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Candidate surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number | | | | | |

Candidate Number | | | | |

Monday 4 November 2019

Afternoon (Time: 1 hour 40 minutes) | Paper Reference **WCH05/01**

Chemistry
Advanced
Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry (including synoptic assessment)

Candidates must have: Scientific calculator
Data Booklet

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 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.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed
  – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- 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 give units where appropriate.
- Check your answers if you have time at the end.

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SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 What are the oxidation states of chromium in the ions shown?

	$[Cr(OH)_6]^{3-}$	$[Cr(H_2O)_6]^{2+}$	$Cr_2O_7^{2-}$
☒ **A**	–3	+2	–2
☒ **B**	–3	+6	+2
☒ **C**	+3	+6	+6
☒ **D**	+3	+2	+6

(Total for Question 1 = 1 mark)

2 In which of these compounds does iron have its highest oxidation number?

☒ **A** K_2FeO_4

☒ **B** $(NH_4)_2Fe(SO_4)_2.6H_2O$

☒ **C** $K_3Fe(CN)_6$

☒ **D** $K_4Fe(CN)_6$

(Total for Question 2 = 1 mark)

3 A transition metal **M** forms an octahedral complex in which 3 mol of a ligand **L** combine with 1 mol of **M**.

L is most likely to be

☒ **A** ammonia.

☒ **B** 1,2-diaminoethane.

☒ **C** EDTA.

☒ **D** water.

(Total for Question 3 = 1 mark)

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4 What are the shapes of the complexes shown?

	$[CrCl_4]^-$	$[Pt(NH_3)_2Cl_2]$
☒ **A**	tetrahedral	tetrahedral
☒ **B**	square planar	tetrahedral
☒ **C**	tetrahedral	square planar
☒ **D**	square planar	square planar

(Total for Question 4 = 1 mark)

5 One mole of sulfur dioxide reacts exactly with two moles of ions of a metal Q.

The oxidation number of Q in the ions is +4.

The sulfur dioxide is converted to sulfate(VI) ions.

What is the final oxidation number of Q?

☒ **A** +6

☒ **B** +3

☒ **C** +2

☒ **D** 0

(Total for Question 5 = 1 mark)

6 The reaction

$$[Fe(H_2O)_6]^{3+}(aq) + 3OH^-(aq) \rightarrow [Fe(H_2O)_3(OH)_3](s) + 3H_2O(l)$$

is an example of

☒ **A** oxidation.

☒ **B** reduction.

☒ **C** condensation.

☒ **D** ionic precipitation.

(Total for Question 6 = 1 mark)

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7 Lithium tetrahydridoaluminate(III), $LiAlH_4$, can be used to convert

- ☒ **A** CH_3CHO to CH_3CH_2OH
- ☒ **B** C_2H_5COOH to CH_3COCH_3
- ☒ **C** C_2H_4 to C_2H_6
- ☒ **D** C_6H_6 to C_6H_{12}

(Total for Question 7 = 1 mark)

8 The electrophile in the preparation of benzenesulfonic acid, $C_6H_5SO_3H$, from benzene is

- ☒ **A** SO_2
- ☒ **B** SO_3
- ☒ **C** SO_4^{2-}
- ☒ **D** HSO_4^-

(Total for Question 8 = 1 mark)

9 Benzenediazonium salts are made by reacting phenylamine with nitrous acid at a temperature of 0–10 °C.

This temperature range must be used because the

- ☒ **A** benzene ring is nitrated at higher temperatures.
- ☒ **B** reaction is highly exothermic.
- ☒ **C** activation energy of the reaction is low.
- ☒ **D** diazonium ion decomposes above 10 °C.

(Total for Question 9 = 1 mark)

10 The solution formed when ethylamine is dissolved in water

- ☒ **A** contains zwitterions.
- ☒ **B** is neutral.
- ☒ **C** is acidic.
- ☒ **D** is alkaline.

(Total for Question 10 = 1 mark)

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11 The compound formed when ethanoyl chloride reacts with phenylamine is

☒ **A** $CH_3CONHC_6H_5$

☒ **B** $C_2H_5CONHC_6H_5$

☒ **C** $C_6H_5CONHCH_3$

☒ **D** $C_6H_5CONHC_2H_5$

(Total for Question 11 = 1 mark)

12 A white smoke forms when methylamine and hydrogen chloride mix. The formula of the white smoke is

☒ **A** NH_4Cl

☒ **B** CH_3NH_2Cl

☒ **C** CH_3NH_3Cl

☒ **D** $CH_3CONHCl$

(Total for Question 12 = 1 mark)

13 The **low** resolution proton nmr spectrum of a compound contains only three peaks.

Which of the following compounds could give this spectrum?

☒ **A** but-1-ene

☒ **B** butanal

☒ **C** butanone

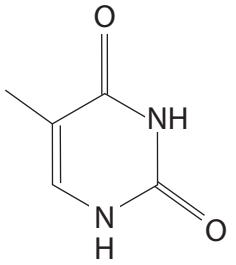
☒ **D** butanoic acid

(Total for Question 13 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

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14 Thymine is a naturally occurring compound with the structure shown.



Which of the groups listed is **not** present in its structure?

☒ **A** Alkyl

☒ **B** Alkene

☒ **C** Amide

☒ **D** Ketone

(Total for Question 14 = 1 mark)

15 E_{cell} for a chemical reaction is proportional to both

☒ **A** ΔS_{system} and K

☒ **B** ΔS_{total} and K

☒ **C** ΔS_{system} and $\ln K$

☒ **D** ΔS_{total} and $\ln K$

(Total for Question 15 = 1 mark)

16 Which are correct for a standard hydrogen electrode?

	Temperature / K	Solution
☒ **A**	273	$[H^+(aq)] = 1.00\,mol\,dm^{-3}$
☒ **B**	273	$[OH^-(aq)] = 1.00\,mol\,dm^{-3}$
☒ **C**	298	$[H^+(aq)] = 1.00\,mol\,dm^{-3}$
☒ **D**	298	$[OH^-(aq)] = 1.00\,mol\,dm^{-3}$

(Total for Question 16 = 1 mark)

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17 The redox reaction between aqueous iodide ions and aqueous peroxodisulfate ions is slow.

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

Which of these ions catalyses this reaction?

☒ **A** $H^+(aq)$

☒ **B** $Mg^{2+}(aq)$

☒ **C** $Fe^{2+}(aq)$

☒ **D** $OH^-(aq)$

(Total for Question 17 = 1 mark)

18 The repeat units of four polymers are shown

Polymer	Repeat unit
W	—$CH_2CH(CONH_2)$—
X	—$HNCH_2CO$—
Y	—$CH(CH_3)CHCN$—
Z	—$HNCH_2CH_2NHOCCH_2CO$—

(a) Which polymer could be formed from a naturally occurring amino acid?

(1)

☒ **A** W

☒ **B** X

☒ **C** Y

☒ **D** Z

(b) Which formula shows the repeat unit of poly(propenamide)?

(1)

☒ **A** W

☒ **B** X

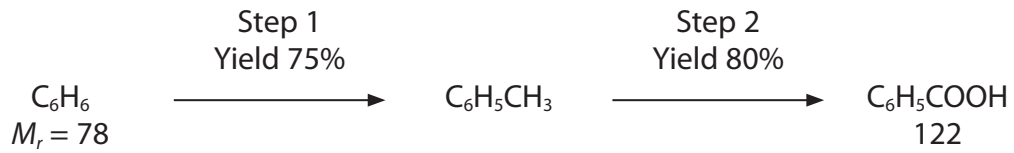
☒ **C** Y

☒ **D** Z

(Total for Question 18 = 2 marks)

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19 In a laboratory preparation, benzoic acid was produced from benzene in two steps.



The mass of benzoic acid, in grams, obtained from 3.90 g benzene was

☒ **A** 1.50

☒ **B** 3.66

☒ **C** 6.10

☒ **D** 10.17

(Total for Question 19 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

20 This question is about the different oxidation states of manganese.

Standard reduction potentials of some electrode reactions involving different oxidation states of manganese are shown.

Electrode reaction	$E^{\ominus}$ / V
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	−1.19
$MnO_4^-(aq) + e^- \rightleftharpoons MnO_4^{2-}(aq)$	+0.56
$MnO_4^{2-}(aq) + 2H_2O(l) + 2e^- \rightleftharpoons MnO_2(s) + 4OH^-(aq)$	+0.59
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51

(a) Use your Data Booklet to select a metal commonly found in the laboratory which would reduce $Mn^{2+}(aq)$ to Mn, but which does **not** react with water at room temperature.

Write an **ionic** equation for this reaction of $Mn^{2+}(aq)$ with the metal you have selected.

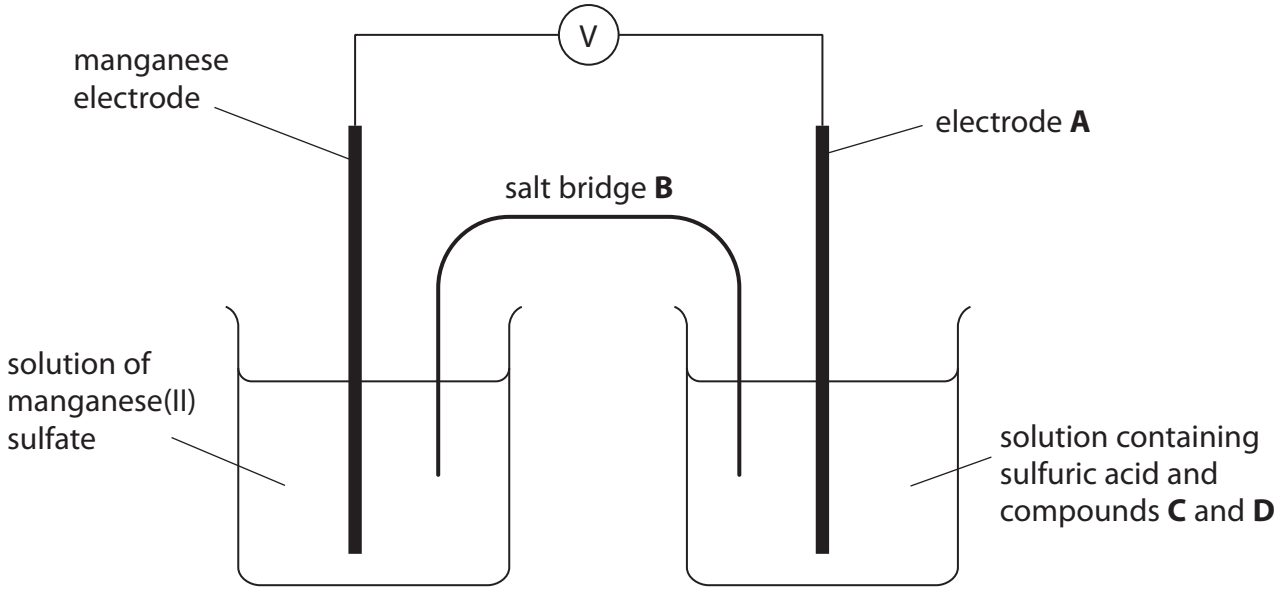
State symbols are not required.

(2)

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(b) A cell can be used to measure the standard cell potential, $E^{\ominus}_{cell}$, for the reaction of manganate(VII) ions with manganese in acid conditions.

$$2MnO_4^-(aq) + 5Mn(s) + 16H^+(aq) \rightleftharpoons 7Mn^{2+}(aq) + 8H_2O(l)$$



(i) Identify, by name or formula, the substances needed to measure the standard cell potential, $E^{\ominus}_{cell}$.

(4)

Electrode **A** is made of .....

Salt bridge **B** contains a solution of .....

Compound **C** .....

Compound **D** .....

(ii) Calculate the value of the standard cell potential, $E^{\ominus}_{cell}$.
Use the data in the table at the start of the question on page 9.

(1)

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(c) Potassium manganate(VI), K_2MnO_4, can be prepared by heating a mixture of potassium manganate(VII), $KMnO_4$, and concentrated potassium hydroxide solution. On cooling, green crystals form.

$$4KMnO_4 + 4KOH \rightarrow 4K_2MnO_4 + O_2 + 2H_2O$$

Write the half-equation that shows hydroxide ions acting as a reducing agent in this reaction.
State symbols are not required.

(1)

(d) Manganate(VI) ions, MnO_4^{2-}, disproportionate into MnO_2 and MnO_4^- in alkaline conditions.

(i) Write the equation for this reaction using appropriate half-equations from the table at the start of the question on page 9.
State symbols are not required.

(2)

(ii) Calculate the $E^{\ominus}_{cell}$ for this reaction and state whether or not this disproportionation is thermodynamically feasible.

(1)

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21 This question is about copper and zinc.

(a) Complete the electronic configurations for copper and zinc atoms.

(1)

		3d					4s
Copper	(Ar)	↑↓					
Zinc	(Ar)	↑↓					

(b) The first and second ionisation energies of copper and zinc are shown.

	Copper	Zinc
1st ionisation energy / kJ mol^{-1}	746	906
2nd ionisation energy / kJ mol^{-1}	1958	1733

*(i) Suggest why the first ionisation energy of copper is less than the first ionisation energy of zinc.

(2)

*(ii) Suggest why the second ionisation of copper is greater than the second ionisation energy of zinc.

(2)

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*(iii) Zinc compounds are usually white, whereas many copper compounds are coloured.

Explain fully why hexaaquazinc ions, $[Zn(H_2O)_6]^{2+}$, are colourless in solution.

(2)

(c) When a few drops of aqueous ammonia are added to a solution of copper(II) sulfate, a precipitate forms. If excess ammonia is then added, the precipitate dissolves.

(i) State the colour of the precipitate and the colour of the solution after the addition of excess ammonia.

(1)

Precipitate .....

Solution .....

(ii) Complete the equation for the reaction of the precipitate with excess ammonia. State symbols are not required.

(2)

$[Cu(H_2O)_4(OH)_2]$ + ... NH_3 $\rightarrow$

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(d) When aqueous sodium hydroxide is added to a solution of zinc sulfate, a white precipitate forms which is soluble in both excess sodium hydroxide and in dilute sulfuric acid.

(i) State the term used to describe a compound that forms a salt with both sodium hydroxide and sulfuric acid.

(1)

.....

(ii) Write an equation for the reaction of the white precipitate with excess sodium hydroxide.
State symbols are not required.

(1)

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(e) Brass is an alloy of copper and zinc.

3.50 g of a sample of brass was reacted with concentrated nitric acid. The resulting solution of copper(II) nitrate and zinc nitrate was neutralised and made up to a volume of 250.0 cm^3.

Excess potassium iodide was reacted with 25.0 cm^3 portions of this solution. Zinc ions do not react with potassium iodide, but copper(II) ions do.

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

The iodine formed was titrated with sodium thiosulfate solution of concentration 0.150 mol dm^{-3}. The mean titre was 24.50 cm^3.

(i) Complete the equation for the reaction of iodine with thiosulfate ions. State symbols are not required.

(1)

$$I_2 + 2S_2O_3^{2-} \rightarrow \text{.....} + \text{.....}$$

*(ii) Calculate the percentage by mass of copper in the sample of brass. Give your answer to **three** significant figures.

(4)

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22 This question is about some ions and molecules that have delocalised electrons.

(a) Give the meaning of the term **delocalised**, when referring to electrons.

(1)

(b) The carboxylate ion (—COO^-) has delocalised electrons.

(i) Draw the displayed formula of a carboxylate ion, indicating the delocalised electrons.

(1)

(ii) Suggest the OCO bond angle.

(1)

(c) Benzene molecules also contain delocalised electrons.

(i) State the number of delocalised electrons in each benzene molecule, **and** identify the type of orbital from which they originate.

(1)

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(ii) Name the **physical** method which gives evidence for delocalisation in benzene. State how the result indicates that there is delocalisation.

(2)

*(d) The C—O bond in phenol is shorter than the C—O bond in methanol. Describe how the delocalisation of electrons can be used to explain this.

(2)

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(e) Phenol can be nitrated more easily than benzene.

(i) **Name** the reagent which should be used for the nitration of phenol. Indicate the concentration needed.

(1)

.....

(ii) Give the structure of two possible **isomeric** products of this nitration.

(1)

(iii) State the reagents and conditions needed for the formation of nitrobenzene from benzene.

(2)

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(Total for Question 22 = 12 marks)

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23 This question is about amino acids.

(a) Explain why amino acids are very soluble in water.

(2)

(b) Name the reagent which is used to detect amino acids on a chromatogram.

(1)

(c) A dipeptide **X** has the molecular formula $C_5H_{10}N_2O_4$.

X was hydrolysed by heating under reflux with hydrochloric acid.
Two naturally occurring amino acids, **Y** and **Z**, were formed.
Only **Z** was optically active.

(i) Deduce the structure of **Y**, which is **not** optically active.

(1)

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(ii) The amino acid **Z** has molecular formula $C_3H_7NO_3$.

One mole of **Z** reacts with two moles of phosphorus(V) chloride, PCl_5.

State what can be deduced from this reaction about the structure of **Z**.
Draw the displayed formula of **Z** and circle the chiral centre.

(3)

.....

.....

(iii) **Y** and **Z** were formed by hydrolysis of the compound **X**.

Draw a possible structure of **X**.

(2)

(Total for Question 23 = 9 marks)

TOTAL FOR SECTION B = 40 MARKS

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SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

24

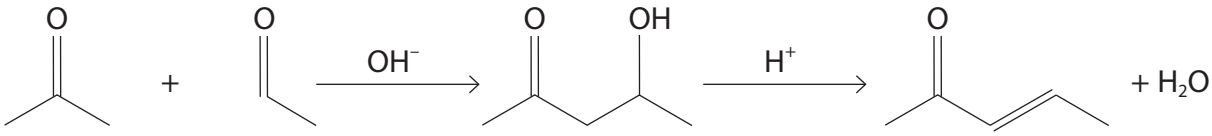
The Importance of Ketones in Organic Synthesis

Naturally occurring ketones are often found in foods. Butane-2,3-dione gives a buttery flavour, and heptan-2-one is found in some blue cheeses. The molecules giving flavour may contain other groups as well as the carbonyl group. Spearmint oil contains C═C bonds and "raspberry ketone" contains a phenolic group.

Camphor is a naturally occurring ketone which reduces itching and is a moth repellent.

Ketones are important in chemical synthesis because they undergo nucleophilic addition reactions. Ketones also react with other carbonyl compounds in condensation reactions. They are used in synthesis to extend the carbon chain in a molecule, for example by reacting with hydrogen cyanide.

"Aldol condensations" are reactions between two carbonyl compounds, such as two ketone molecules, or an aldehyde and a ketone.
One example is the reaction of propanone with ethanal.



propanone ethanal

Aromatic ketones can be made by reacting benzene with acyl chlorides in the Friedel-Crafts reaction. This produces ketones such as ethyl phenyl ketone which contain the C_6H_5CO group.

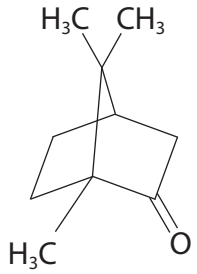
2-hydroxycarboxylic acids can be prepared from ketones, and these compounds are intermediates from which many other products can be made.

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(a) Camphor is a strong smelling ketone extracted from camphor trees.



Deduce its molecular formula.

(1)

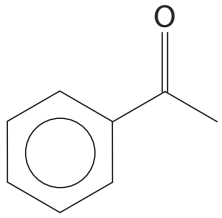
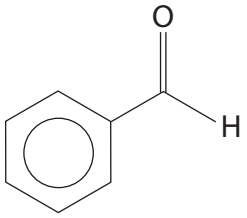
(b) Benzene reacts with propanoyl chloride in the presence of a catalyst of aluminium chloride to form ethyl phenyl ketone, $C_6H_5COCH_2CH_3$.

Give the mechanism for this reaction, including an equation for the formation of the electrophile.

(4)

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(c) Suggest the structure of the **final** product of the aldol condensation reaction between phenylethanone and benzaldehyde.

	
Phenylethanone	Benzaldehyde

(1)

(d) 2-hydroxycarboxylic acids are used as anti-wrinkle products in the cosmetics industry.

2-hydroxy-2-methylpentanoic acid can be made from pentan-2-one in two steps. Draw the intermediate compound and give the reagent(s) needed in each step. Reaction conditions are not required.

(3)



pentan-2-one intermediate 2-hydroxy-2-methylpentanoic acid

Reagents for Step 1 .....

Reagents for Step 2 .....

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(e) The empirical formula of organic compounds can be found by complete combustion of a known mass of the compound. The mass of each product is then determined.

(i) Water and carbon dioxide are always formed on complete combustion of organic compounds.

Identify the substances that can be used to absorb each of these products so their mass can be measured.

(2)

Water .....

Carbon dioxide .....

(ii) Give a reason why the percentage of oxygen in the compound cannot be found **directly** from the mass of the combustion products.

(1)

.....

.....

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(f) The compound known as raspberry ketone was analysed by combustion and the results are shown.

Element	% by mass
C	73.17
H	7.32
O	19.51

(i) Calculate the empirical formula of raspberry ketone.

(2)

(ii) The relative molecular mass of raspberry ketone is 164.

Deduce its molecular formula.

(1)

(iii) Describe how the relative molecular mass of a compound can be found from its mass spectrum.

(1)

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(iv) Raspberry ketone is a substituted phenol.

Give a chemical test which distinguishes phenol from benzene and describe the positive result.

(2)

.....

.....

.....

.....

.....

.....

(v) Raspberry ketone reacts with a solution of iodine in sodium hydroxide to give a pale yellow precipitate.

The **high** resolution proton nmr spectrum of raspberry ketone shows peaks due to the phenol group. Outside this region, there are two triplets and a singlet in the spectrum.

Use this information to deduce a structure for raspberry ketone.

Label the atoms which produce the singlet and the atoms which produce the two triplets in the nmr spectrum.

(3)

(Total for Question 24 = 21 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)	
.9 i ium 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
.0 a ium 1	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
.1 K ssium 9	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
.5 b dium 7	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
2.9 s ium 5	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
23] r cium 7	[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

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