GradeMax

Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
International Advanced Level

Centre Number | Candidate Number

Monday 18 January 2021

Morning (Time: 1 hour 45 minutes) | Paper Reference **WCH15/01**

Chemistry

International Advanced Level

Unit 5: Transition Metals and Organic Nitrogen Chemistry

You must have:
Scientific calculator, Data booklet

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

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.*
- In the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing how 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.

Turn over ▶

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P 6 7 8 1 9 A 0 1 2 8

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 in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 When an alkene is added to a solution of potassium manganate(VII), the purple solution turns colourless.

In terms of electron transfer and oxidation number, how does the manganese change in this reaction?

	Electron transfer	Oxidation number
☒ **A**	gains electrons	increases
☒ **B**	gains electrons	decreases
☒ **C**	loses electrons	increases
☒ **D**	loses electrons	decreases

(Total for Question 1 = 1 mark)

2 The standard hydrogen electrode uses an electrode of platinum coated in a finely divided form of the metal called platinum black.

What is the purpose of this coating?

☒ **A** to increase the rate of the equilibrium between the hydrogen gas and the hydrogen ions

☒ **B** to provide an inert protective coating for the electrode

☒ **C** to increase the electrical conductivity of the electrode

☒ **D** to ensure that the conditions remain standard

(Total for Question 2 = 1 mark)

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3 An electrochemical cell is set up to measure $E^{\ominus}_{cell}$ for the reaction

$$Fe(s) + Sn^{2+}(aq) \rightarrow Fe^{2+}(aq) + Sn(s)$$

(a) What is the cell diagram for this cell?

(1)

☒ **A** $Fe(s) \mid Fe^{2+}(aq) \parallel Sn(s) \mid Sn^{2+}(aq)$

☒ **B** $Fe^{2+}(aq) \mid Fe(s) \parallel Sn^{2+}(aq) \mid Sn(s)$

☒ **C** $Fe(s) \mid Fe^{2+}(aq) \parallel Sn^{2+}(aq) \mid Sn(s)$

☒ **D** $Fe^{2+}(aq) \mid Fe(s) \parallel Sn(s) \mid Sn^{2+}(aq)$

(b) The standard electrode potential for the Fe / Fe^{2+} electrode system is –0.44 V and $E^{\ominus}_{cell}$ for the reaction is +0.30 V.

What is the standard electrode potential for the Sn / Sn^{2+} electrode system?

(1)

☒ **A** –0.74 V

☒ **B** –0.14 V

☒ **C** +0.14 V

☒ **D** +0.74 V

(Total for Question 3 = 2 marks)

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

4 Hydrogen-oxygen fuel cells can operate in acidic or alkaline conditions.

What is the reaction at the anode in an alkaline hydrogen-oxygen fuel cell?

- ☒ **A** $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$
- ☒ **B** $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$
- ☒ **C** $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$
- ☒ **D** $H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$

(Total for Question 4 = 1 mark)

5 Which of these has the greatest number of unpaired electrons in each of its atoms?

- ☒ **A** chromium
- ☒ **B** iron
- ☒ **C** manganese
- ☒ **D** vanadium

(Total for Question 5 = 1 mark)

6 Nickel is classified as a transition metal. This is because nickel

- ☒ **A** is a d block element
- ☒ **B** has partially filled d orbitals
- ☒ **C** forms stable ions with partially filled d orbitals
- ☒ **D** forms stable compounds in which it has different oxidation states

(Total for Question 6 = 1 mark)

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7 Platinum forms a complex with the formula $Pt(NH_3)_2Cl_2$ and chromium forms a complex with the formula $CrCl_4^-$.

(a) What are the shapes of these complexes?

(1)

- ☒ **A** both complexes are square planar
- ☒ **B** both complexes are tetrahedral
- ☒ **C** $Pt(NH_3)_2Cl_2$ is tetrahedral and $CrCl_4^-$ is square planar
- ☒ **D** $Pt(NH_3)_2Cl_2$ is square planar and $CrCl_4^-$ is tetrahedral

(b) What is the bonding between the ligands and the central atom in these complexes?

(1)

- ☒ **A** the bonding in both complexes is ionic
- ☒ **B** the bonding in both complexes is dative covalent
- ☒ **C** the bonding in $Pt(NH_3)_2Cl_2$ is dative covalent and in $CrCl_4^-$ is ionic
- ☒ **D** the bonding in $Pt(NH_3)_2Cl_2$ is ionic and in $CrCl_4^-$ is dative covalent

(Total for Question 7 = 2 marks)

8 Cobalt chloride is used as a test for the presence of water.

This test depends on the fact that

- ☒ **A** anhydrous cobalt(II) chloride is blue and hydrated cobalt(II) chloride is pink
- ☒ **B** anhydrous cobalt(II) chloride is pink and hydrated cobalt(II) chloride is blue
- ☒ **C** cobalt(II) chloride is blue and cobalt(III) chloride is pink
- ☒ **D** cobalt(II) chloride is pink and cobalt(III) chloride is blue

(Total for Question 8 = 1 mark)

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9 Iodide ions are oxidised by peroxodisulfate ions in aqueous solution.

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

This reaction is catalysed by adding Fe^{2+} ions to the solution.

This catalysis is effective because

- ☒ **A** Fe^{2+} reacts with iodide ions and with peroxodisulfate ions
- ☒ **B** Fe^{2+} has many electrons in its outermost subshells
- ☒ **C** Fe^{2+} has many active sites on which the reaction can occur
- ☒ **D** Fe^{2+} is readily oxidised to Fe^{3+} which is then reduced to Fe^{2+}

(Total for Question 9 = 1 mark)

10 The delocalised electrons in benzene result from the overlap of

- ☒ **A** s orbitals to form σ bonds
- ☒ **B** s orbitals to form π bonds
- ☒ **C** p orbitals to form σ bonds
- ☒ **D** p orbitals to form π bonds

(Total for Question 10 = 1 mark)

11 The reaction of ethene with bromine occurs under normal laboratory conditions but the reaction of benzene with bromine to form bromobenzene requires heat and the presence of a catalyst.

The best explanation for the difference in reactivity is that the delocalised electrons in benzene

- ☒ **A** repel electrophiles
- ☒ **B** result in a kinetic barrier to intermediate formation
- ☒ **C** result in benzene having an endothermic enthalpy of formation
- ☒ **D** make benzene thermodynamically stable with respect to the formation of bromobenzene

(Total for Question 11 = 1 mark)

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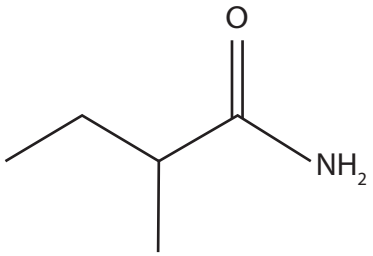
12 What is the name of the compound shown?



- ☒ **A** 1-methylpropanamide
- ☒ **B** 3-methylpropanamide
- ☒ **C** 2-methylbutanamide
- ☒ **D** 3-methylbutanamide

(Total for Question 12 = 1 mark)

13 Separate 0.1 mol dm^{-3} aqueous solutions of ammonia, butylamine and phenylamine were prepared.

Which of the following sequences shows the solutions in order of **increasing** pH?

- ☒ **A** butylamine, phenylamine, ammonia
- ☒ **B** ammonia, butylamine, phenylamine
- ☒ **C** phenylamine, ammonia, butylamine
- ☒ **D** ammonia, phenylamine, butylamine

(Total for Question 13 = 1 mark)

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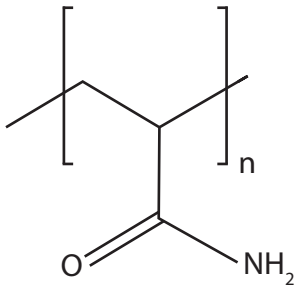
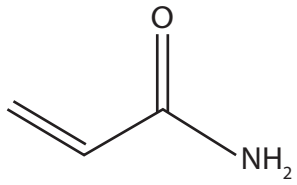
14 The repeat unit of a polymer is shown.

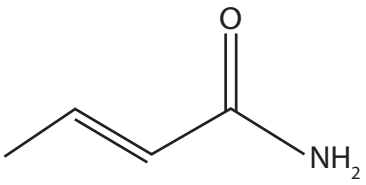


What is the structure of the monomer?

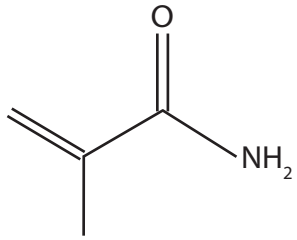
☒ **A**



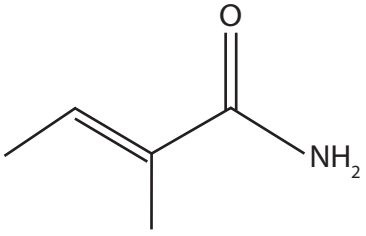
☒ **B**



☒ **C**



☒ **D**



(Total for Question 14 = 1 mark)

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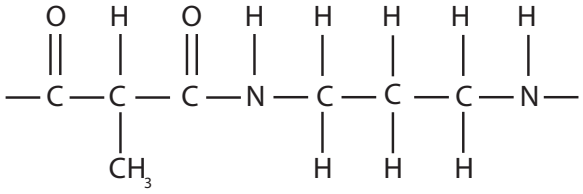
15 The repeat unit of a polymer is shown.

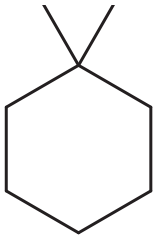


This polymer could be

- ☒ **A** both a polypeptide and a polyamide
- ☒ **B** neither a polypeptide nor a polyamide
- ☒ **C** a polypeptide but not a polyamide
- ☒ **D** a polyamide but not a polypeptide

(Total for Question 15 = 1 mark)

16 The structure of a hydrocarbon is shown.



How many peaks will there be in the ^{13}C NMR spectrum of this compound?

- ☒ **A** four
- ☒ **B** five
- ☒ **C** seven
- ☒ **D** eight

(Total for Question 16 = 1 mark)

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

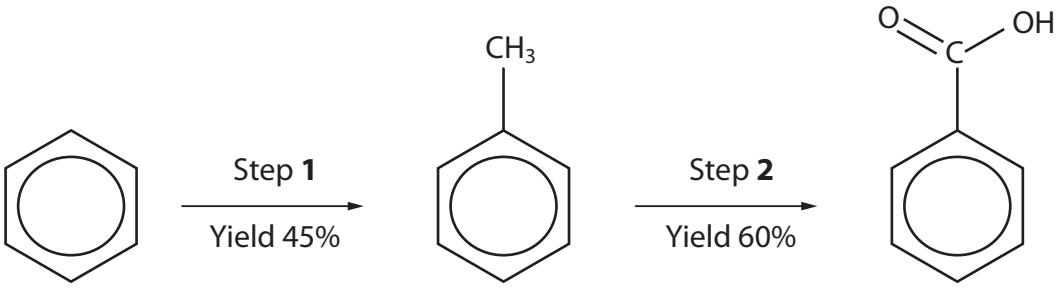
17 When a sample of a hydrocarbon is burned completely in oxygen, 2.64 g of carbon dioxide and 0.81 g of water are formed.

Which of these could be the **molecular** formula of the hydrocarbon?

- ☒ **A** C_2H_3
- ☒ **B** C_4H_3
- ☒ **C** C_4H_6
- ☒ **D** $C_{12}H_9$

(Total for Question 17 = 1 mark)

18 Benzenecarboxylic acid may be produced from benzene in a two-step synthesis.



benzene
$M_r = 78$

methylbenzene
$M_r = 92$

benzenecarboxylic acid
$M_r = 122$

8.24 g of benzenecarboxylic acid was formed in this synthesis.

What mass of benzene was used?

- ☒ **A** 3.48 g
- ☒ **B** 5.27 g
- ☒ **C** 19.51 g
- ☒ **D** 30.52 g

(Total for Question 18 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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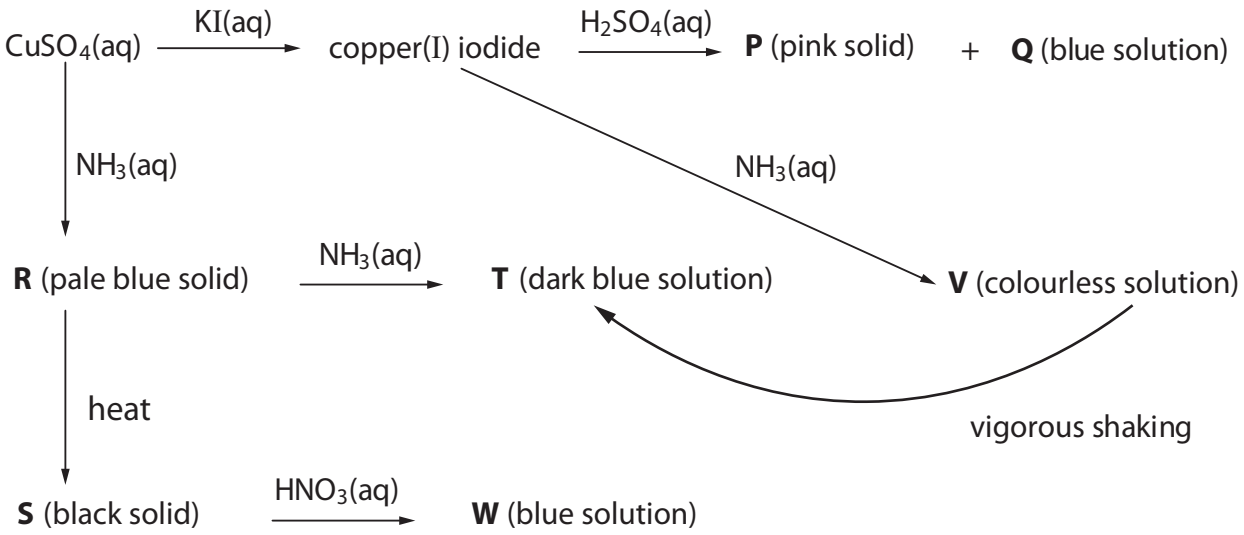
SECTION B

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

19 The diagram summarises some reactions of copper compounds.



(a) Identify, by name (including the oxidation state) or formula, the species in the sequence that contain copper.

(7)

P .....

Q .....

R .....

S .....

T .....

V .....

W .....

(b) **T** and **V** are the same type of chemical species.

(i) Name this type of chemical species.

(1)

.....

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(ii) Explain why **T** is coloured while **V** is colourless.
A detailed explanation of the fact that **T** is coloured is **not** required.

(3)

(iii) Suggest an explanation for the change of **V** into **T** on shaking.

(2)

(c) The reaction between copper(I) iodide and sulfuric acid is a disproportionation.

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

(1)

(ii) Show that the reaction in (c)(i) is thermodynamically feasible.
Use the standard electrode potentials of the relevant half-cells from the Data Booklet.

(2)

(d) The rare mineral mitscherlichite has the chemical formula $K_2CuCl_4 \cdot nH_2O$.

4.26 g of mitscherlichite was dissolved in distilled water and the solution made up to 250.0 cm^3. Excess potassium iodide solution was added to a 25.0 cm^3 portion of this solution and the iodine formed was titrated against a solution of sodium thiosulfate with a concentration of 0.0500 mol dm^{-3}.

This procedure was repeated until concordant results were obtained.
The mean accurate titre was 26.65 cm^3.

The equations for the reactions are

$$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

$$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$$

Calculate the value of n, the number of moles of water of crystallisation per mole of mitscherlichite.

(6)

(Total for Question 19 = 22 marks)

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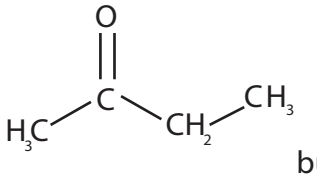
20 Ketones are useful starting compounds in organic synthesis.

This question is about butanone.



butanone

(a) The mass spectrum of butanone has significant peaks at $m/z = 43$ and at $m/z = 57$.

(i) Give the structures of the species responsible for these two peaks.

(2)

(ii) Give the structure of **one** other species that you would expect to produce a peak at a different m/z value in the mass spectrum of butanone.

(1)

(b) Devise a reaction scheme to prepare propan-1-ol from butanone, using no more than **four** steps.

Identify the reagents and essential conditions for each step and give the name or structure of each of the intermediate compounds.

(4)

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(c) Devise a reaction scheme to prepare 2-methylbut-2-ene from butanone, using no more than **four** steps.

Identify the reagents and essential conditions for each step and give the name or structure of each of the intermediate compounds.

(5)

(Total for Question 20 = 12 marks)

21 A yellow crystalline solid **E** dissolved in distilled water to give a yellow solution. Addition of dilute sulfuric acid to this solution produced an orange solution **F**. Warming **F** with ethanol resulted in a green solution **G**, and the formation of ethanal.

A standard cell was set up using solutions of **F** and **G** for the right-hand electrode and ethanol and ethanal for the left-hand electrode.
$E^{\ominus}_{cell}$ was found to be +1.94 V.

$$CH_3CHO(aq) + 2H^+(aq) + 2e^- \rightleftharpoons C_2H_5OH(aq) \quad E^{\ominus} = -0.61\ V$$

(a) Deduce the formulae of the ions responsible for the colours of **F** and **G**, using the standard electrode potential and $E^{\ominus}$ given, and the values in the Data Booklet.

(2)

(b) Write the overall equation for the reaction in the cell.
State symbols are not required.

(2)

(c) Write the ionic equation for the reaction of the aqueous solution of **E** with dilute sulfuric acid. State symbols are not required.

(1)

(Total for Question 21 = 5 marks)

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22 Using excess oxygen, 25 cm^3 of a gaseous hydrocarbon C_xH_y was burned completely.

After cooling to room temperature the total gas volume was measured and found to be 75 cm^3 less than the total gas volume before the mixture was ignited.

When the product gases were shaken with potassium hydroxide solution, the total gas volume decreased by a further 100 cm^3.

All gas volumes were measured at room temperature and pressure.

A general equation for the combustion of a hydrocarbon is

$$C_xH_y + \left(x + \frac{y}{4}\right) O_2 \rightarrow xCO_2 + \left(\frac{y}{2}\right) H_2O$$

(a) Determine the molecular formula of C_xH_y. You **must** show your working.

(3)

(b) When C_xH_y was added to a little bromine water and the mixture shaken, the bromine water remained yellow.

Suggest **two** possible structures for C_xH_y.

(2)

(Total for Question 22 = 5 marks)

*23 Compare and contrast the mechanism of the action of platinum as a catalyst in the removal of pollutants from car engine exhaust fumes with that of vanadium(V) oxide as a catalyst in the Contact Process for the manufacture of sulfuric acid.

General definitions of catalysts are **not** required.

(6)

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(Total for Question 23 = 6 marks)

TOTAL FOR SECTION B = 50 MARKS

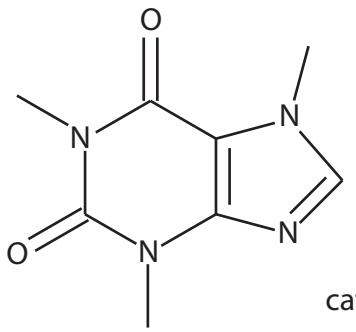
SECTION C

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

Coffee Chemistry

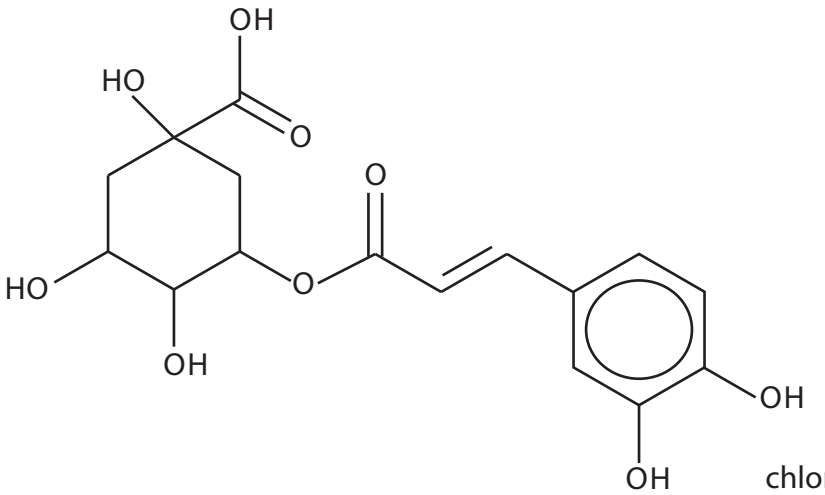
24 There are over a thousand chemical compounds in coffee and their physiological effects are the subject of considerable speculation and research. The verdict on coffee is contradictory: some of the compounds have been identified as toxic and even carcinogenic but others are antioxidants associated with cancer prevention. Recent research has identified compounds in coffee that might be used in the treatment of prostate cancer.

By far the best known compound in coffee is caffeine, the most widely consumed psychoactive drug in the world. In small amounts it is a stimulant but doses in excess of 10 g per day are toxic. Caffeine contains amide and amine groups.



caffeine

Chlorogenic acid is responsible for the acidic taste of coffee. It is an antioxidant and has also been shown to slightly decrease blood pressure.



chlorogenic acid

Caffeic acid, quinic acid and acetoin are also present in coffee.

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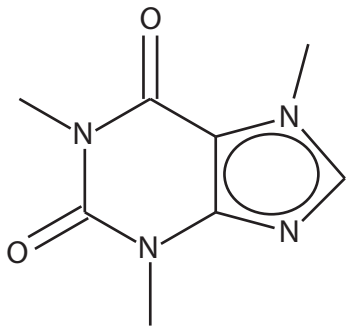
(a) Another way of drawing the structure of caffeine is shown.



(i) The bonding represented by this diagram of caffeine differs from that given in the passage.

Explain what this diagram indicates about the bonding in caffeine, stating the effect on the structure of caffeine.

(3)

(ii) Suggest why caffeine is a much weaker base than a primary amine such as ethylamine, even though the right-hand ring has two amine groups.

(2)

(b) A 200 cm^3 cup of coffee contains approximately 85 mg of caffeine.

(i) Calculate the concentration, in mol dm^{-3}, of caffeine in this cup of coffee. Give your answer to an appropriate number of significant figures.

(4)

(ii) The removal of caffeine from the body is a first order reaction with a half-life of between three and seven hours for an adult.

An adult drinks coffee containing a total of 160 mg of caffeine.

Calculate to the nearest hour the **minimum** time needed for the amount of caffeine in their body to drop to 20 mg.

(2)

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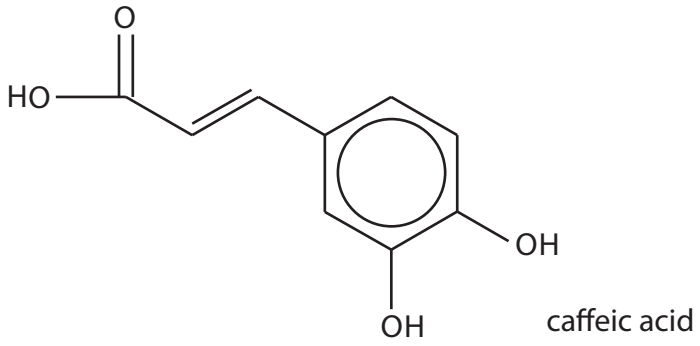
(c) Chlorogenic acid is an ester of caffeic acid, a compound that is present in all plants.



caffeic acid

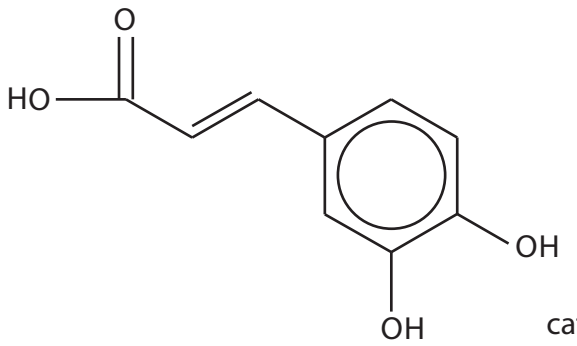
(i) A student suggested that caffeic acid could be synthesised by an electrophilic substitution of 1,2-dihydroxybenzene.

Draw the mechanism of this electrophilic substitution, including the formation of a suitable electrophile.

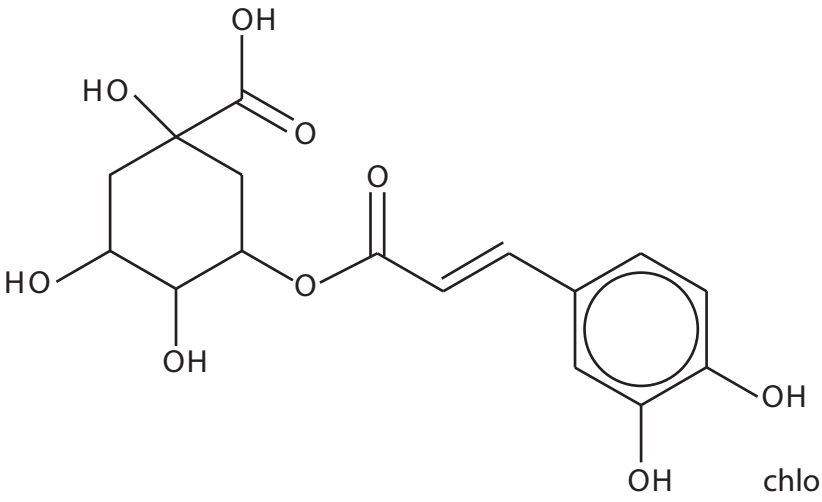
(5)

(ii) Deduce the structure of quinic acid which combines with caffeic acid to form chlorogenic acid.

(1)



caffeic acid



chlorogenic acid

quinic acid

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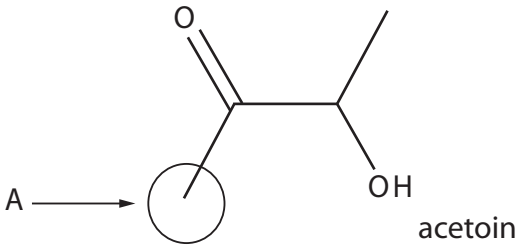
(d) The structure of acetoin is shown with one of the proton environments labelled.



acetoin

(i) Identify the other proton environments of acetoin on the structure and label them B, C etc.

(1)

(ii) Complete the table to show the splitting pattern in the high resolution proton NMR spectrum of acetoin.

(2)

Proton environment	Splitting pattern
A	

(Total for Question 24 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 90 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)											(13)	(14)	(15)	(16)	(17)	
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	(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 radius 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							

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

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

* Lanthanide series

* Actinide 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
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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GradeMax