

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 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 ►

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 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)

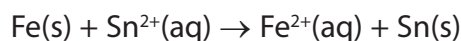
- 2 The standard hydrogen electrode uses an electrode of platinum coated in a finely divided form of the metal called platinum black.

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)

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



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

(1)

- ☐ A $\text{Fe(s)} \mid \text{Fe}^{2+}(\text{aq}) \parallel \text{Sn(s)} \mid \text{Sn}^{2+}(\text{aq})$
- ☐ B $\text{Fe}^{2+}(\text{aq}) \mid \text{Fe(s)} \parallel \text{Sn}^{2+}(\text{aq}) \mid \text{Sn(s)}$
- ☐ C $\text{Fe(s)} \mid \text{Fe}^{2+}(\text{aq}) \parallel \text{Sn}^{2+}(\text{aq}) \mid \text{Sn(s)}$
- ☐ D $\text{Fe}^{2+}(\text{aq}) \mid \text{Fe(s)} \parallel \text{Sn(s)} \mid \text{Sn}^{2+}(\text{aq})$

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

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

(1)

- ☐ A -0.74 V
- ☐ B -0.14 V
- ☐ C $+0.14 \text{ V}$
- ☐ D $+0.74 \text{ V}$

(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 $\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \rightarrow 4\text{OH}^-(\text{aq})$
- ☐ B $4\text{OH}^-(\text{aq}) \rightarrow \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^-$
- ☐ C $2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$
- ☐ D $\text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^-$

(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 $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ 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 $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ is tetrahedral and CrCl_4^- is square planar
- ☐ D $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ 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 $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ is dative covalent and in CrCl_4^- is ionic
- ☐ D the bonding in $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ 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.

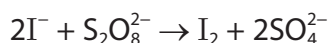
This test depends on the fact that

- ☐ 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.



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)

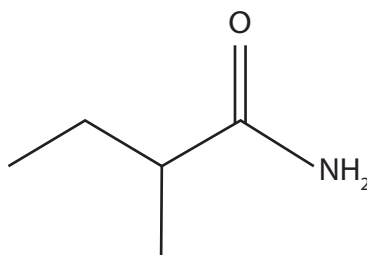
- 11 The reaction of ethene with bromine occurs under normal laboratory conditions but the reaction of benzene with bromine to form bromobenzene requires heat and the presence of a catalyst.

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)

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.

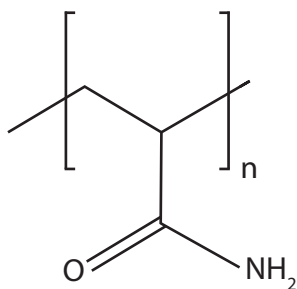
Which of the following sequences shows the solutions in order of **increasing** pH?

- ☐ A butylamine, phenylamine, ammonia
- ☐ B ammonia, butylamine, phenylamine
- ☐ C phenylamine, ammonia, butylamine
- ☐ D ammonia, phenylamine, butylamine

(Total for Question 13 = 1 mark)

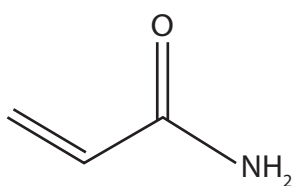
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14 The repeat unit of a polymer is shown.

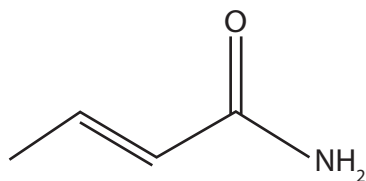


What is the structure of the monomer?

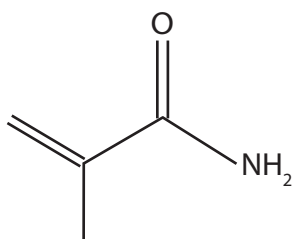
☐ A



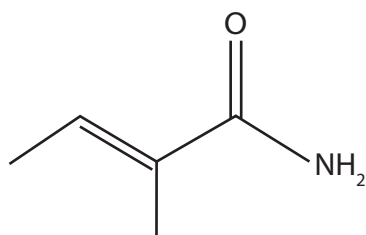
☐ B



☐ C

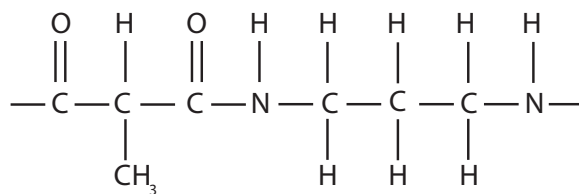


☐ D



(Total for Question 14 = 1 mark)

15 The repeat unit of a polymer is shown.

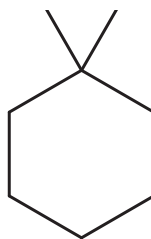


This polymer could be

- ☐ **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)

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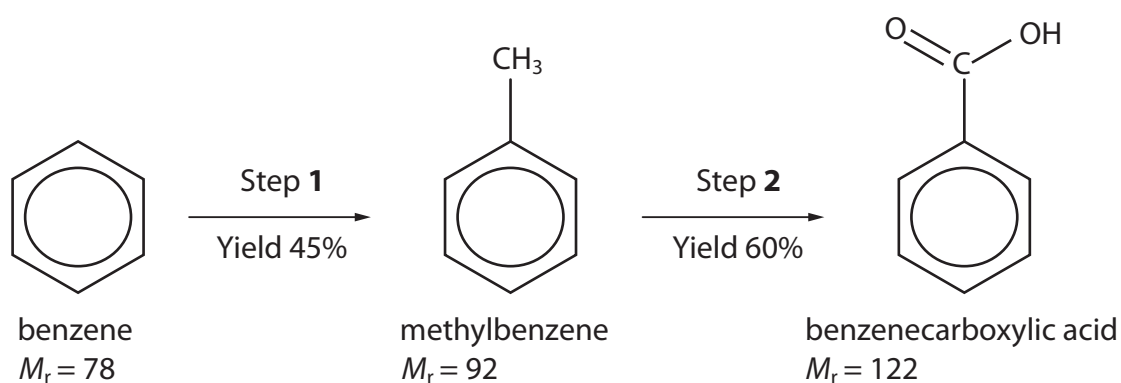
- 17 When a sample of a hydrocarbon is burned completely in oxygen, 2.64 g of carbon dioxide and 0.81 g of water are formed.

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.



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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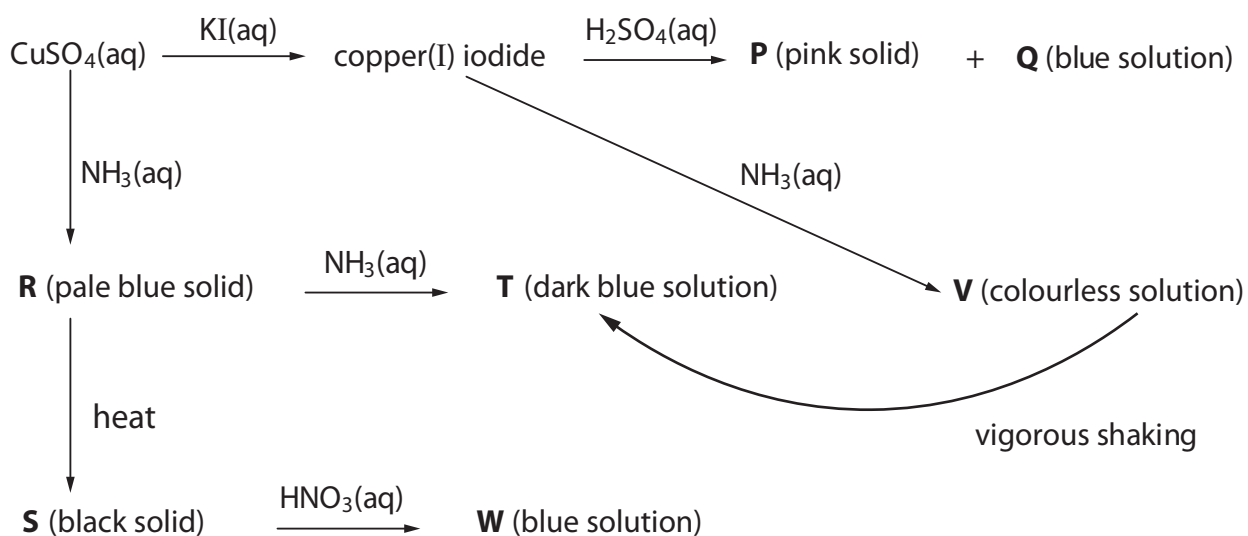
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SECTION B

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)

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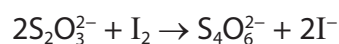
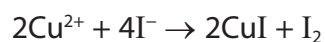
(d) The rare mineral mitscherlichite has the chemical formula $\text{K}_2\text{CuCl}_4 \cdot n\text{H}_2\text{O}$.

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 $0.0500 \text{ mol dm}^{-3}$.

This procedure was repeated until concordant results were obtained.

The mean accurate titre was 26.65 cm^3 .

The equations for the reactions are

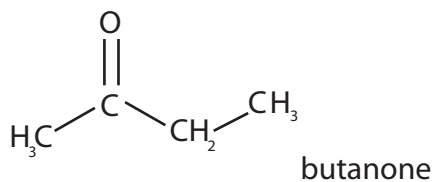


Calculate the value of n , the number of moles of water of crystallisation per mole of mitscherlichite.

(6)

20 Ketones are useful starting compounds in organic synthesis.

This question is about 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)

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(4)

- (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)

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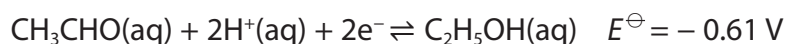
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(Total for Question 20 = 12 marks)

- 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.

$E_{\text{cell}}^{\ominus}$ was found to be +1.94 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)

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- (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)

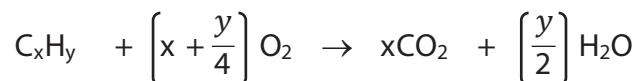
22 Using excess oxygen, 25 cm³ of a gaseous hydrocarbon C_xH_y was burned completely.

After cooling to room temperature the total gas volume was measured and found to be 75 cm³ 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 cm³.

All gas volumes were measured at room temperature and pressure.

A general equation for the combustion of a hydrocarbon is



(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)

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- *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)

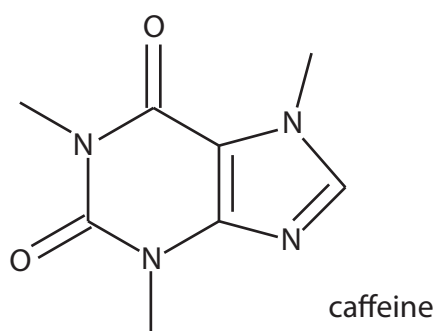
SECTION C

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

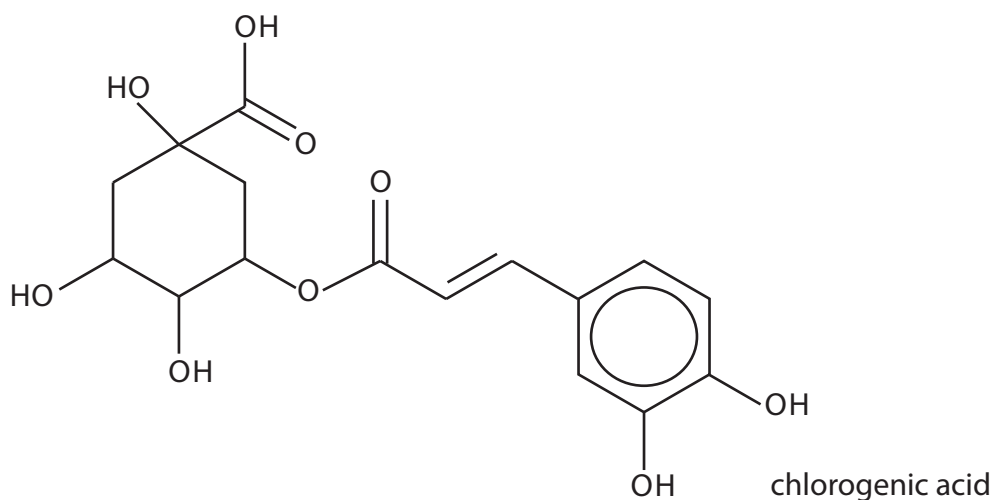
Coffee Chemistry

- 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.

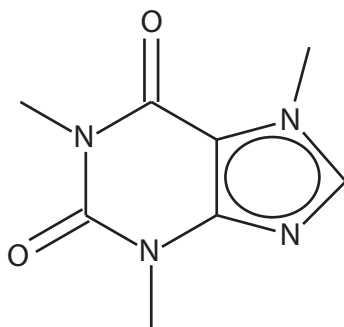


Chlorogenic acid is responsible for the acidic taste of coffee. It is an antioxidant and has also been shown to slightly decrease blood pressure.



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

(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)

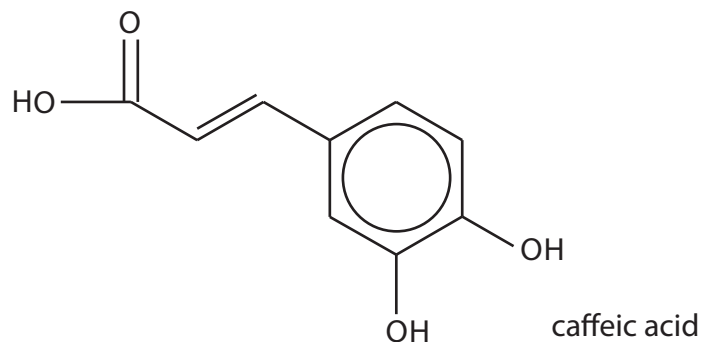
- (ii) The removal of caffeine from the body is a first order reaction with a half-life of between three and seven hours for an adult.

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)

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



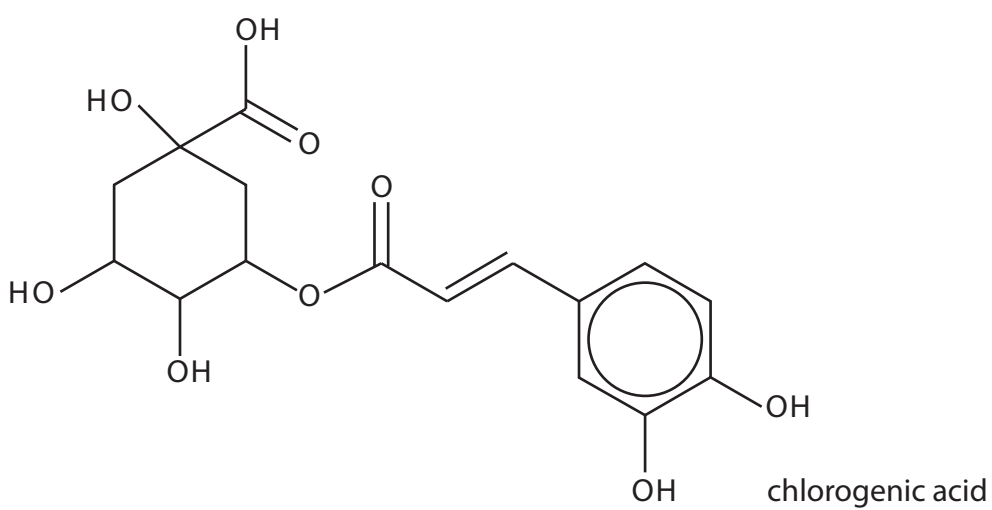
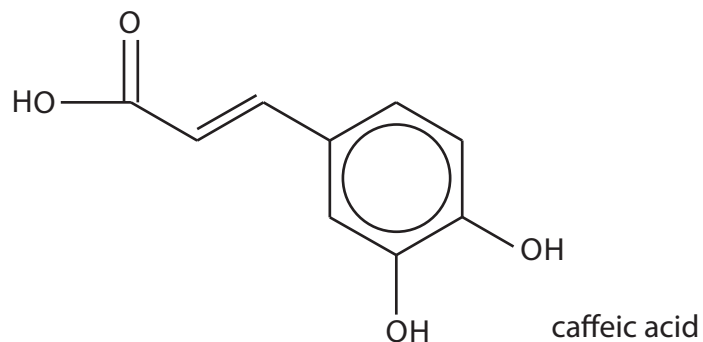
- (i) A student suggested that caffeic acid could be synthesised by an electrophilic substitution of 1,2-dihydroxybenzene.

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

(5)

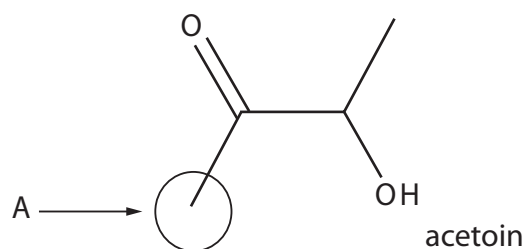
- (ii) Deduce the structure of quinic acid which combines with caffeic acid to form chlorogenic acid.

(1)



quinic acid

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



- (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)

1.0

H

hydrogen

1

Key

relative atomic mass

atomic symbol

name

atomic (proton) number

1

2

3

4

5

6

7

8

9

0

Li

lithium

3

6.9

Be

beryllium

4

9.0

B

boron

5

10.8

C

carbon

6

12.0

N

nitrogen

7

14.0

O

oxygen

8

16.0

F

fluorine

9

19.0

Ne

neon

10

20.2

Na

sodium

11

23.0

Mg

magnesium

12

24.3

Al

aluminium

13

27.0

Si

silicon

14

28.1

P

phosphorus

15

31.0

S

sulfur

16

32.1

Cl

chlorine

17

35.5

Ar

argon

18

39.9

K

potassium

19

39.1

Ca

calcium

20

40.1

Sc

scandium

21

45.0

Ti

titanium

22

47.9

V

vanadium

23

50.9

Cr

chromium

24

52.0

Mn

manganese

25

54.9

Fe

iron

26

55.8

Co

cobalt

27

58.9

Ni

nickel

28

58.7

Cu

copper

29

63.5

Zn

zinc

30

65.4

Ga

gallium

31

69.7

Ge

germanium

32

72.6

As

arsenic

33

74.9

Se

selenium

34

79.0

Br

bromine

35

79.9

Kr

krypton

36

83.8

Rb

rubidium

37

85.5

Sr

strontium

38

87.6

Y

yttrium

39

88.9

Zr

zirconium

40

91.2

Nb

niobium

41

92.9

Mo

molybdenum

42

95.9

Tc

technetium

43

[98]

Ru

ruthenium

44

101.1

Rh

rhodium

45

102.9

Pd

palladium

46

106.4

Ag

silver

47

107.9

Cd

cadmium

48

112.4

In

indium

49

114.8

Sn

tin

50

118.7

Sb

antimony

51

121.8

Te

tellurium

52

127.6

I

iodine

53

126.9

Xe

xenon

54

131.3

Cs

cesium

55

132.9

Ba

barium

56

137.3

La*

lanthanum

57

138.9

Hf

hafnium

72

178.5

Ta

tantalum

73

180.9

W

tungsten

74

183.8

Re

rhenium

75

186.2

Os

osmium

76

190.2

Ir

iridium

77

192.2

Pt

platinum

78

195.1

Au

gold

79

197.0

Hg

mercury

80

200.6

Tl

thallium

81

204.4

Pb

lead

82

207.2

Bi

bismuth

83

209.0

Po

polonium

84

[209]

At

astatine

85

[210]

Rn

radon

86

[222]

Fr

francium

87

[223]

Ra

radium

88

[226]

Ac*

actinium

89

[227]

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

Rg

roentgenium

111

[272]

Ds

darmstadtium

110

[271]

Mt

meitnerium

109

[268]

Hs

hassium

108

[277]

Bh

bohrium

107

[264]

Sg

seaborgium

106

[266]

Db

dubnium

105

[262]

Rf

rutherfordium

104

[261]

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	euroium	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