

Please check the examination details below before entering your candidate information

Candidate surname

Other names

**Pearson Edexcel**  
**International**  
**Advanced Level**

Centre Number

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Candidate Number

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**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.

Turn over ►

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**Pearson**

## 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 . 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?

	$[\text{Cr}(\text{OH})_6]^{3-}$	$[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$	$\text{Cr}_2\text{O}_7^{2-}$
<input type="checkbox"/> A	-3	+2	-2
<input type="checkbox"/> B	-3	+6	+2
<input type="checkbox"/> C	+3	+6	+6
<input type="checkbox"/> D	+3	+2	+6

(Total for Question 1 = 1 mark)

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

- A  $\text{K}_2\text{FeO}_4$
- B  $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$
- C  $\text{K}_3\text{Fe}(\text{CN})_6$
- D  $\text{K}_4\text{Fe}(\text{CN})_6$

(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?

	$[\text{CrCl}_4]^-$	$[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$
<input type="checkbox"/> A	tetrahedral	tetrahedral
<input type="checkbox"/> B	square planar	tetrahedral
<input type="checkbox"/> C	tetrahedral	square planar
<input type="checkbox"/> 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.

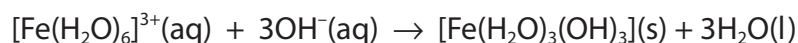
The sulfur dioxide is converted to sulfate(VI) ions.

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



is an example of

- A oxidation.
- B reduction.
- C condensation.
- D ionic precipitation.

(Total for Question 6 = 1 mark)



7 Lithium tetrahydridoaluminate(III),  $\text{LiAlH}_4$ , can be used to convert

- A  $\text{CH}_3\text{CHO}$  to  $\text{CH}_3\text{CH}_2\text{OH}$
- B  $\text{C}_2\text{H}_5\text{COOH}$  to  $\text{CH}_3\text{COCH}_3$
- C  $\text{C}_2\text{H}_4$  to  $\text{C}_2\text{H}_6$
- D  $\text{C}_6\text{H}_6$  to  $\text{C}_6\text{H}_{12}$

(Total for Question 7 = 1 mark)

8 The electrophile in the preparation of benzenesulfonic acid,  $\text{C}_6\text{H}_5\text{SO}_3\text{H}$ , from benzene is

- A  $\text{SO}_2$
- B  $\text{SO}_3$
- C  $\text{SO}_4^{2-}$
- D  $\text{HSO}_4^-$

(Total for Question 8 = 1 mark)

9 Benzenediazonium salts are made by reacting phenylamine with nitrous acid at a temperature of  $0-10^\circ\text{C}$ .

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  $10^\circ\text{C}$ .

(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)



11 The compound formed when ethanoyl chloride reacts with phenylamine is

- A  $\text{CH}_3\text{CONHC}_6\text{H}_5$
- B  $\text{C}_2\text{H}_5\text{CONHC}_6\text{H}_5$
- C  $\text{C}_6\text{H}_5\text{CONHCH}_3$
- D  $\text{C}_6\text{H}_5\text{CONHC}_2\text{H}_5$

(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  $\text{NH}_4\text{Cl}$
- B  $\text{CH}_3\text{NH}_2\text{Cl}$
- C  $\text{CH}_3\text{NH}_3\text{Cl}$
- D  $\text{CH}_3\text{CONHCl}$

(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?

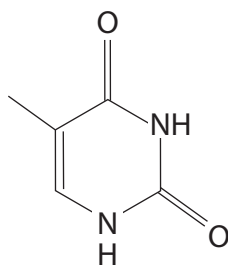
- A but-1-ene
- B butanal
- C butanone
- D butanoic acid

(Total for Question 13 = 1 mark)

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



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  $E_{\text{cell}}$  for a chemical reaction is proportional to both

- A  $\Delta S_{\text{system}}$  and  $K$
- B  $\Delta S_{\text{total}}$  and  $K$
- C  $\Delta S_{\text{system}}$  and  $\ln K$
- D  $\Delta S_{\text{total}}$  and  $\ln K$

(Total for Question 15 = 1 mark)

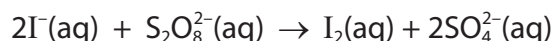
16 Which are correct for a standard hydrogen electrode?

	Temperature / K	Solution
<input type="checkbox"/> A	273	$[\text{H}^+(\text{aq})] = 1.00 \text{ mol dm}^{-3}$
<input type="checkbox"/> B	273	$[\text{OH}^-(\text{aq})] = 1.00 \text{ mol dm}^{-3}$
<input type="checkbox"/> C	298	$[\text{H}^+(\text{aq})] = 1.00 \text{ mol dm}^{-3}$
<input type="checkbox"/> D	298	$[\text{OH}^-(\text{aq})] = 1.00 \text{ mol dm}^{-3}$

(Total for Question 16 = 1 mark)



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



Which of these ions catalyses this reaction?

- A  $\text{H}^+(\text{aq})$
- B  $\text{Mg}^{2+}(\text{aq})$
- C  $\text{Fe}^{2+}(\text{aq})$
- D  $\text{OH}^-(\text{aq})$

(Total for Question 17 = 1 mark)

18 The repeat units of four polymers are shown

Polymer	Repeat unit
W	$-\text{CH}_2\text{CH}(\text{CONH}_2)-$
X	$-\text{HNCH}_2\text{CO}-$
Y	$-\text{CH}(\text{CH}_3)\text{CHCN}-$
Z	$-\text{HNCH}_2\text{CH}_2\text{NHOCCH}_2\text{CO}-$

(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)?

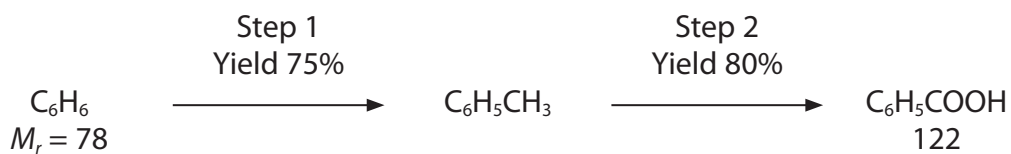
(1)

- A W
- B X
- C Y
- D Z

(Total for Question 18 = 2 marks)



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	$E^\ominus / \text{V}$
$\text{Mn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mn}(\text{s})$	-1.19
$\text{MnO}_4^-(\text{aq}) + \text{e}^- \rightleftharpoons \text{MnO}_4^{2-}(\text{aq})$	+0.56
$\text{MnO}_4^{2-}(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightleftharpoons \text{MnO}_2(\text{s}) + 4\text{OH}^-(\text{aq})$	+0.59
$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51

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

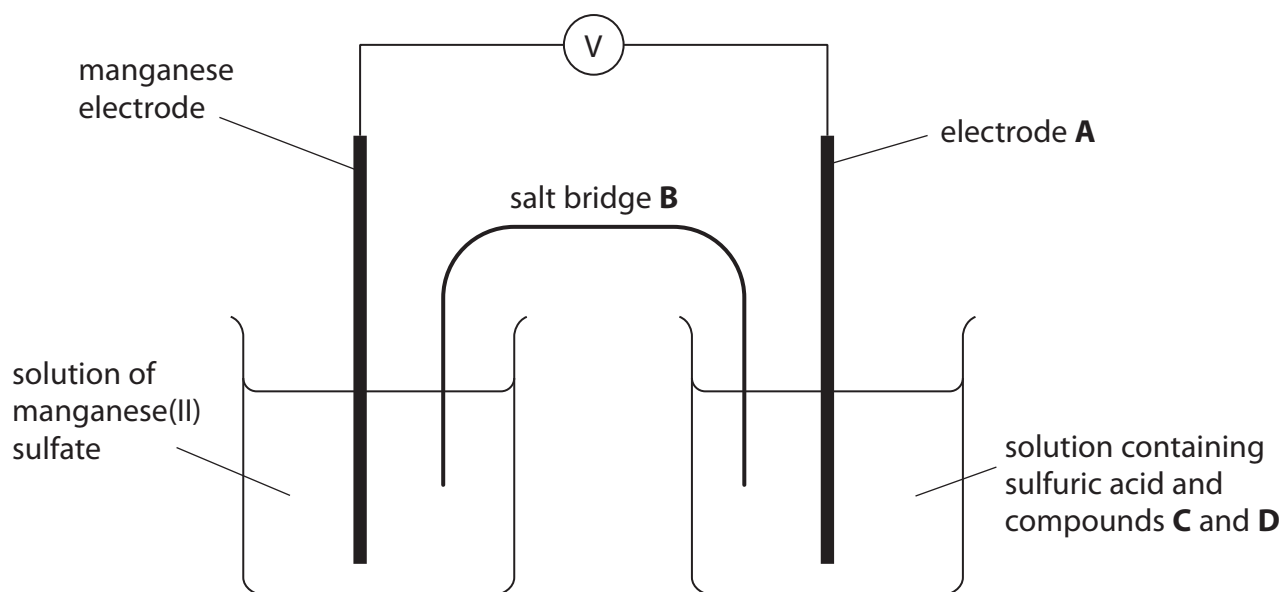
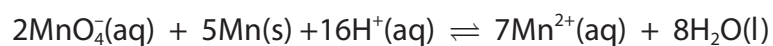
Write an **ionic** equation for this reaction of  $\text{Mn}^{2+}(\text{aq})$  with the metal you have selected.

State symbols are not required.

(2)



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



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

(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,  $E_{\text{cell}}^{\ominus}$ .  
Use the data in the table at the start of the question on page 9.

(1)



- (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.



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  $E_{cell}^\ominus$  for this reaction and state whether or not this disproportionation is thermodynamically feasible.

(1)

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(Total for Question 20 = 11 marks)



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 / $\text{kJ mol}^{-1}$	746	906
2nd ionisation energy / $\text{kJ mol}^{-1}$	1958	1733

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

(2)

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\*(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,  $[\text{Zn}(\text{H}_2\text{O})_6]^{2+}$ , are colourless in solution.

(2)

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(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.

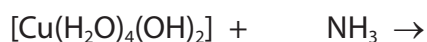
(1)

Precipitate.....

Solution.....

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

(2)



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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)

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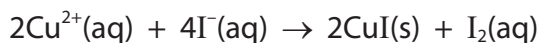
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(e) Brass is an alloy of copper and zinc.

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<sup>3</sup>.

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



The iodine formed was titrated with sodium thiosulfate solution of concentration 0.150 mol dm<sup>-3</sup>. The mean titre was 24.50 cm<sup>3</sup>.

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

(1)



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

(4)

(Total for Question 21 = 17 marks)



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 ( $-\text{COO}^-$ ) 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)





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

(2)

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\*(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)

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

(2)

(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)

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

(1)

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(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)



(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 = 49 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

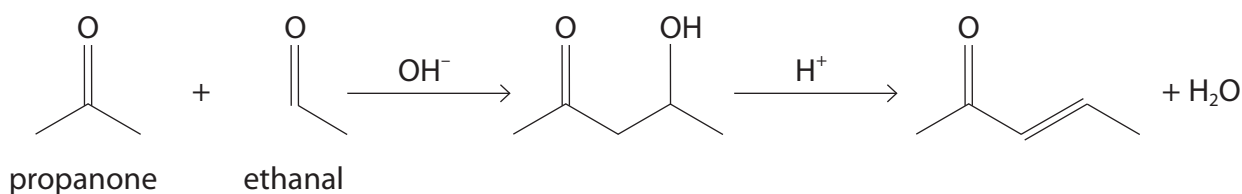
Naturally occurring ketones are often found in foods. Butane-2,3-dione gives a buttery flavour, and heptan-2-one is found in some blue cheeses. The molecules giving flavour may contain other groups as well as the carbonyl group. Spearmint oil contains C=C bonds and “raspberry ketone” contains a phenolic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



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<sub>6</sub>H<sub>5</sub>CO group.

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

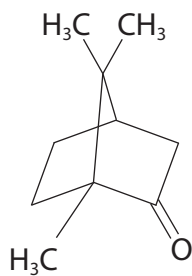
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(a) Camphor is a strong smelling ketone extracted from camphor trees.



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<sub>6</sub>H<sub>5</sub>COCH<sub>2</sub>CH<sub>3</sub>.

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

(4)

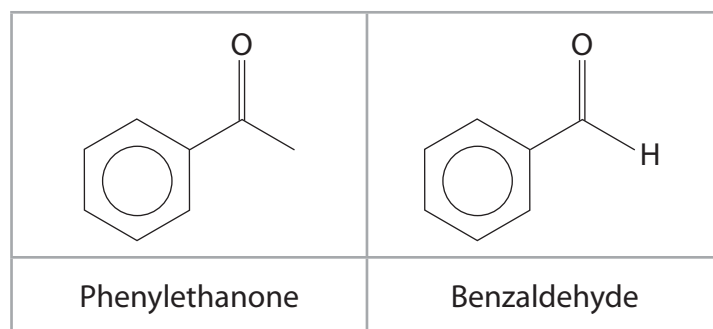
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- (c) Suggest the structure of the **final** product of the aldol condensation reaction between phenylethanone and benzaldehyde.



(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)



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)

.....

.....



- (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)
- .....
- .....



(iv) Raspberry ketone is a substituted phenol.

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

(2)

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(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)

TOTAL FOR SECTION C = 21 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

**Key**  
relative atomic mass  
**atomic symbol**  
name  
atomic (proton) number

(1)	6.9 <b>Li</b> lithium 3	9.0 <b>Be</b> beryllium 4	11 <b>Na</b> sodium	12 <b>Mg</b> magnesium	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
	39.1 <b>K</b> potassium 19	40.1 <b>Ca</b> calcium 20	39.1 <b>K</b> potassium 19	40.1 <b>Ca</b> calcium 20	45.0 <b>Sc</b> scandium 21	47.9 <b>Ti</b> titanium 22	47.9 <b>Ti</b> titanium 22	50.9 <b>V</b> vanadium 23	52.0 <b>Cr</b> chromium 24	54.9 <b>Mn</b> manganese 25	55.8 <b>Fe</b> iron 26	58.9 <b>Co</b> cobalt 27	58.7 <b>Ni</b> nickel 28	63.5 <b>Cu</b> copper 29	65.4 <b>Zn</b> zinc 30	10.8 <b>B</b> boron 5	12.0 <b>C</b> carbon 6	14.0 <b>N</b> nitrogen 7	16.0 <b>O</b> oxygen 8	19.0 <b>F</b> fluorine 9	20.2 <b>Ne</b> neon 10
	85.5 <b>Rb</b> rubidium 37	87.6 <b>Sr</b> strontium 38	85.5 <b>Rb</b> rubidium 37	87.6 <b>Sr</b> strontium 38	88.9 <b>Y</b> yttrium 39	91.2 <b>Zr</b> zirconium 40	91.2 <b>Zr</b> zirconium 40	92.9 <b>Nb</b> niobium 41	95.9 <b>Mo</b> molybdenum 42	[98] <b>Tc</b> technetium 43	101.1 <b>Ru</b> ruthenium 44	102.9 <b>Rh</b> rhodium 45	106.4 <b>Pd</b> palladium 46	107.9 <b>Ag</b> silver 47	112.4 <b>Cd</b> cadmium 48	114.8 <b>In</b> indium 49	118.7 <b>Sn</b> tin 50	121.8 <b>Sb</b> antimony 51	127.6 <b>Te</b> tellurium 52	126.9 <b>I</b> iodine 53	131.3 <b>Xe</b> xenon 54
	132.9 <b>Cs</b> caesium 55	137.3 <b>Ba</b> barium 56	132.9 <b>Cs</b> caesium 55	137.3 <b>Ba</b> barium 56	138.9 <b>La*</b> lanthanum 57	178.5 <b>Hf</b> hafnium 72	178.5 <b>Hf</b> hafnium 72	180.9 <b>Ta</b> tantalum 73	183.8 <b>W</b> tungsten 74	186.2 <b>Re</b> rhenium 75	190.2 <b>Os</b> osmium 76	192.2 <b>Ir</b> iridium 77	195.1 <b>Pt</b> platinum 78	197.0 <b>Au</b> gold 79	200.6 <b>Hg</b> mercury 80	204.4 <b>Tl</b> thallium 81	207.2 <b>Pb</b> lead 82	209.0 <b>Bi</b> bismuth 83	[209] <b>Po</b> polonium 84	[210] <b>At</b> astatine 85	[222] <b>Rn</b> radon 86
	[223] <b>Fr</b> francium 87	[226] <b>Ra</b> radium 88	[223] <b>Fr</b> francium 87	[226] <b>Ra</b> radium 88	[227] <b>Ac*</b> actinium 89	[261] <b>Rf</b> rutherfordium 104	[261] <b>Rf</b> rutherfordium 104	[262] <b>Db</b> dubnium 105	[266] <b>Sg</b> seaborgium 106	[264] <b>Bh</b> bohrium 107	[277] <b>Hs</b> hassium 108	[268] <b>Mt</b> meitnerium 109	[271] <b>Ds</b> darmstadtium 110	[272] <b>Rg</b> roentgenium 111	Elements with atomic numbers 112-116 have been reported but not fully authenticated						

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

\* Lanthanide series  
\* Actinide series

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