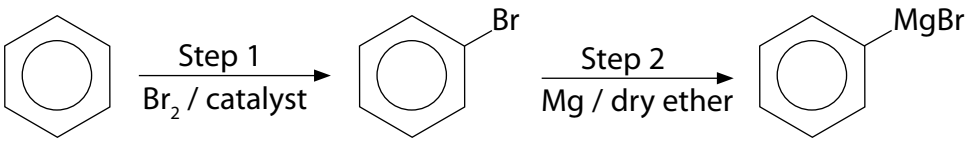
Write an equation for the polymerization of phenylethene.

(2)

(e) Diphenylmethane is used to provide the geranium fragrance in soap.



It can be synthesised in five steps from benzene. The first two steps in the process are



phenylmagnesium bromide

(i) Name the catalyst in Step 1.

(1)

(ii) Write a three step synthesis to convert phenylmagnesium bromide to diphenylmethane, including reagents used in each step.

(6)

(Total for Question 10 = 14 marks)

TOTAL FOR PAPER = 120 MARKS

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
* Actinide series	232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

CHEMISTRY A LEVEL PAPER 3 MARK SCHEME

Question Number	Answer	Additional guidance	Mark
1(a)	An answer that makes reference to the following points: • step 2: insoluble impurities are removed by filtration of the hot solution (1) • step 4: soluble impurities remain in the solvent left after filtering the cooled mixture (1) • step 5: the solid product is washed so that no soluble impurities form on the product as it dries (1)		**3**
1(b)	A description that makes reference to the following points: • the melting temperature is over a larger range / is not sharp (1) • the measured melting temperature is less than for the pure solid (1)		**2**

(Total Question 1 = 5 marks)

Question Number	Answer	Additional guidance	Mark
2(a)	• Fe^{2+} / $Fe(H_2O)_6^{2+}$ (1) • Cr^{3+} / $Cr(H_2O)_6^{3+}$ (1)	Allow Ni^{2+} / $Ni(H_2O)_6^{2+}$ V^{3+} / $V(H_2O)_6^{3+}$ Ignore names	**2**
2(b)(i)	Cr^{3+} / $Cr(H_2O)_6^{3+}$ (1)	Ignore names	**1**
2(b)(ii)	$Cr(OH)_3$/ $Cr(H_2O)_3(OH)_3$ (1)	Ignore names	**1**
2(b)(iii)	$Cr(OH)_6^{3-}$ (1)	Accept other correct species Ignore names (no ecf from (b)(i))	**1**
2(c)	Any **one** from: • purple to colourless • purple (solution) decolourised (1)	 Allow final colour of solution to be orange Allow pink for purple	**1**
2(d)(i)	Cl^- (1)	Reject Cl Ignore names	**1**

Question Number	Answer	Additional guidance	Mark
2(d)(ii)	An explanation that makes reference to the following points: ammonia solution cannot be used because: • ammonia reacts with the iron ions to form a precipitate (1) **or** • a precipitate of (Iron(II) hydroxide/ $Fe(OH)_2$/ $Fe(H_2O)_4(OH)_2$ forms (1) **AND** • and so obscures the dissolving of the white precipitate (1)		**2**

(Total Question 2 = 9 marks)

Question number	Answer	Additional guidance	Mark
3(a)(i)	• evaluation of number of moles of propanone = 0.025 × 2.0 = 0.050 mol (1) • which is greater than the amount of iodine, which is 0.050 × 0.020 = 0.0010 mol (1)		**2**
3(a)(ii)	• measuring cylinder/burette (1)		**1**
3(a)(iii)	• pipette (1)		**1**
3(b)	An explanation that makes reference to the following points: • the order with respect to iodine is zero (1) • because the graph is a straight line, showing that the change in iodine concentration is constant (1)		**2**
3(c)	An answer that makes reference to the following points: • 1st order with respect to H^+ and propanone (1) • H^+ and propanone involved in reaction before rate determining step (therefore 1st order) (1) • iodine involved after rate determining step / slow step (therefore zero order) (1)		**3**

(Total Question 3 = 9 marks)

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>4(a)</td><td>• axes: correct way round, labelled, suitable scale (1)

• all points plotted correctly, with best fit straight line (1)

• calculation of gradient of straight line (1)

• use of gradient = $-E_a$ /R to calculate E_a (in kJ mol^{-1}) (1)</td><td>Plotted points must cover at least half the graph paper on each axis
Allow ±½ a square

Gradient = (-) 5970 Allow ± 200

Activation energy = 5970 x 8.31 / 1000
= +49.6 (kJ mol^{-1})
Final answer must be positive.</td><td>4</td></tr>
<tr><td>*4(b)</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table></td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning.
For example, an answer with five indicative marking points, which is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>6</td></tr>
</table>

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*4(b) Cont.</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr>
</table>
Indicative content:

activation energy (E_A) for the formation of A is lower than that for B (E_B)
hence at 40 ºC more collisions exceed E_A than exceed E_B
so A is formed more quickly than B at 40 ºC
at 160 ºC more collisions exceed E_B (and E_A) than at 40 ºC
therefore both isomers are formed
but the reactions are reversible and B is the more stable isomer, therefore A will convert to B
</td><td></td><td></td></tr>
</table>

(Total Question 4 = 10 marks)

Question Number	Answer	Additional guidance	Mark
5(a)	• substitution into $\Delta S^{\ominus}$ equation (1) • evaluation of $\Delta S^{\ominus}$ (1) • substitution into $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$, using $\Delta S^{\ominus}$ in kJ K^{-1} mol^{-1} (1) • correct answer to 3 sf (1) • since $\Delta G^{\ominus}$ is negative, the reaction is feasible (1)	Example of calculation $\Delta S^{\ominus}$ = (2 x 193) - 192 -(3 x 131) = −199 J K^{-1} mol^{-1} / − 0.199 kJ K^{-1} mol^{-1} $\Delta G^{\ominus}$ = − 92.0 - (298 x − 0.199) = − 32.7 kJ mol^{-1} / − 32 700 J mol^{-1} The first four marking points can be awarded for a correct answer to 3 sf with no working	**5**
5(b)	An explanation that makes reference to the following points: • (as temperature increases) $T\Delta S$ becomes more negative (1) • (eventually) $\Delta H - T\Delta S$ becomes positive (1)		**2**

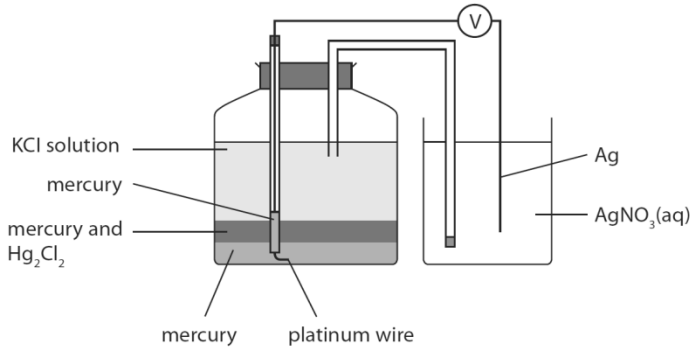
Question Number	Answer	Additional guidance	Mark
5(c)	• Correct expression for K_p (1) • Calculation of mole fractions for N_2, H_2 and NH_3 (1) • Calculation of partial pressures for N_2, H_2 and NH_3 (1) • Substitution and evaluation of K_p (1) • Units: atm^{-2} (1)	Example of calculation (total number of moles = 18) mf N_2 = 2.88 ÷ 18 = 0.16 mf H_2 = 8.64 ÷ 18 = 0.48 mf NH_3 = 6.48 ÷ 18 = 0.36 pN_2 = 0.16 x 200 = 32 atm pH_2 = 0.48 x 200 = 96 atm pNH_3 = 0.36 x 200 = 72 atm $K_p = \frac{p^2NH_3(g)}{pN_2(g).p^3H_2(g)}$ $K_p = \frac{72^2}{32 \times 96^3} = 1.83 \times 10^{-4}$ atm^{-2} Alternative method for calculation: $\frac{0.36^2}{0.16 \times 0.48^3}$ (= 7.32421875) $K_p = \frac{0.36^2}{0.16 \times 0.48^3} \times \frac{1}{200^2} = 1.83 \times 10^{-4}$ atm^{-2} Correct answer with no working with units scores 5 marks	**5**

(Total Question 5 = 12 marks)

Question Number	Answer	Additional guidance	Mark
6(a)	An answer that makes reference to the following: • suitable volumes of ethanol and water (1) • evidence of calculation to show one component of mixture in excess (1) • mixed together in simple calorimeter / polystyrene cup with lid (1) • stir and measure maximum temperature change (1) • calculate energy change using $Q=mc\Delta T$ (1) • calculate strength of hydrogen bond per mole by scaling up from the amount of limiting component of mixture (i.e. component not in excess) (1)		**6**
6(b)(i)	• evaluation of number of moles of 2-hydroxybenzoic acid used (1) • calculation of mass of aspirin at 100% yield (1) • calculation of mass of aspirin at 65% yield (1)	<u>Example of calculation</u> 2 / 138 = 0.0145 mol 0.0145 x 180 = 2.61 g 2.61/100 x 65 = 1.70 g Correct answer with no working scores 3 marks	**3**

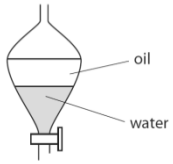
Question Number	Answer	Additional guidance	Mark
6(b)(ii)	The mark for each reason must be linked with the correct improvement. • Improvement: swap the water inflow and outflow in the condenser (1) • Reason: to improve efficiency of condensing process (1) • Improvement: add anti-bumping granules to flask (1) • Reason: to promote smooth boiling/to prevent material escaping from top of condenser (1) • Improvement: insert condenser into neck of flask (1) • Reason: to prevent escape of reagents (1)		**6**

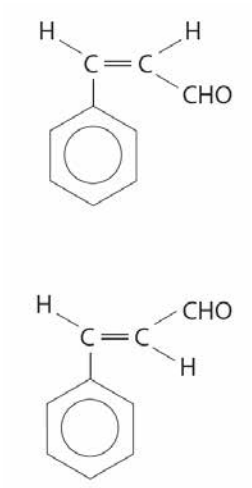
(Total for question 6 = 15 marks)

Question Number	Answer	Additional guidance	Mark
7(a)(i)	• (saturated) potassium nitrate (1)	Allow potassium chloride	**1**
7(a)(ii)	An explanation that makes reference to the following points: • to complete the circuit (1) • by allowing movement of (positive and negative) ions (1)		**2**
7(b)(i)	• container/beaker containing the side arm and silver, both dipping into silver nitrate solution (1) • connecting wire from silver and calomel electrode to complete the circuit (1) • (high resistance/digital) voltmeter (1)		**3**
7(b)(ii)	• solution concentration 1.0 mol dm^{-3} (1) • temperature 298 K (1)	Ignore mention of pressure	**2**

Question Number	Answer	Additional guidance	Mark
7(c)(i)	• correct equation (1) • emf = 0.80 – (+)0.27 = (+)0.53 (V) (1)	No sign in answer scores 1 mark, a minus sign given scores 0 marks Correct answer with no working scores 2 marks	**2**
7(c)(ii)	• (+)0.03 (V) (1)		**1**
7(c)(iii)	• $Fe^{2+}(aq) + Ag^{+}(aq) \rightarrow Fe^{3+}(aq) + Ag(s)$ (1)	Allow reversible arrows	**1**
7(c)(iv)	• rearrangement and substitution into equation (1) • evaluation of ln *K* and conversion to *K* (1)	Example of calculation $\ln K = \frac{2892}{8.31 \times 298} = (+)1.1678$ $K = 3.21502 = 3.22$ Ignore sf except 1 Note if ln *K* = 1.1678 is used answer is 3.21 Correct answer with no working scores 2 marks	**2**

(**Total for question 7 = 14 marks**)

Question Number	Answer	Additional guidance	Mark
8(a) (i)	 • cinnamon oil upper layer (1) • separating funnel (1)	Funnel must be suitable for a stopper	**2**
8(a)(ii)	• addition of (anhydrous) sodium sulfate / calcium chloride / magnesium sulfate (1)		**1**
8(a)(iii)	• from cloudy to clear (1)	Do not accept colourless in place of clear	**1**
8(b)(i)	• contains C=C/alkene (1)		**1**
8(b)(ii)	• contains carbonyl group/ aldehyde or ketone (1)	C=O alone	**1**
8(b)(iii)	• aldehyde/ -CHO (1)		**1**

Question Number	Answer	Additional guidance	Mark
8(c)(i)	• 77 $C_6H_5^+$ (1) • 103 $C_8H_7^+$ (1)	Must show a charge but only penalise omission once Allow structural, displayed or skeletal formulae	**2**
8(c)(ii)		Allow non-displayed benzene C-Hs	**2**
8(c)(iii)	• The peak is due to the presence of an atom of a (^{13}C) isotope (1)	Allow reference to other named isotope of H or O	**1**

Question Number	Answer	Additional guidance	Mark
8(d)	• initial moles of NaOH in 250 cm^3 (1) • excess moles of NaOH in 25.0 cm^3 (1) • expression for moles of total NaOH reacted (1) • evaluation of moles of cinnamic acid (1) • evaluation of M_r of cinnamic acid to 1 dp (1)	Example calculation Initial moles of NaOH = (250 ÷ 1000) x 0.500 = 0.125 Moles of excess NaOH in 25.0 cm^3 = (28.25 ÷ 1000) x 0.400 = 0.0113 Moles of NaOH reacted = 0.125 – (10 x 0.0113) Moles of cinnamic acid = moles of NaOH reacted = 0.012 M_r of cinnamic acid = 1.78 ÷ 0.012 = 148.3 Allow ecf from 2nd mark Correct answer to 1 dp with no working scores 5 marks	**5**

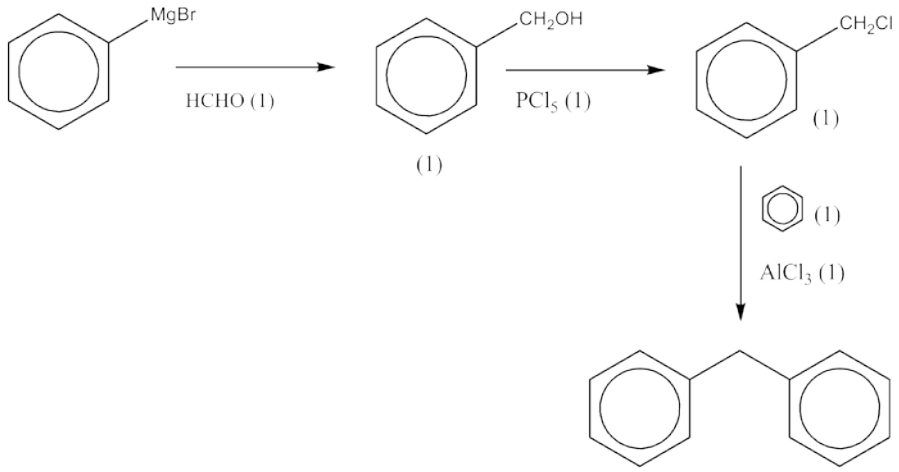
(Total for Question 8 = 17 marks)

Question Number	Answer	Additional guidance	Mark
9(a)(i)	An explanation that makes reference to the following points: • copper forms an ion with an incomplete d-sub-shell / with a configuration of $3d^9$ (1) • but the <u>only</u> ion formed by zinc has a completely filled d-sub-shell (1)		**2**
9(a)(ii)	An explanation that makes reference to the following points: • (in brass) the layers of positive ions can slide over one another (1) • and there are (always) electrons between the layers preventing repulsion between the ions in one layer and those in another layer (1) • (in sodium chloride) when a layer of ions is displaced, ions with the same charge become close to one another and repel (1)		**3**
9(b)(i)	• brown fumes (1) • a green/blue solution forming (1)		**2**

Question Number	Answer	Additional guidance	Mark
9(b)(ii)	• $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$ (1)	State symbols must be present	**1**
9(b)(iii)	• amount of thiosulfate (1) • uses amount of thiosulfate = amount of iodine to determine amount of thiosulfate = amount of copper(II) ions in 25 cm^3 portion (1) • evaluation of number of moles of Cu in sample (1) • calculates mass of Cu (1) • • percentage copper to 3 sf (1)	Example of calculation amount of thiosulfate = $\frac{22.7 \times 0.25}{1000}$ = 5.675×10^{-3} (mol) 5.675×10^{-3} (mol) = amount of copper(II) ions in 25 cm^3 portion amount of Cu in sample = $5.675 \times 10^{-3} \times 10$ = 5.675×10^{-2} (mol) mass of Cu = $5.675 \times 10^{-2} \times 63.5$ = 3.603625 percentage copper = 3.603625 x 100 /5.00 = 72.0725 = 72.1% Allow ecf from 2nd mark Correct answer to 3 sf with no working scores 5 marks	**5**
9(b)(iv)	• calculation of percentage uncertainty from balance = ±0.005x 2 x100/5.00 = 0.2% **and** percentage uncertainty in mean titre from burette = 2x±0.05 x 100 /22.7 = 0.44% (1) • so burette reading is most significant (1)		**2**

(Total for Question 9 = 15 marks)

Question Number	Answer	Additional guidance	Mark
10(a)	• $C_6H_5COOH + CaO \rightarrow C_6H_6 + CaCO_3$ (1)	Accept $C_6H_5COOH + CaO \rightarrow C_6H_6 + CaO + CO_2$	**1**
10(b)	An answer that makes reference to the following points: • -2 in cyclohexane <u>and</u> -1 in benzene (1) • so (carbon is) oxidised (1)	 2nd mark stands alone	**2**
10(c)	spectrum 1 is methylbenzene, because • it contains an absorption at 2962 – 2853 cm^{-1} (1) • owing to alkyl C—H stretching (1)	 Identification unqualified gains no marks	**2**
10(d)	$nC_6H_5CH{=}CH_2 \rightarrow \{CH(C_6H_5)—CH_2\}_n$ • correct product formula (1) • balanced equation (1)		**2**
10(e)(i)	Iron / iron(III) bromide	Allow aluminium / aluminium bromide Allow correct formulae	**1**

Question Number	Answer	Additional guidance	Mark
10(e)(ii)	• reagent for step 1 (1) • product of step 1 (1) • reagent for step 2 (1) • product of step 2 (1) • reagent for step 3 (1) • catalyst for step 3 (1)		**6**
	Example of synthesis:  		

(Total for Question 10 = 14 marks)

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