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)

BLANK PAGE

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)

.....

.....

.....

.....

(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)

.....

.....

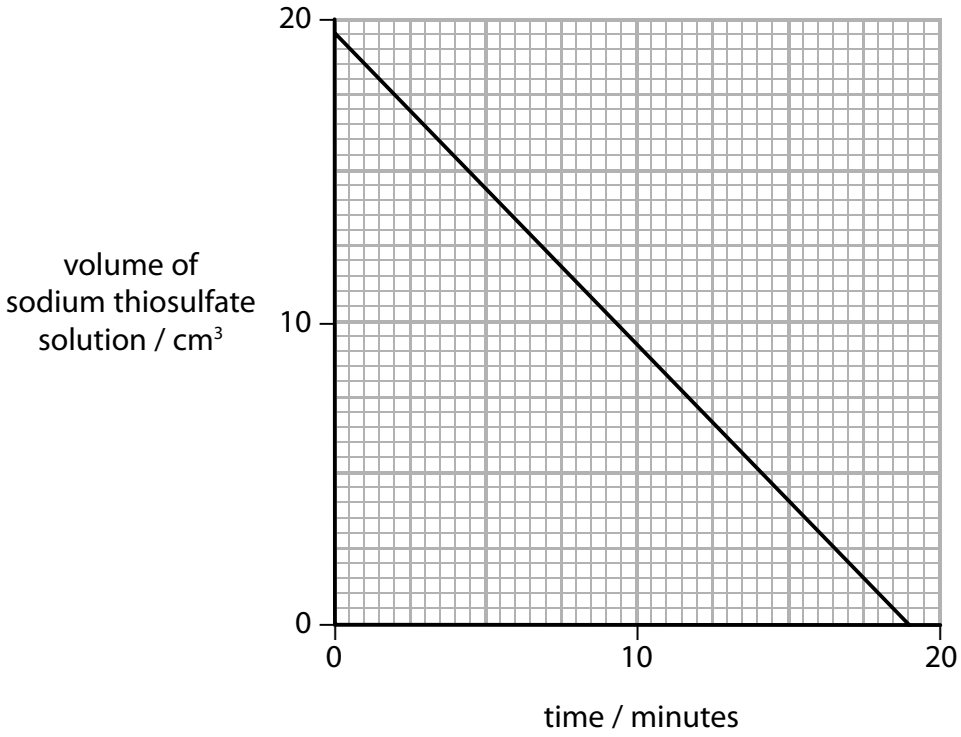
(iii) Name the piece of apparatus which is most suitable for removing the sample from the reaction mixture.

(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)

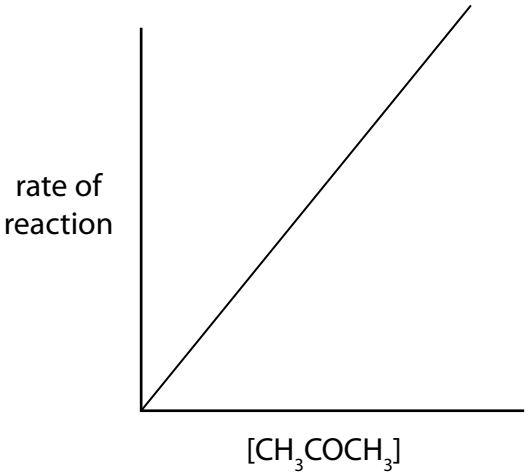
.....

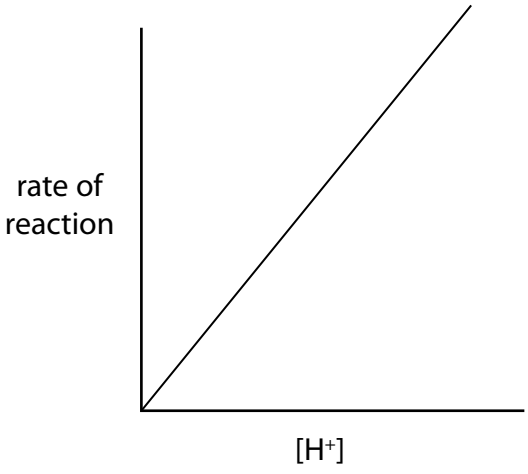
.....

.....

.....

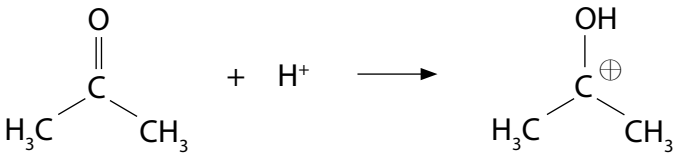
(c) These graphs were obtained in other experiments to determine the order of reaction with respect to propanone and to sulfuric acid.

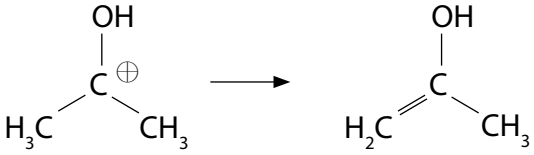


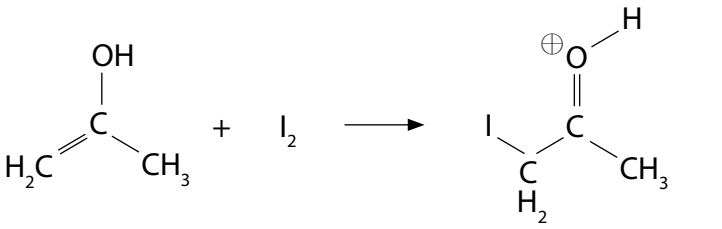


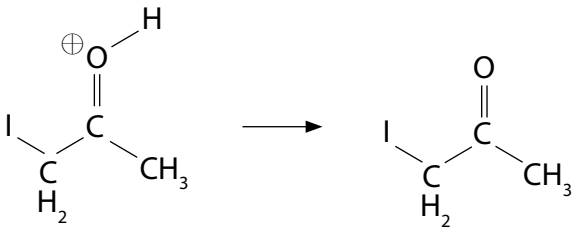
Use these graphs and your answer from part (b) to comment on whether this proposed mechanism for the reaction is correct.

(3)

step 1  fast

step 2  slow

step 3  fast

step 4  fast

.....

.....

.....

.....

.....

(Total for Question 3 = 9 marks)

BLANK PAGE

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

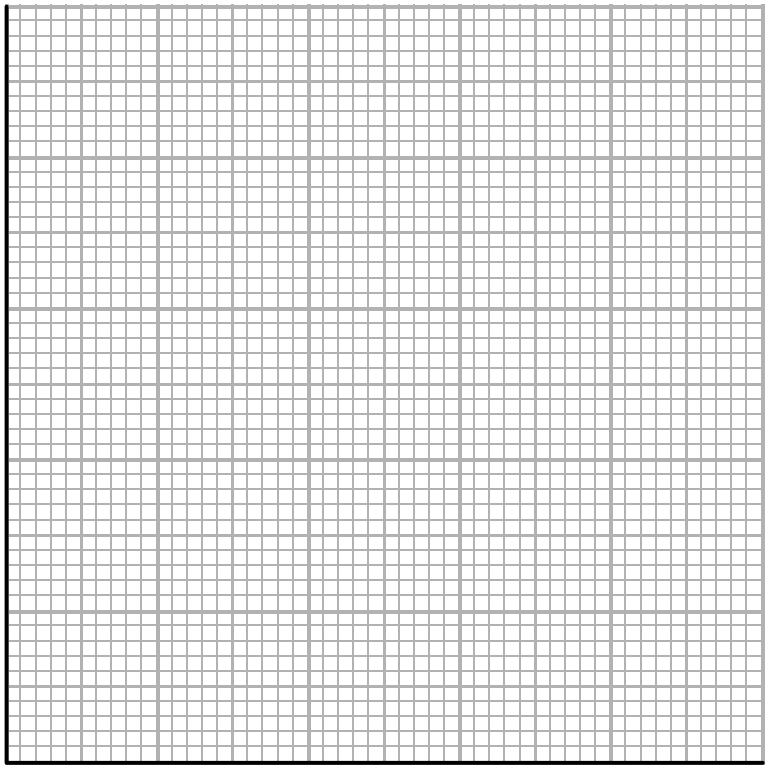
The activation energy, E_a, of the reaction can be found using the equation:

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

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}

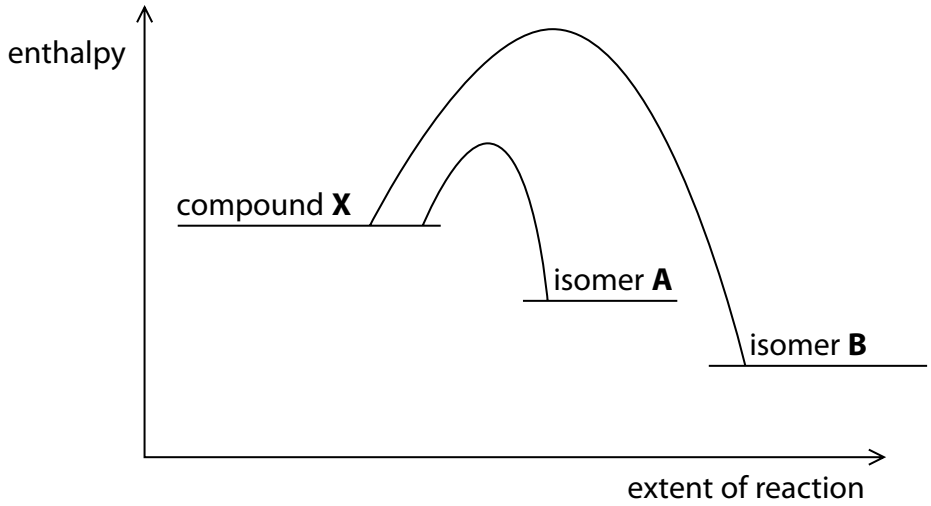
Activation energy = ... kJ mol^{-1}

*(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)

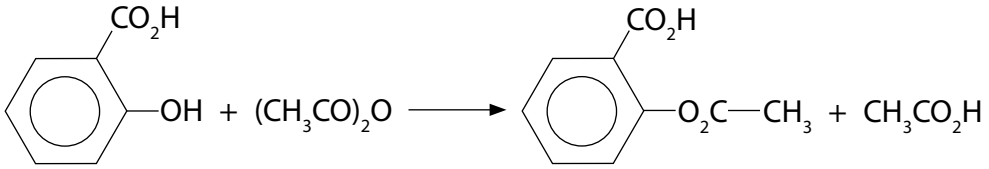
6 This question is about the chemistry of the alcohol functional group.

(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.

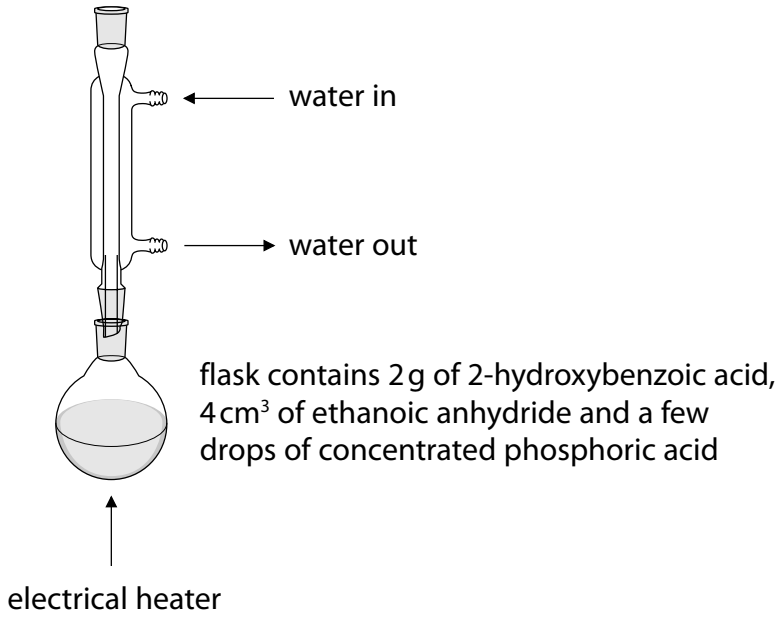
(3)

(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.

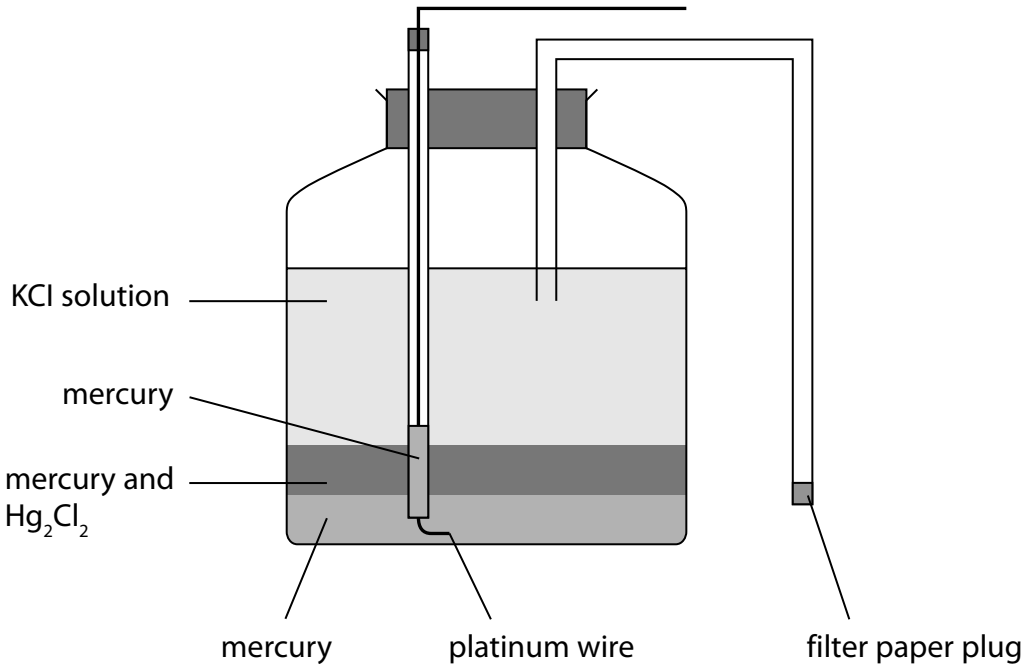
(6)



(Total for Question 6 = 15 marks)

BLANK PAGE

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)

.....

.....

(ii) Explain the purpose of the salt bridge.

(2)

.....

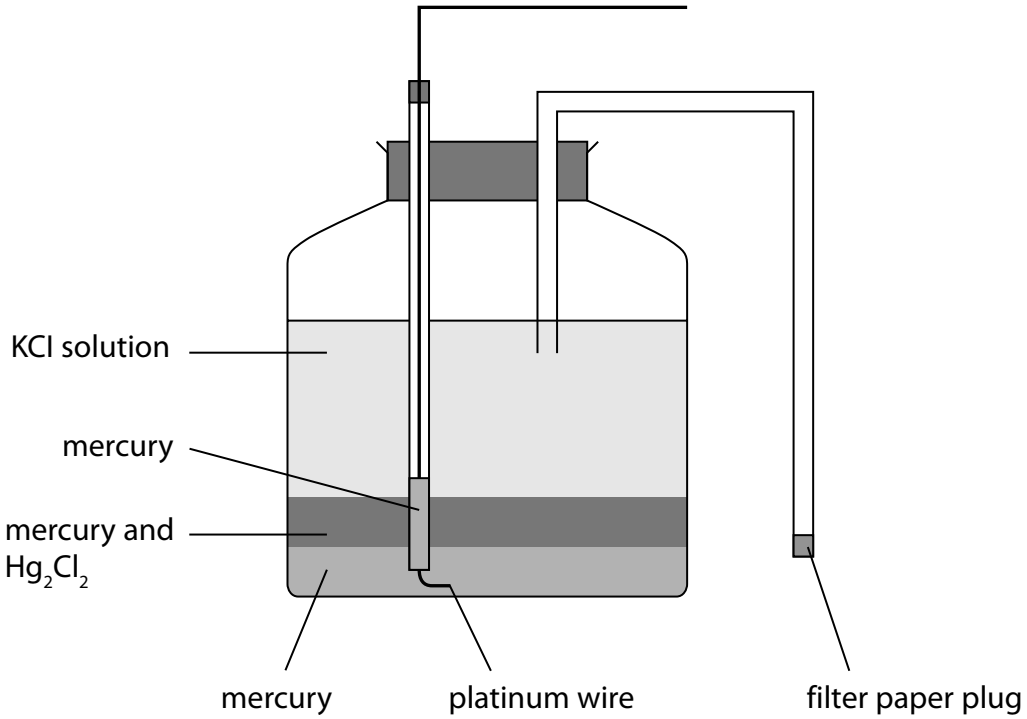
.....

.....

.....

(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)

(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)

BLANK PAGE

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)

.....

.....

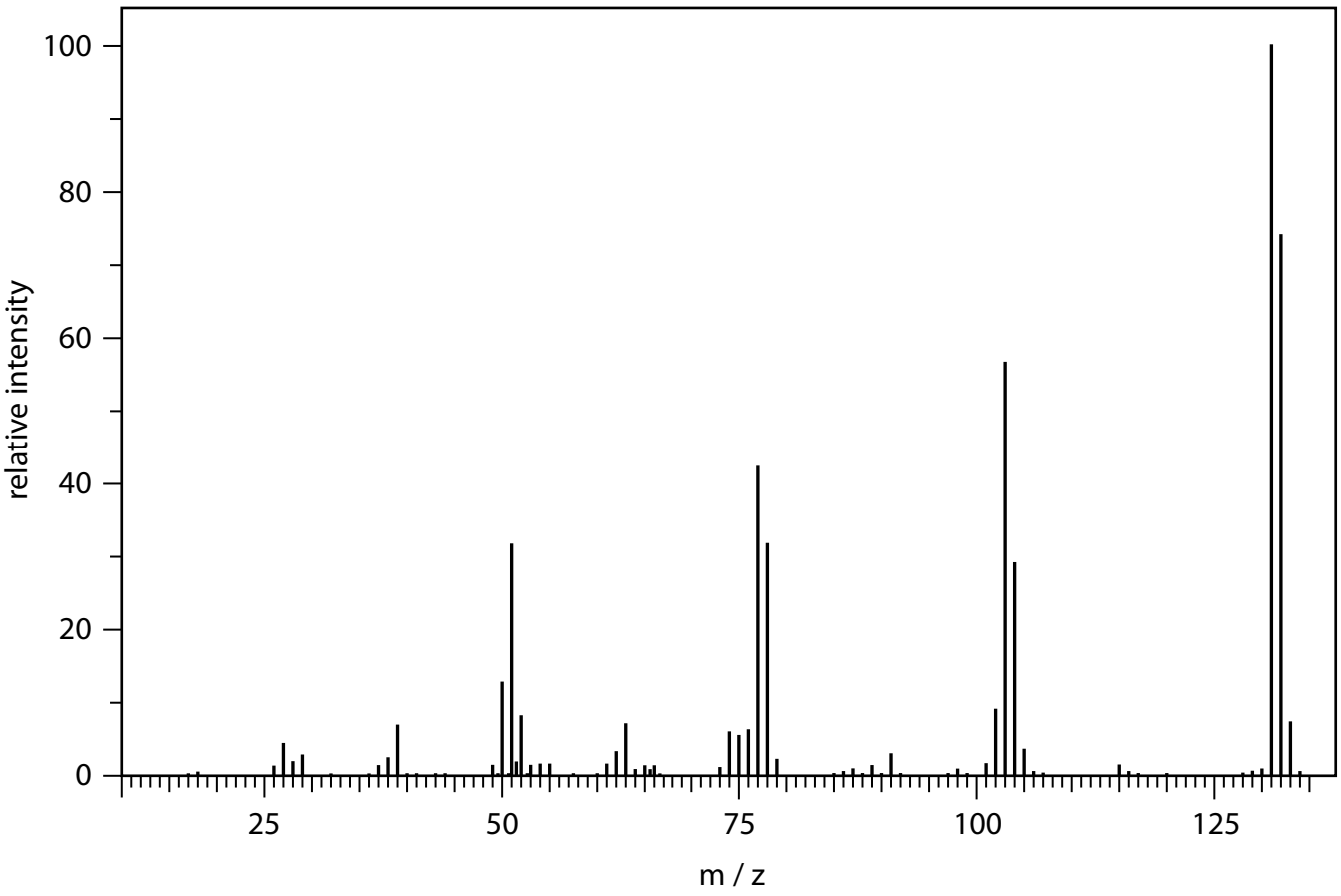
(iii) **Q** forms a red precipitate when boiled with either Benedict's or Fehling's solution.

(1)

.....

.....

(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)

.....

.....

.....

.....

.....

(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)

.....

.....

.....

.....

.....

(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)

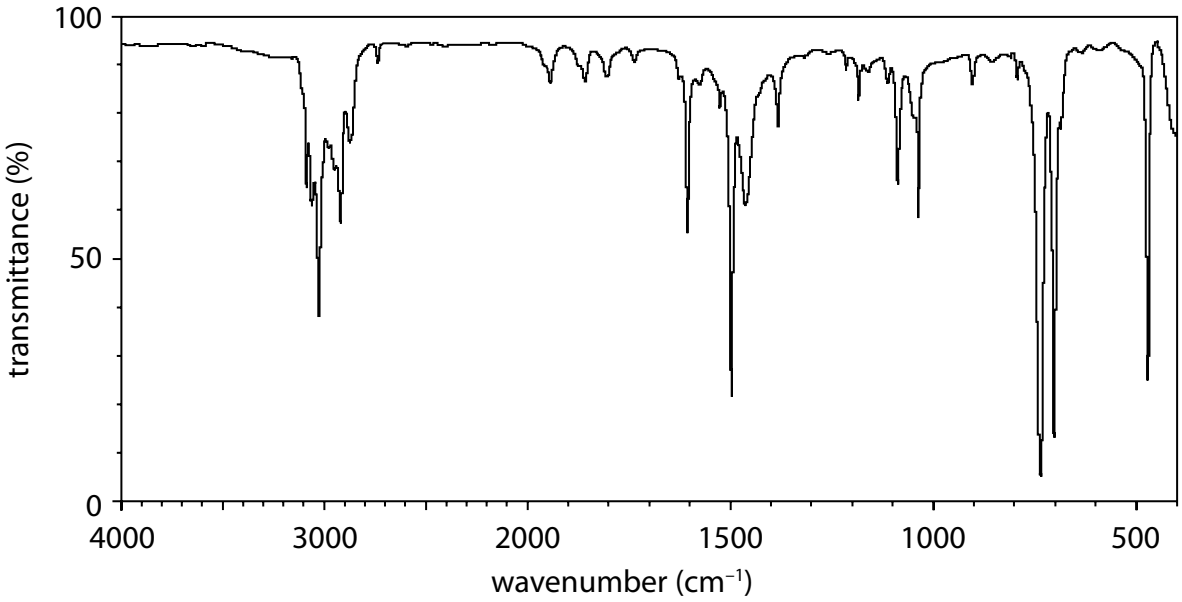
(c) The infrared spectra of benzene and methylbenzene are shown.

Identify which infrared spectrum is that of methylbenzene.

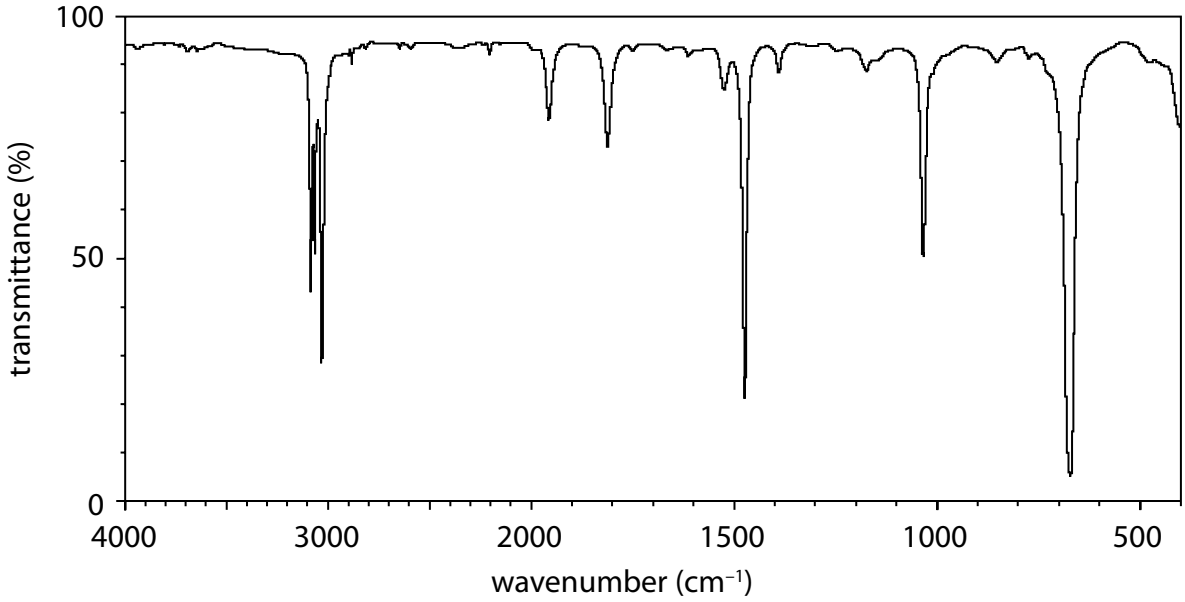
Justify your answer by identifying **one** distinguishing feature in your chosen spectrum.

(2)

Spectrum 1



Spectrum 2

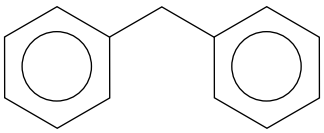


(d) Phenlyethene is used to make the polymer poly(phenylethene).

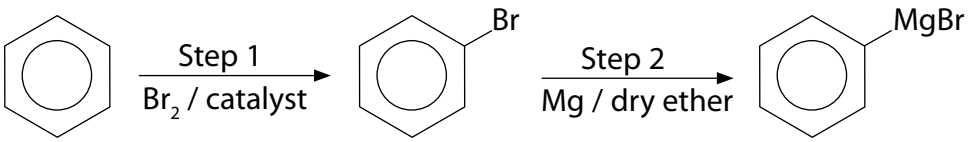
Write an equation for the polymerization of phenylethene.

(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