Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number	Candidate Number

Wednesday 19 June 2019

Morning (Time: 2 hours 30 minutes)	Paper Reference **9CH0/03**

Chemistry

Advanced
Paper 3: General and Practical Principles in Chemistry

Candidates must have: Scientific calculator Data Booklet Ruler	Total Marks

Instructions

- Use **black** ink or **black** 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.*
- For the question marked with an **asterisk** (*), 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.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

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Pearson

Answer ALL questions.

Write your answers in the spaces provided.

1 This question is about acids and bases.

(a) State what is meant by a Brønsted-Lowry acid.

(1)

(b) Identify the acid-base conjugate pairs in this reaction.

(1)

$$CH_3COOH + HCOOH \rightarrow CH_3COOH_2^+ + HCOO^-$$

(c) Write the expression that defines the pH of a solution.

(1)

(d) Calculate the concentration of hydrogen ions, in mol dm^{-3}, in a solution with a pH of 2.76

(1)

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(e) Explain why the pH of a $1 \times 10^{-8}\ mol\,dm^{-3}$ solution of nitric acid, HNO_3, is not 8.

[Ionic product of water, $K_w = 1.00 \times 10^{-14}\ mol^2\,dm^{-6}$]

(2)

(Total for Question 1 = 6 marks)

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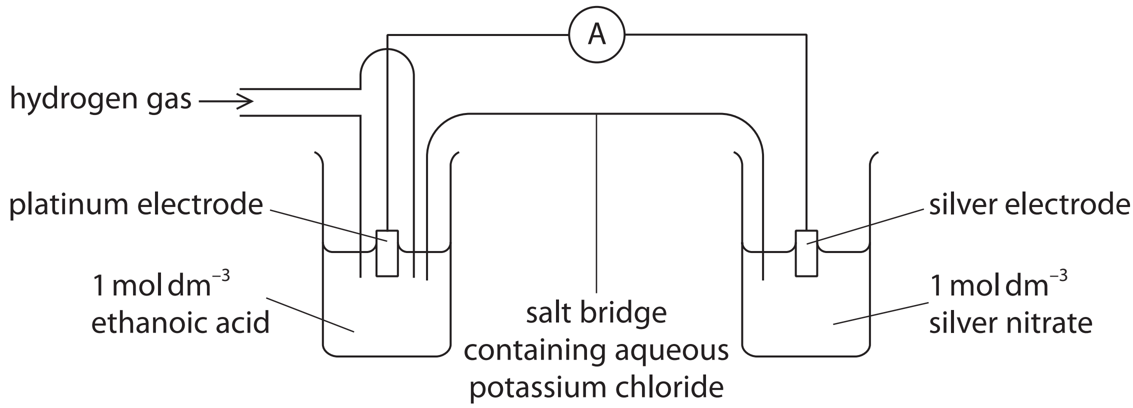
2 This question is about the $Ag^{+}(aq)|Ag(s)$ half-cell.

(a) A student was asked to plan an experiment to measure the standard electrode potential of the $Ag^{+}(aq)|Ag(s)$ half-cell.

(i) State the conditions of temperature and pressure under which standard electrode potentials are measured.

(1)

(ii) The student drew the diagram shown.



Identify **three** mistakes in this diagram and the modifications that should be made to correct them.

(3)

Mistake in diagram	Modification needed to correct mistake

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(b) The standard electrode potential, $E^{\ominus}$, of the $Ag^+(aq)|Ag(s)$ half-cell is +0.80 V.

The effect of changing the concentration of the ions on the value of the electrode potential, E, in this half-cell is calculated using the equation

$$E = E^{\ominus} + \frac{RT}{96500} \times \ln[Ag^+(aq)]$$

where T is the temperature in kelvin and R is the gas constant.

The electrode potential of a $Ag^+(aq)|Ag(s)$ half-cell was measured at 20 °C and found to be +0.72 V.

Calculate the concentration of silver ions, in mol dm^{-3}, in this half-cell.

(3)

(Total for Question 2 = 7 marks)

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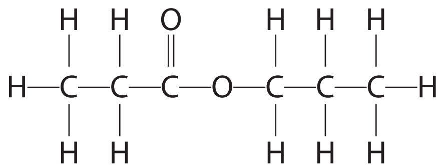
3 This question is about esters with the molecular formula $C_6H_{12}O_2$.

(a) Propyl propanoate has the structure shown.



Devise a synthetic pathway to prepare propyl propanoate starting with 1-bromopropane as the **only** organic compound.

Include the reagents for each step in the synthesis, and the names or structures of the intermediate compounds.

(5)

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(b) Another ester, **A**, with molecular formula $C_6H_{12}O_2$, was hydrolysed.
It produced ethanoic acid, and an alcohol, **B**, with molecular formula $C_4H_{10}O$.

Alcohol **B** undergoes an elimination reaction to produce a mixture of but-1-ene and but-2-ene.

Deduce the structures of **B** and **A**. Justify your structure of **B**.

(3)

(Total for Question 3 = 8 marks)

4 Compound **C** is a pink crystalline solid containing two cations and one anion.

(a) Three tests were carried out on **C**. The observation made for each test was recorded in the table.

(i) Complete the statements in the inference column by writing the names or formulae of the species.

(6)

Test	Observation	Inference
Test 1 Aqueous sodium hydroxide was added to solid **C** and the mixture warmed The gas evolved was tested with damp red litmus paper	The red litmus paper turned blue	The gas evolved was One of the cations in **C** is
Test 2 Concentrated hydrochloric acid was added to an aqueous solution of **C**	The pink solution turned blue	The other cation in **C** is The formula of the complex ion in the blue solution is
Test 3 Dilute hydrochloric acid and aqueous barium chloride were added to an aqueous solution of **C**	A white precipitate formed	The white precipitate is The anion in **C** is

(ii) Use the results of the tests in (a)(i) to give a formula of **C**.
Do not include water of crystallisation.

(1)

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(b) Write the **ionic** equation for the reaction between the cation in **C** and sodium hydroxide producing the gas in **Test 1**.
State symbols are not required.

(1)

(c) State the type of reaction occurring in **Test 2**.

(1)

(d) Give a reason why dilute hydrochloric acid is needed in **Test 3**.

(1)

(Total for Question 4 = 10 marks)

5 This question is about redox reactions.

(a) Name the ion with formula PO_3^{3-}. Include the relevant oxidation number.

(1)

(b) State what happens to a reducing agent during a reaction, in terms of oxidation number **and** electrons.

(1)

(c) Identify the species that is the strongest reducing agent from the list of standard electrode potentials in the Data Booklet.

(1)

(d) Manganese(IV) oxide, MnO_2, and manganate(VII) ions, MnO_4^-, react in alkaline solution to form manganate(VI) ions, MnO_4^{2-}.

(i) Write the **ionic** equation for this reaction.
State symbols are not required.

(2)

(ii) Give a reason why this reaction is **not** disproportionation.

(1)

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(e) Sodium tetrahydridoborate(III), $NaBH_4$, is used in organic chemistry.
It is an alternative reagent to lithium tetrahydridoaluminate(III) for the reduction of carbonyl compounds.

(i) Draw a dot-and-cross diagram of the BH_4^- ion.

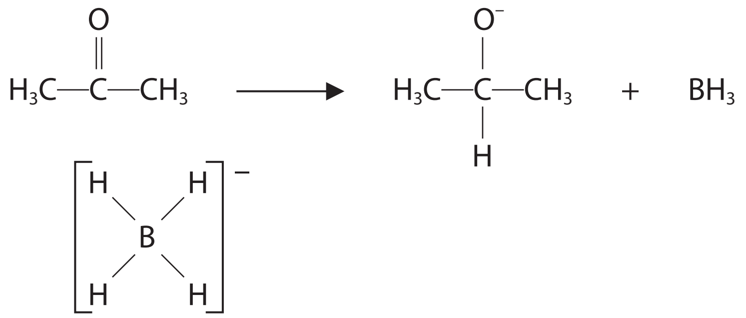
Use crosses (×) for the boron electrons, dots (•) for the hydrogen electrons and triangles (△) for the additional electron forming the negative ion.

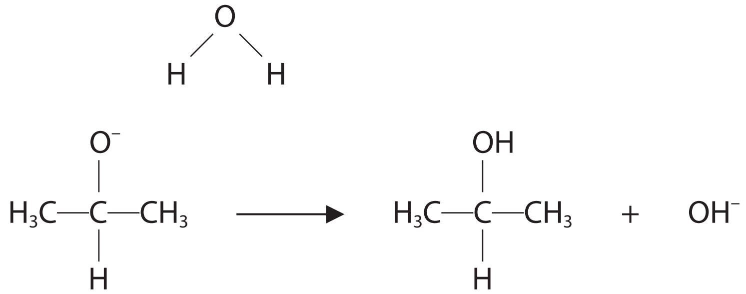
(1)

(ii) The BH_4^- ions reduce carbonyl compounds to alcohols in aqueous solution.

Complete the mechanism for the reduction of propanone to propan-2-ol by adding curly arrows, and any relevant lone pairs and dipoles.

(4)





(Total for Question 5 = 11 marks)

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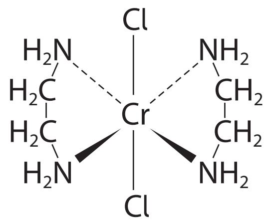
6 This question is about transition metals and their ions.

(a) The **shape** of a complex ion formed from Cr^{3+} ions is shown.



(i) State the coordination number of Cr^{3+} in this complex ion.

(1)

(ii) State the overall charge on this complex ion.

(1)

(b) The complex ions of transition metals have different colours in aqueous solution.

Two factors that affect the colour of the solution are the oxidation number of the central metal ion, and the ligands present.

Give examples to illustrate these factors by referring to complex ions of iron and/or copper. Include the formula and colour of each complex.

An explanation of why transition metal ions are coloured is **not** required.

(3)

(c) Tungsten wire catalyses the decomposition of ammonia.

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

In an experiment, the following results were obtained.

Time /s	Partial pressure of ammonia / kPa
0	0.350
100	0.335
200	0.319
300	0.303
400	0.287
500	0.271

(i) Plot a graph of partial pressure of ammonia against time.

(2)

(ii) Deduce the rate equation for this reaction by using your graph in (c)(i).
Justify your answer.

(2)

(iii) Use the graph to calculate the rate constant. Include units in your answer.

(2)

(iv) Describe the stages in the catalytic decomposition of ammonia by tungsten.

(3)

(Total for Question 6 = 14 marks)

7 A group of students analysed a hydrated salt with the formula $KH_3(C_2O_4)_{\mathbf{y}}.\mathbf{z}H_2O$ where **y** and **z** are whole numbers.

The students carried out experiments to determine the values of **y** and **z**.

(a) **Experiment 1** – to determine the value of **y**

One student was provided with a 0.0235 mol dm^{-3} solution of the salt.

25.0 cm^3 portions of the salt solution were acidified with excess dilute sulfuric acid and heated to about 60 °C.

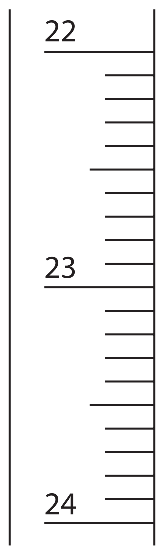
Each portion was titrated with 0.0203 mol dm^{-3} potassium manganate(VII).

The results of four titrations are shown in the table.

Titration number	1	2	3	4
Final burette reading / cm^3	23.85	47.20	24.05	48.10
Initial burette reading / cm^3	0.00	24.00	0.50	25.00
Titre / cm^3	23.85	23.20	23.55	23.10

(i) Complete the diagram to show the final burette reading in **Titration 1**.

(2)



(ii) Explain why this student should use a mean titre of 23.15 cm^3 and not 23.43 cm^3 in the calculation.

(2)

(iii) The uncertainty in each burette reading is ±0.05 cm^3.

Calculate the percentage uncertainty in the titre volume of potassium manganate(VII) solution used in **Titration 2**.

(1)

(iv) The equation for the reaction is

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

Deduce, by calculation, the value of **y**, to the nearest whole number, in the formula $KH_3(C_2O_4)_{\mathbf{y}}.\mathbf{z}H_2O$.

Use the mean titre of 23.15 cm^3 and other data from **Experiment 1**.

You **must** show your working.

(4)

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(b) **Experiment 2** – to determine the value of **z**

Another student wrote an account of the method for this experiment.

> *A crucible was weighed.*
>
> *A sample of the hydrated salt was added to the crucible and it was reweighed.*
>
> *The crucible and salt were heated to remove the water of crystallisation and then allowed to cool.*
>
> *The crucible and contents were weighed again.*
>
> *Results*
>
> | | |
> |---|---|
> | *Mass of crucible* | *= 19.56 g* |
> | *Mass of crucible +* $KH_3(C_2O_4)_y.\mathbf{z}H_2O$ | *= 22.97 g* |
> | *Mass of crucible +* $KH_3(C_2O_4)_y$ | *= 22.52 g* |

(i) Deduce, by calculation, the value of **z**, to the nearest whole number, in the formula $KH_3(C_2O_4)_{\mathbf{y}}.\mathbf{z}H_2O$.

You must use the data from **Experiment 2** and your value of **y** in (a)(iv).

You **must** show your working.

(3)

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(ii) A third student carried out Experiment 2 and calculated a value of **z** that was lower than expected.

This student evaluated the experiment and gave two suggestions for **z** being lower.

Suggestion **1**
"Some of the crystals jumped out of the crucible while it was being heated."

Suggestion **2**
"It was difficult to tell when all the water of crystallisation had been lost."

Evaluate these two suggestions to decide whether they could account for the lower value of **z** obtained from the experimental results.

Include an explanation of the effect each suggestion would have on the calculated value of **z** and how the method could be improved to prevent these errors.

(5)

(Total for Question 7 = 17 marks)

8 1-bromobutane can be prepared from butan-1-ol and hydrogen bromide.

$$CH_3CH_2CH_2CH_2OH + HBr \rightarrow CH_3CH_2CH_2CH_2Br + H_2O$$

Hydrogen bromide can be made from sodium bromide and 50% concentrated sulfuric acid.

(a) The steps for the preparation of impure 1-bromobutane are summarised.

Step **1** Dissolve the sodium bromide in distilled water in a pear-shaped flask and then add 20.0 cm^3 of butan-1-ol.

Step **2** Surround the flask with an ice bath to **cool the mixture**, before adding concentrated sulfuric acid drop by drop.

Step **3** Remove the flask from the ice bath and add a few **anti-bumping granules** to the reaction mixture.

Step **4** Set up the apparatus for **heating under reflux**. Heat the mixture in the flask for 30 minutes and then allow the apparatus to cool.

Step **5** Rearrange the apparatus for distillation and heat the mixture until no more 1-bromobutane distils over.

(i) Parts of the method are given in **bold** type in Steps **2**, **3** and **4**.
Give a reason why each of these parts is necessary.

(3)

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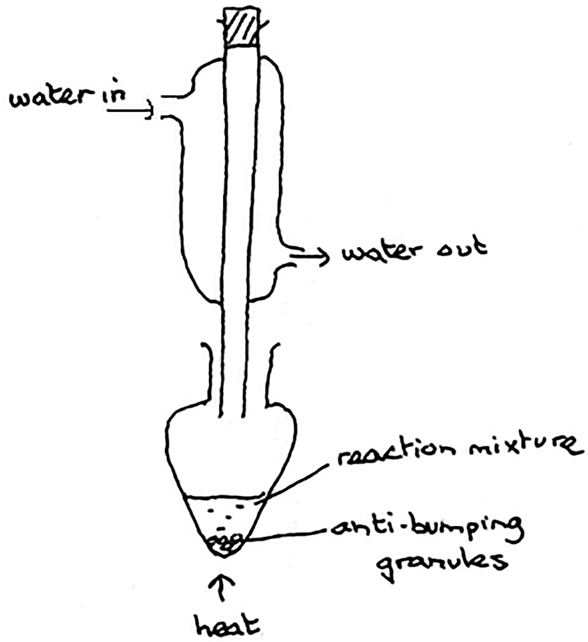
(ii) A student drew a diagram of the apparatus used for heating under reflux in Step **4**. There are three errors in the apparatus shown in the diagram. Assume the apparatus is suitably clamped.



Identify the three errors, including the effect of each error.

(3)

(iii) The student corrected the errors.
While the mixture was heating under reflux, the student noticed a small amount of a brown vapour was formed.

Explain why the brown vapour forms.

(2)

(b) The distillate collected in Step **5** is a mixture consisting of two layers.
There is an aqueous layer and a layer containing impure 1-bromobutane.

Data

Densities:

water	$1.00\,g\,cm^{-3}$
butan-1-ol	$0.81\,g\,cm^{-3}$
1-bromobutane	$1.27\,g\,cm^{-3}$

Boiling temperature of 1-bromobutane = 102 °C

The steps for the purification of the 1-bromobutane are summarised.

Step **6** Transfer the mixture from Step **5** to a separating funnel and remove the aqueous layer.

Step **7** Wash the impure 1-bromobutane with concentrated hydrochloric acid in the separating funnel. Remove the aqueous layer.

Step **8** Add aqueous sodium hydrogencarbonate to the impure 1-bromobutane in the separating funnel.

Step **9** Shake the mixture in the separating funnel and, from time to time, invert the funnel and open the tap.

Step **10** Collect the 1-bromobutane layer from Step **9** in a small conical flask. Add anhydrous sodium sulfate and swirl the flask until the liquid becomes clear.

Step **11** Decant the 1-bromobutane into a clean pear-shaped flask and redistil it. Measure the volume of 1-bromobutane produced.

(i) State the position of the aqueous layer in the separating funnel at the start of Step **6**. Justify your answer.

(1)

(ii) Concentrated hydrochloric acid is used to remove any unreacted butan-1-ol in the mixture in Step **7**.

Give the reasons for carrying out Steps **8**, **9** and **10**.

(3)

(iii) Give a suitable temperature **range** over which to collect the pure 1-bromobutane in the redistillation in Step **11**.

(1)

(iv) The volume of 1-bromobutane collected was 12.0 cm^3.

Calculate the number of molecules of 1-bromobutane produced in this experiment.

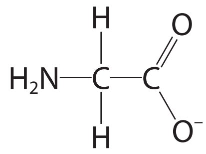
Give your answer to an appropriate number of significant figures.

(2)

(Total for Question 8 = 15 marks)

9 Some organic compounds contain metals.

(a) Glycinate ions are formed from the amino acid glycine.



glycinate ion

(i) Explain the effect, if any, of an aqueous solution containing glycinate ions on plane-polarised monochromatic light.

(2)

(ii) A hot aqueous solution of glycine is added to a hot solution of copper(II) ethanoate.
When the mixture is cooled, crystals of copper(II) glycinate are formed.

Write the equation for this reaction.
State symbols are not required.

(2)

(iii) In an experiment, the crystals are filtered, weighed and the percentage yield calculated.

Student **1** obtained a yield of 102.6%.

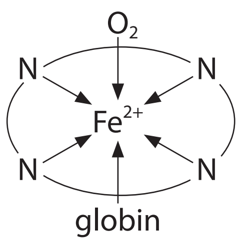
Student **2** obtained a yield of 56.4%.

The expected yield is 82% and the students carried out the calculation correctly.

Discuss possible reasons for the yields obtained by these students.

(4)

(b) Haemoglobin is an iron(II) complex. It carries oxygen around the body.
Part of the structure of haemoglobin is shown.



The four nitrogen atoms are part of a multidentate ligand in the haem group.

Explain why inhaling carbon monoxide can be fatal.

(2)

*(c) Grignard reagents contain a metal.

Discuss how Grignard reagents are formed and used in adding one or more carbon atoms to the carbon chain in 1-bromopropane to produce primary, secondary and tertiary alcohols and a carboxylic acid.

Include a suitable example for each reaction and give reagents, conditions and products. You may include equations in your answer.

(6)

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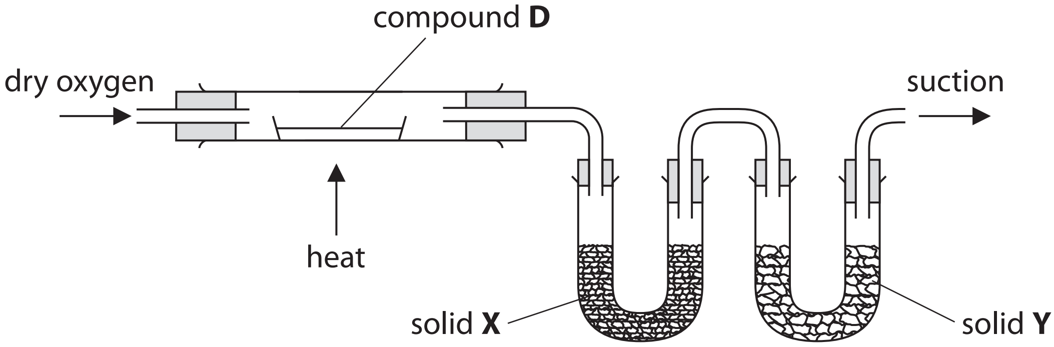
(Total for Question 9 = 16 marks)

10 Organic compound **D** contains the elements carbon, hydrogen, oxygen and nitrogen only.

(a) A sample of **D** was burned completely in the apparatus shown.
Solid **X** absorbed the water formed in the combustion.
Solid **Y** absorbed the carbon dioxide.



(i) The masses of solids **X** and **Y** increased during the experiment.

Explain the effect, if any, on the changes in mass of **X** and **Y** if the oxygen gas was not dry.

(3)

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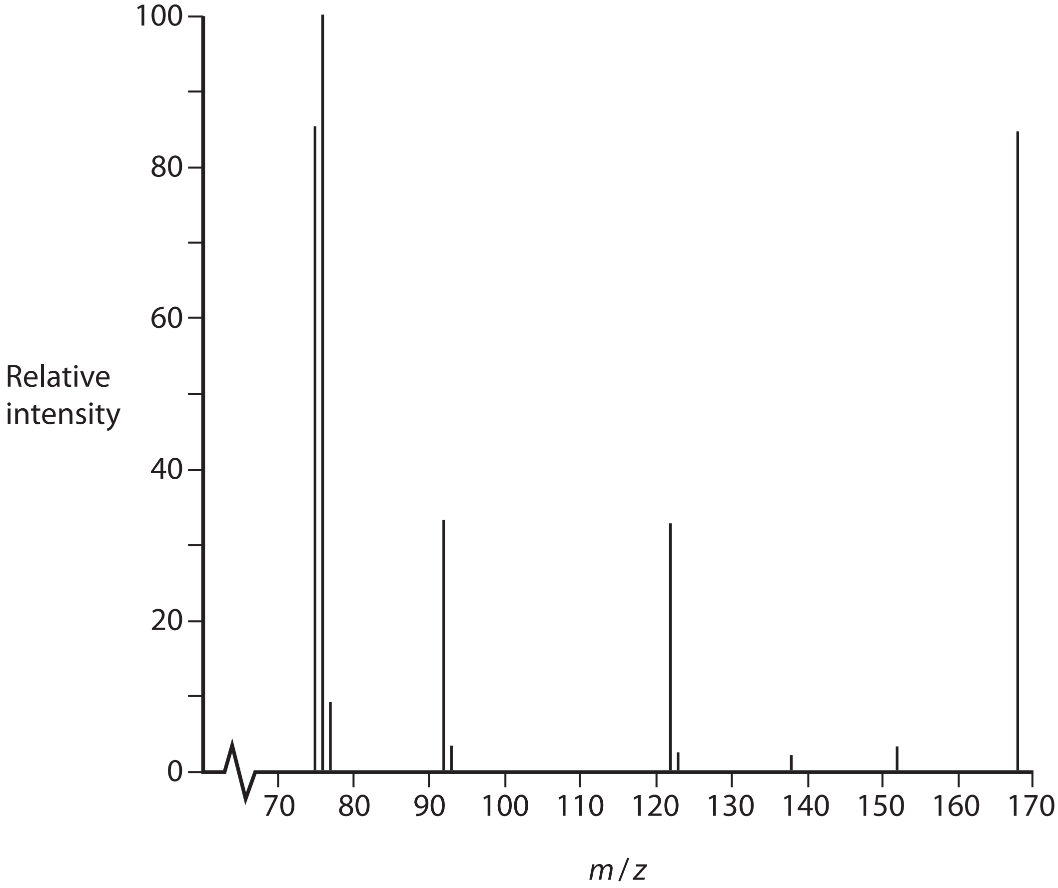
(ii) On combustion in dry oxygen, 3.36 g of **D** produced 0.72 g of water and 5.28 g of carbon dioxide.
This sample of **D** also contained 0.56 g of nitrogen.

Use these data to calculate the empirical formula of compound **D**.

You **must** show your working.

(5)

(b) Part of the mass spectrum of **D** is shown.



Deduce the molecular formula of **D**. Justify your answer.

(2)

(c) Compound **D** contains a benzene ring.

(i) Give the molecular formula of the species that causes the peak at $m/z = 76$ in the mass spectrum of **D**.

(1)

(ii) Draw the structures of the **three** possible isomers of **D** containing a benzene ring.

(2)

(iii) The ^{13}C NMR spectrum of compound **D** has four peaks.

Identify the structure of **D**. Justify your answer by labelling the different carbon environments in **all** the structures drawn in (c)(ii).

(3)

(Total for Question 10 = 16 marks)

TOTAL FOR PAPER = 120 MARKS

The Periodic Table of Elements

1.0
H
hydrogen
1

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(18)*
																	4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											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											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 4	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