Oxford Cambridge and RSA

Tuesday 4 June 2019 – Afternoon

A Level Chemistry B (Salters)

H433/01 Fundamentals of Chemistry

Time allowed: 2 hours 15 minutes

You must have:
- the Data Sheet for Chemistry B (Salters) (sent with general stationery)

You may use:
- a scientific or graphical calculator

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION
- The total mark for this paper is **110**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **36** pages.

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SECTION A

You should spend a maximum of 40 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

1 Which statement about an atom of ^{23}Na is correct?

A It is an isomer of sodium.

B It has an atomic number of 23.

C It has 12 neutrons in its nucleus.

D It has a mass number of 11.

Your answer ☐ **[1]**

2 A solution of salt **X** gives a green precipitate with sodium hydroxide solution.

What is **X**?

A Iron(II) chloride

B Iron(III) sulfate

C Barium chloride

D Barium sulfate

Your answer ☐ **[1]**

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3 In which row of the table does the formula match the systematic name and the homologous series?

	Formula	Systematic name	Homologous series
A	C_6H_{12}	cyclohexane	cycloalkane
B	$C_5H_{11}OH$	pentan-1-ol	aldehyde
C	C_3H_6	prop-1-ene	alkane
D	C_7H_{16}	septane	alkane

Your answer ☐ **[1]**

4 What is a principle of green chemistry?

A Heating a reaction to speed it up

B Improving the atom economy of a process

C Disposing of waste efficiently

D Using organic solvents

Your answer ☐ **[1]**

5 Which equation is correct?

A $C_4H_8 + 5O_2 \rightarrow 3CO_2 + CO + 4H_2O$

B $C_2H_5OH + 3\frac{1}{2}O_2 \rightarrow 2CO_2 + 3H_2O$

C $C_2H_4 + 3\frac{1}{2}O_2 \rightarrow 2CO_2 + 2H_2O$

D $C_8H_{18} + 12\frac{1}{2}O_2 \rightarrow 8CO_2 + 9H_2O$

Your answer ☐ **[1]**

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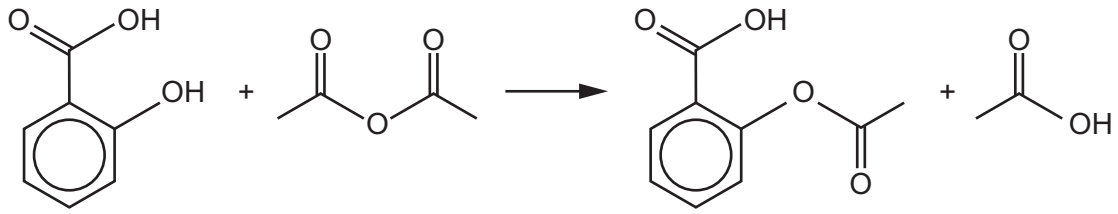
6 Aspirin is synthesised by the reaction below.



M_r 138 M_r 102

What is the atom economy of this reaction for producing aspirin?

A 25%

B 43%

C 50%

D 75%

Your answer ☐ **[1]**

7 Which substance in the table has a giant ionic structure?

Substance	Melting point	Solubility in water	Electrical conductivity
A	High	Insoluble	Conducts when solid or molten
B	High	Insoluble	None
C	Low	Soluble	None
D	High	Soluble	Conducts when molten or in solution

Your answer ☐ **[1]**

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8 The steps involved in measuring the concentration of a coloured solution with a colorimeter are given below in a random order.

1. Measure the absorbance of several known concentrations of the solution.

2. Measure the absorbance of the sample of unknown concentration.

3. Plot a calibration curve.

4. Select a suitable coloured filter.

What is the correct order for these steps?

A 1, 2, 3, 4

B 4, 3, 2, 1

C 4, 1, 3, 2

D 3, 1, 4, 2

Your answer ☐ **[1]**

9 Which row of the table is correct?

	Formula	**Systematic name**
A	$NaClO$	sodium chlorate(I)
B	CuS	copper(I) sulfide
C	$NaIO_3$	sodium iodate(III)
D	HNO_2	nitrous acid

Your answer ☐ **[1]**

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10 The abundance of various gases in the air is shown in the table.

Gas	Abundance (by volume)
N_2	78%
CO_2	3.7×10^{-2}%
CH_4	1.8 ppm

Which statement about the table is correct?

A There is roughly 200 times as much nitrogen as carbon dioxide.

B The abundance of nitrogen is 7.8×10^4 ppm.

C There is roughly 200 times as much CO_2 as CH_4.

D The abundance of CO_2 is 0.0037%.

Your answer ☐ **[1]**

11 The relative rates of hydrolysis of chloropropane and iodopropane are compared.

Which statement is correct?

A Chloropropane hydrolyses faster because the C–C*l* bond is more polar than C–I.

B Chloropropane hydrolyses faster because the C–C*l* bond is weaker than C–I.

C Iodopropane hydrolyses faster because the C–I bond is weaker than C–C*l*.

D Iodopropane hydrolyses faster because the C–I bond is more polar than C–C*l*.

Your answer ☐ **[1]**

12 Which statement about the manufacture of methanol is correct?

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta_r H = -91\,kJ\,mol^{-1}$$

A The best yield of methanol is obtained at high temperature.

B A catalyst increases the yield of methanol.

C The pressure used is limited by the cost of energy and machinery.

D The best yield of methanol is obtained at low pressure.

Your answer ☐ **[1]**

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13 Which reaction does **not** occur?

A $C_6H_5COOH + NaOH \rightarrow C_6H_5COONa + H_2O$

B $C_6H_5OH + NaOH \rightarrow C_6H_5ONa + H_2O$

C $2C_6H_5COOH + CaCO_3 \rightarrow (C_6H_5COO)_2Ca + CO_2 + H_2O$

D $2C_6H_5OH + Na_2CO_3 \rightarrow 2C_6H_5ONa + CO_2 + H_2O$

Your answer ☐ **[1]**

14 What occurs as Group 2 is descended?

A There is a greater attraction between Group 2 cations and Cl^- ions.

B The hydration enthalpies of the Group 2 cations become less negative.

C The charge density of the Group 2 cations increases.

D The lattice enthalpies of the sulfates become more negative.

Your answer ☐ **[1]**

15 Which statement about enzyme catalysed reactions is correct?

A The rate determining step is always the formation of an enzyme substrate complex.

B They always speed up at higher temperatures.

C The rate equation can vary depending on the substrate concentration.

D They are zero order with respect to enzyme concentration.

Your answer ☐ **[1]**

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16 Entropy values for the combustion of propane are shown below.

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

Substance	Entropy / J K^{-1} mol^{-1}
$C_3H_8(g)$	+269.9
$O_2(g)$	+205.0
$CO_2(g)$	+213.6
$H_2O(g)$	+188.7

What is the entropy change for the combustion of propane?

A –829.6

B –72.6

C +100.7

D +1125.7

Your answer ☐ **[1]**

17 Excess ammonia solution is added separately to $Cu^{2+}(aq)$ and $Fe^{2+}(aq)$.
The solutions are left in the air.

Which row of the table represents the colour changes seen?

	$Cu^{2+}(aq)$	$Fe^{2+}(aq)$
A	Pale blue precipitate → dark blue solution	Dark green precipitate → orange precipitate
B	Green/blue solution → dark blue solution	Green precipitate remaining green
C	Pale blue precipitate → green/blue solution	Orange precipitate → dark green precipitate
D	Pale blue precipitate → dark blue solution	Orange precipitate → dark green precipitate

Your answer ☐ **[1]**

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18 A vinegar contains 5.0 g of ethanoic acid in each 100 cm^3 of solution and no other acids.

What is the pH of this vinegar?

For ethanoic acid $K_a = 1.7 \times 10^{-5}$ mol dm^{-3}, $M_r = 60$

A 2.42

B 2.92

C 5.85

D 6.73

Your answer ☐ **[1]**

19 When all the water is driven off from 11.89 g of $NiCl_2 \cdot xH_2O$, the residue weighs 6.49 g.

What is the value of *x*?

A 2

B 3

C 4

D 6

Your answer ☐ **[1]**

20 A student adds 10 cm^3 of water to 12 cm^3 of a 0.010 mol dm^{-3} solution.

What is the resulting concentration in mol dm^{-3}?

A 0.0045

B 0.0055

C 0.0083

D 0.018

Your answer ☐ **[1]**

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21 Sodium carbonate and hydrochloric acid react as follows.

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$

0.010 mol of Na_2CO_3 is mixed with 0.015 mol of HCl.

What volume of CO_2 is formed (in cm^3 at RTP)?

A 180

B 240

C 360

D 720

Your answer ☐ **[1]**

22 Which statement about the greenhouse effect is correct?

A UV radiation from the Sun increases the vibrational energy of greenhouse gases.

B The Earth absorbs UV radiation and emits IR radiation.

C Greenhouse gases absorb UV radiation from the Earth.

D All gases in the atmosphere contribute to the greenhouse effect.

Your answer ☐ **[1]**

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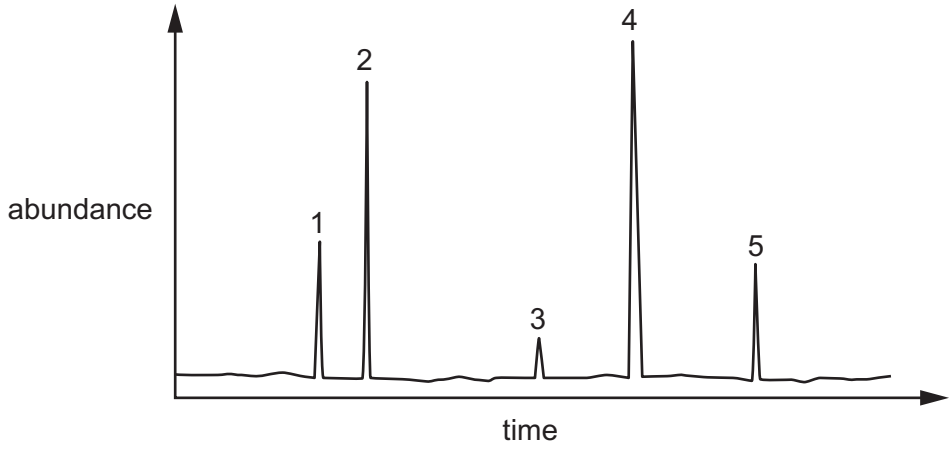
23 The diagram below shows a gas chromatogram.



Which statement about the gas chromatogram is correct?

A The mixture consisted of at least 5 different substances.

B Substance 5 came out of the column first.

C Substance 1 had the greatest affinity for the stationary phase.

D Substance 5 had the greatest affinity for the mobile phase.

Your answer ☐ **[1]**

24 The reaction for the formation of sulfur trioxide is shown below.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

60 cm^3 of sulfur dioxide are mixed with 60 cm^3 of oxygen and allowed to reach equilibrium.

What is a possible equilibrium mixture from this reaction?

	Volume SO_2 / cm^3	**Volume O_2 / cm^3**	**Volume SO_3 / cm^3**
A	0	0	120
B	50	55	10
C	48	54	18
D	20	30	40

Your answer ☐ **[1]**

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25 The solubility product of magnesium hydroxide, $Mg(OH)_2$, is 2.00×10^{-11} $mol^3 dm^{-9}$.

What is the solubility of magnesium hydroxide, in mol dm^{-3}?

A 3.16×10^{-6}

B 4.47×10^{-6}

C 1.71×10^{-4}

D 2.71×10^{-4}

Your answer ☐ **[1]**

26 0.125 mol of CuO is reacted with excess sulfuric acid and the solution allowed to crystallise.

What mass of hydrated copper sulfate, $CuSO_4 \cdot 5H_2O$, is formed if the yield is 75.0%?

A 15.0 g

B 20.0 g

C 23.4 g

D 31.2 g

Your answer ☐ **[1]**

27 A reaction that occurs during the production of bromine in some industrial plants is shown below.

$Br_2(aq) + SO_2(g) + 2H_2O(l) \longrightarrow 2HBr(aq) + H_2SO_4(aq)$

Which statement about this reaction is correct?

A Bromine is oxidised.

B Sulfur ends in oxidation state +4.

C The mixture becomes less acidic during the reaction.

D Bromide ions are formed.

Your answer ☐ **[1]**

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28 Which type(s) of radiation can break covalent bonds?

1 IR

2 UV

3 visible

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

29 Which statement(s) is/are correct about the active site of an enzyme?

1 It is formed by the tertiary structure of a protein.

2 It changes shape at high temperature.

3 It has the same shape as the substrate.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

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30 Which statement(s) is/are correct about amino acids?

1 They all have a chiral centre.

2 They form buffer solutions in aqueous solution.

3 They form crystalline solids.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

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SECTION B

Answer **all** the questions.

31 Ammonia is made by the reaction shown in **equation 31.1**.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta_r H = -92\,kJ\,mol^{-1}$ **Equation 31.1**

(a) The reaction can be allowed to reach dynamic equilibrium.

Explain what is meant by **dynamic equilibrium**.

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..... **[2]**

(b) At a certain temperature, the equilibrium constant, K_c, for the reaction in **equation 31.1** is $3.0\,dm^6\,mol^{-2}$.

In an equilibrium mixture, the concentrations of nitrogen and hydrogen are as shown below.

Gas	Equilibrium concentration / mol dm^{-3}
Nitrogen	2.0
Hydrogen	1.6

Calculate the concentration of ammonia in the equilibrium mixture.

concentration of ammonia = ... mol dm^{-3} **[3]**

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(c) A Chemist says the process would be more efficient if the ammonia produced is continuously liquefied and removed from the reaction vessel.

Comment on the Chemist's suggestion using ideas of equilibrium and the equilibrium constant.

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..... **[2]**

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(d) Some of the ammonia is converted to nitric acid in the sequence of reactions shown below:

$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \quad \Delta_r H = -905\,kJ\,mol^{-1}$ **Equation 31.2**

$2NO(g) + O_2(g) \rightarrow 2NO_2(g) \quad \Delta_r H = -114\,kJ\,mol^{-1}$ **Equation 31.3**

$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g) \quad \Delta_r H = -117\,kJ\,mol^{-1}$ **Equation 31.4**

(i)* A student considers the operating conditions for the reaction in **equation 31.2**.

The student recommends a **pressure** just greater than the pressure of the atmosphere and a **temperature** of 500 K in the presence of a platinum **catalyst**.

Comment on this choice of conditions. **[6]**

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Additional answer space if required

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(ii) Give the sign of ΔS_{sys} in **equation 31.3**, with a reason.

Use this to explain whether the reaction becomes more or less feasible at higher temperatures.

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..... **[3]**

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32 DNA carries the instructions for synthesising the primary structures of protein molecules.
Its backbone consists of alternating phosphate and deoxyribose sugar units. Bases are attached to the sugar units.

(a) Use the Data Sheet to draw a section of DNA.

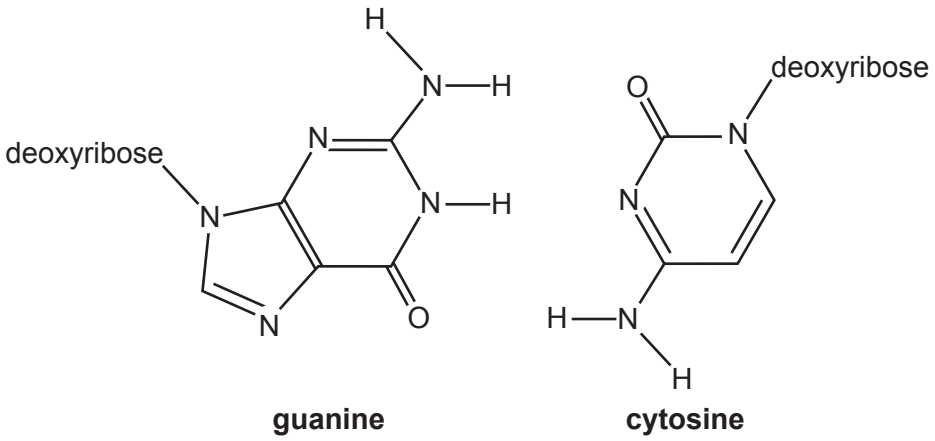
The section of DNA must consist of two phosphate units, one deoxyribose sugar unit and one thymine unit, all joined by condensation reactions.

[3]

(b) The double helix of DNA is formed by the bases pairing using hydrogen bonds.

Complete the diagram to show all the hydrogen bonds between guanine and cytosine.

Show the relevant lone pairs and partial charges.



[3]

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(c) The sequence of bases in DNA determines the primary structure of the protein synthesised.

Draw the structural formula for a section of a protein molecule formed from one each of the amino acids shown in **Fig. 32.1**.

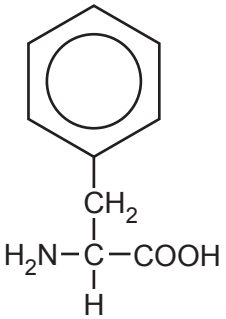
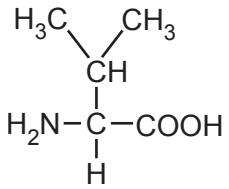
Phenylalanine	**Valine**
	

Fig. 32.1

[2]

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(d)* An HIV protease enzyme acts on the protein substrate shown in **Fig. 32.2**.

Protein substrate

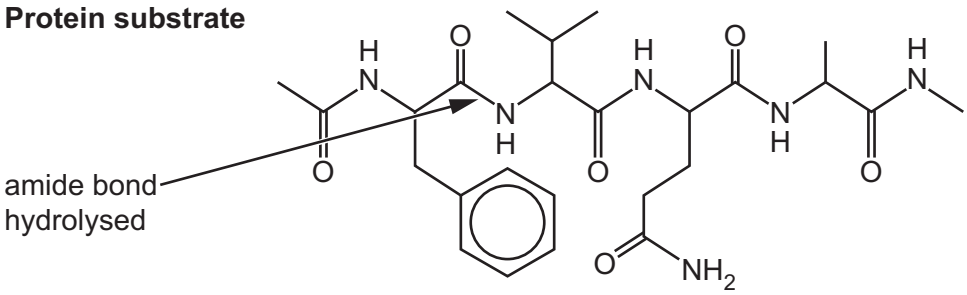

Fig. 32.2

The substrate in **Fig. 32.3** acts as an inhibitor to the HIV protease enzyme.

HIV protease inhibitor

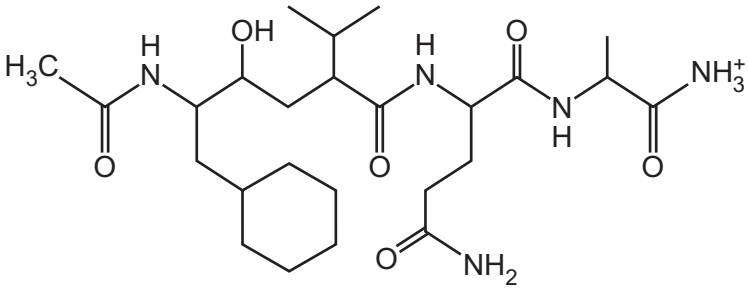

Fig. 32.3

Explain how an enzyme works and suggest how the HIV protease inhibitor affects the function of the protease enzyme. **[6]**

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Additional answer space if required

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33 Ozone in the stratosphere causes the absorption of UV radiation.

(a) When ozone absorbs UV radiation the following reaction occurs:

$$O_3 \xrightarrow{h\nu} O_2 + O$$

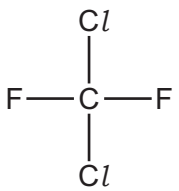
This reaction is one that absorbs the harmful UV radiation that causes sunburn.
One wavelength in this radiation is 330 nm.

Calculate the bond enthalpy of the bond broken in ozone by this wavelength.
($1\,nm = 1 \times 10^{-9}\,m$)

bond enthalpy = ...kJ mol^{-1} **[3]**

(b) The natural reactions involving ozone in the atmosphere are disrupted by the presence of chlorine radicals from CFCs, for example CCl_2F_2.

Show, by means of curly arrows, the formation of a chlorine radical from the molecule below.



Name the type of bond breaking. ..... **[1]**

(c) Some reactions involved in the depletion of ozone by CFCs are shown in the table below.

Classify each of these reactions as initiation, propagation or termination, by ticking the appropriate columns in the table.

Reaction	Initiation	Propagation	Termination
$CCl_2F_2 \rightarrow CClF_2 + Cl$			
$Cl + O_3 \rightarrow ClO + O_2$			
$ClO + O \rightarrow Cl + O_2$			
$Cl + Cl \rightarrow Cl_2$			

[2]

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(d) Ozone in the stratosphere is at a pressure of 1100 Pa and a temperature of –20 °C.

(i) Calculate the amount in moles of ozone in 1.5 dm^3 of ozone from the stratosphere.

amount of ozone = ...mol **[2]**

(ii) Calculate the volume (in cm^3) that this number of moles would occupy on the surface of the Earth where the pressure is 97 kPa and the temperature is 298 K.

Give your answer to an **appropriate** number of significant figures.

volume of ozone = ... cm^3 **[2]**

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(e) Nitrogen monoxide, NO, is formed in a car engine and it is converted to nitrogen dioxide.

Ozone is formed by the action of sunlight on nitrogen dioxide.

Ozone in the troposphere is a pollutant and can cause photochemical smog.

(i) Explain how nitrogen monoxide forms in a car engine.

.....

..... **[2]**

(ii) Describe the appearance of the atmosphere as nitrogen monoxide is converted to nitrogen dioxide.

..... **[1]**

(f) One of the products of the reaction of ozone with unburned fuel from car exhausts is $(CH_3)_3CCH_2CH(CH_3)CHO$.

(i) Name the functional group in $(CH_3)_3CCH_2CH(CH_3)CHO$.

..... **[1]**

(ii) Give the equation for the reaction of HCN with the functional group identified in **(f)(i)**.

[1]

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34 Over the years, Chemists have investigated the origins of the elements and how life on Earth began.

(a) Helium is formed in the Sun by fusion reactions.

Complete the nuclear equations below to show how helium is formed.

$$\text{.....}^{2}\text{H} + \text{.....}^{1}\text{H} \rightarrow \text{.....}^{3}\text{He} + \chi$$

$$\text{.....}^{3}\text{He} + \text{.....}^{3}\text{He} \rightarrow \text{.....}^{4}\text{He} + \text{.....} + \text{.....}$$

[2]

(b) There is a theory that the molecules of life were formed from elements made in stars. These molecules came to Earth from space on comets.

Recent analysis of comets has found compounds including methylamine.

Draw a 'dot-and-cross' diagram for methylamine, CH_3NH_2.

Label two **different** bond angles.

[3]

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(c) Another theory is that life developed near hot vents deep under the sea. At these hot vents geothermally heated water rich in minerals emerges from the ocean floor.

Bacteria evolve and synthesise carbohydrates using hydrogen sulfide from the hot vent. These bacteria then form the basis of food chains for organisms such as tube worms.

$12H_2S + 6CO_2 \rightarrow C_6H_{12}O_6 + 6H_2O + 12S \quad \Delta_r H = -379.9\,kJ\,mol^{-1}$ **Equation 34.1**

Use the data in the table to find the enthalpy change of formation of glucose, $C_6H_{12}O_6$.

Substance	$\Delta_f H$ / **kJ mol^{-1}**
H_2S	–20.6
CO_2	–393.5
H_2O	–285.8
S	0

$\Delta_f H$ $C_6H_{12}O_6$ = ...kJ mol^{-1} **[3]**

(d) Analysis of water from a hot vent showed a variety of other minerals dissolved from the Earth's crust, such as copper chloride.

Give the electronic configuration of the chloride ion, using subshells and atomic orbitals.

..... **[1]**

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(e) Two students want to find the concentration of Cu^{2+} ions in some seawater from near a hot vent.

They use a titration method involving potassium iodide and sodium thiosulfate.

The potassium iodide is oxidised to iodine by the Cu^{2+} ions and the liberated iodine is titrated with sodium thiosulfate of known concentration.

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

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

(i) Name a suitable indicator the students should use and give the expected colour change observed.

Indicator .....

Colour change observed ..... **[1]**

(ii) The students are supplied with 0.020 mol dm^{-3} sodium thiosulfate. The students add excess potassium iodide to 50 cm^3 of the seawater and titrate with the sodium thiosulfate.

They find that their mean titre is only 0.95 cm^3 of sodium thiosulfate solution.

Use the students' results to calculate the concentration of Cu^{2+} ions in milligrams per dm^3 of seawater.

concentration = ... mg dm^{-3} **[3]**

(iii) Calculate the percentage uncertainty in a titre of 0.95 cm^3.

percentage uncertainty = ... % **[1]**

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(iv) What could the students do to reduce this percentage uncertainty to around 0.5%?

Describe their experimental method.

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..... **[2]**

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35 Some students have two isomeric compounds **A** and **B** with the molecular formula $C_9H_{10}O$. They are both used in the perfume industry.

The students do some tests to find out which functional groups are present.

(a) They look at the formulae and decide that the molecules are probably unsaturated due to the low proportion of hydrogen.

They test each compound with bromine water.

Both compounds **A** and **B** show a positive result with bromine water.

Describe the colour **change** the students would see in the reaction.

..... **[1]**

(b) They then decide that the molecules could be aromatic.

What does aromatic mean?

..... **[1]**

(c) Compound **A** contains a phenol group.

How do the students identify the phenol group?

Test .....

Expected result ..... **[1]**

(d) The students suspect that compound **B** contains an alcohol group and they want to find out what type of alcohol it is. They decide to see if compound **B** can be oxidised and if so whether the product is an aldehyde or a ketone.

They find that compound **B** is a primary alcohol.

(i) Fill in the table to show the reagents, conditions and colour changes for their tests.

	Reagent(s)	**Conditions**	**Colour change**
Oxidation of alcohol			
Identification of aldehyde or ketone			

[3]

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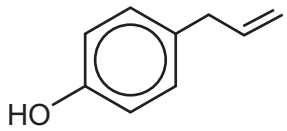
(ii) Draw a **skeletal** formula for the **unsaturated** aromatic compound **B**.

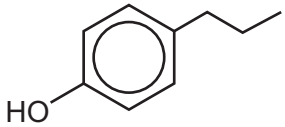
[1]

(e) The students are told that the structure of compound **A** is as shown below.



Other organic products can be made from compound **A**.

(i) Give the reagent and conditions to convert compound **A** into the compound shown below.



Reagent .....

Conditions ..... **[1]**

(ii) The students want to make the ethanoate ester of compound **A**.

Give the equation for a reaction to do this.
Use structural formulae for the organic molecules.

[2]

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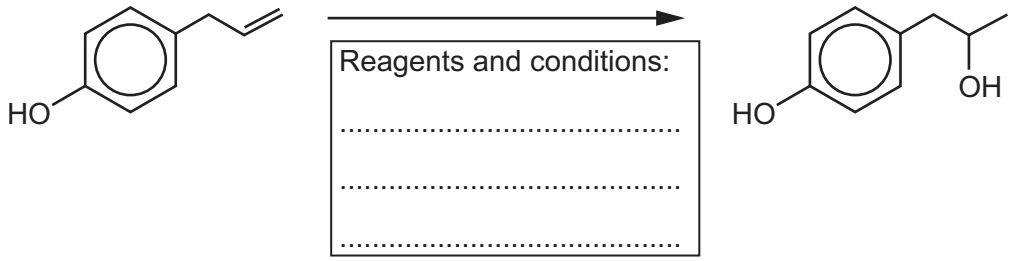
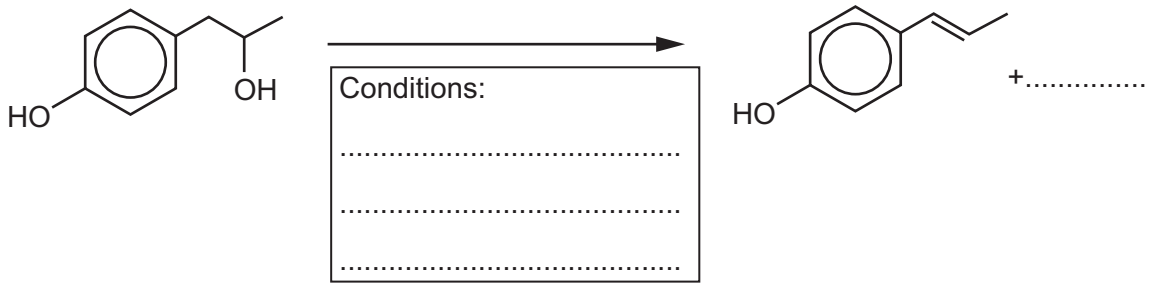
(f) One of the students suggests the method below to change the position of the double bond on the side chain in two steps.





(i) Complete the reaction sequence by writing on the dotted lines. **[2]**

(ii) Comment on the student's method of changing the position of the double bond.

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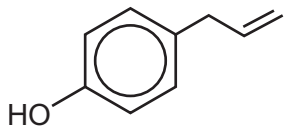
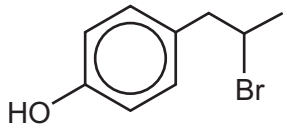
..... **[2]**

(g) Compound **A** is repeated below.



compound **A**

Hydrogen bromide reacts with compound **A** to give the compound shown below.



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(i) Show the mechanism of the reaction of compound **A** with hydrogen bromide.

Use curly arrows and partial and full charges where appropriate.

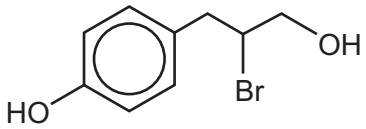
[2]

(ii) Compound **A** is reacted with aqueous hydrogen bromide containing dissolved sodium chloride.

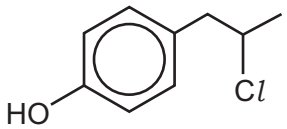
A student suggests that the products shown below are formed in addition to the product in part **(i)**.

Comment on whether the student's suggestions are correct, giving the chemistry involved.

Product 1



Product 2



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..... **[3]**

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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