Oxford Cambridge and RSA

Monday 13 June 2022 – Morning

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

You can use:
- a scientific or graphical calculator
- an HB pencil

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 can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

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

ADVICE
- Read each question carefully before you start your answer.

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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 feature of the structure of the atom was deduced from the Geiger and Marsden experiment?

A Atoms consist of electrons, protons and neutrons.

B The nucleus is small and dense.

C Electrons exist in energy levels/shells.

D Electrons exist in atomic orbitals.

Your answer ☐ **[1]**

2 Which row gives the correct trends for the following properties of Group 2 elements and compounds going down the Group?

	First ionisation enthalpy of element	**Thermal stability of carbonate**
A	Increases	Increases
B	Increases	Decreases
C	Decreases	Increases
D	Decreases	Decreases

Your answer ☐ **[1]**

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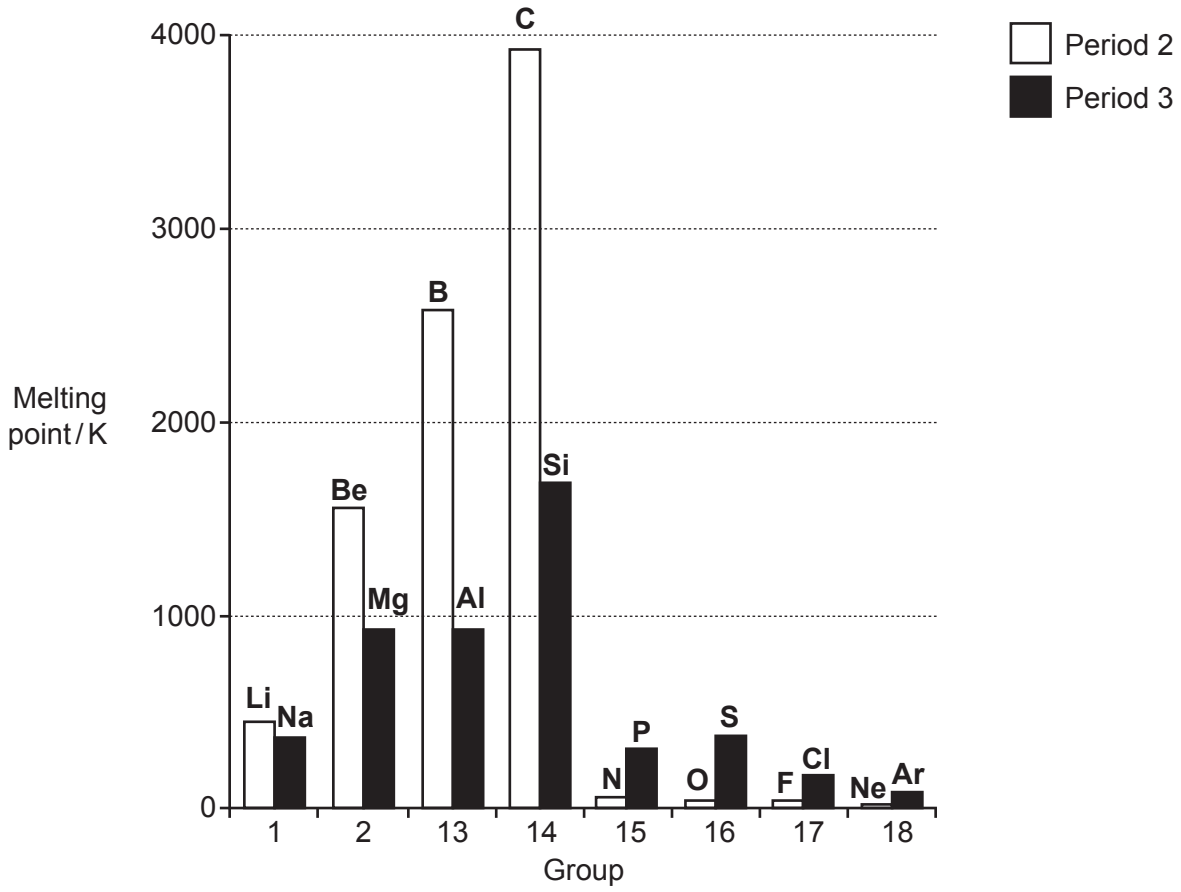
3 The bar chart shows the melting points of the elements in Periods 2 and 3.
What is the correct reason for the large decrease in melting point after Group 14 in both Periods?



A The bonding of the elements changes from metallic to covalent.

B The elements change from metals to non-metals.

C The structure and bonding of the elements change from ionic to simple molecular.

D The structure of the elements changes from giant to molecular.

Your answer ☐ **[1]**

4 What is the correct bond angle in the ammonia molecule?

A 90°

B 107°

C 109°

D 120°

Your answer ☐ **[1]**

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5 In which of the following reactions is iodine oxidised?

A $2Na + I_2 \rightarrow 2NaI$

B $I_2 + 2e^- \rightarrow 2I^-$

C $I_2 + 2At^- \rightarrow At_2 + 2I^-$

D $I_2 + F_2 \rightarrow 2IF$

Your answer ☐ **[1]**

6 Which mixture forms a buffer solution?

A A mixture of a strong acid and a strong base

B A mixture of a strong acid with its salt

C A mixture of a strong base with its salt

D A mixture of a weak acid with its salt

Your answer ☐ **[1]**

7 What is correct about the greenhouse effect?

A Carbon dioxide is the only gas in the troposphere that acts as a greenhouse gas.

B Infrared radiation breaks bonds in molecules in the troposphere.

C The main way that the Earth is heated is by infrared radiation from the Sun.

D The Earth emits infrared radiation.

Your answer ☐ **[1]**

8 What is correct about nitrogen chemistry?

A The ammonia molecule has a lone pair of electrons.

B The ammonium ion has a bond angle of 120°.

C The ammonium ion has four dative covalent bonds.

D The nitrogen molecule has a double bond.

Your answer ☐ **[1]**

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9 Which row is correct?

	$Cu^{2+}(aq) + NaOH(aq)$	$Cu^{2+}(aq) + NH_3(aq)$
A	Blue precipitate soluble in excess NaOH(aq)	Blue precipitate insoluble in excess $NH_3(aq)$
B	Blue precipitate insoluble in excess NaOH(aq)	Blue precipitate insoluble in excess $NH_3(aq)$
C	Blue precipitate soluble in excess NaOH(aq)	Blue precipitate soluble in excess $NH_3(aq)$
D	Blue precipitate insoluble in excess NaOH(aq)	Blue precipitate soluble in excess $NH_3(aq)$

Your answer ☐ **[1]**

10 Ammonia is manufactured using the process shown in **Equation 10.1**.

A high pressure and moderate temperature are used.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92\,kJ\,mol^{-1}$ **Equation 10.1**

What is correct about this manufacturing process?

A Creating a high pressure is expensive and dangerous.

B If the process were attempted at room temperature it would be quicker but give less ammonia.

C The nitrogen gas is expensive.

D The process is beneficial to society because it removes nitrogen from the air.

Your answer ☐ **[1]**

11 Which of the following alcohols **cannot** undergo dehydration?

A $CH_3CH_2CH_2CH_2OH$

B $(CH_3)_2CHCH_2OH$

C $(CH_3)_3COH$

D $CH_3CH(OH)CH_2CH_3$

Your answer ☐ **[1]**

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12 Which equation represents the first ionisation enthalpy of phosphorus?

A $P(l) \rightarrow P^+(g) + e^-$

B $P(s) \rightarrow P^+(s) + e^-$

C $P(s) \rightarrow P^+(g) + e^-$

D $P(g) \rightarrow P^+(g) + e^-$

Your answer ☐ **[1]**

13 Predict which row is correct for selenium, Se.

	melting point / °C	**Structure**	**Bonding**
A	217	Simple molecular	Covalent
B	1026	Giant	Metallic
C	–101	Simple molecular	Covalent
D	–157	Atomic	Instantaneous dipole-induced dipole

Your answer ☐ **[1]**

14 What is the correct order of boiling points?

A $CH_3CH_2COOH > CH_3CH_2CH_2OH > CH_3CH_2CHO$

B $CH_3CH_2COOH > CH_3CH_2CHO > CH_3CH_2CH_2OH$

C $CH_3CH_2CH_2OH > CH_3CH_2COOH > CH_3CH_2CHO$

D $CH_3CH_2CHO > CH_3CH_2COOH > CH_3CH_2CH_2OH$

Your answer ☐ **[1]**

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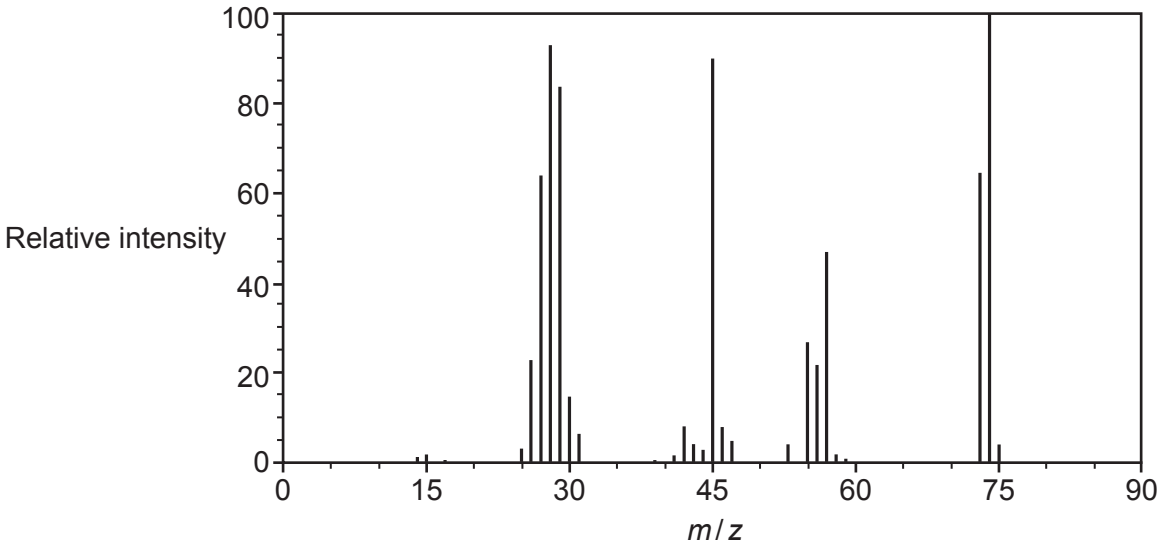
15 What is the correct M_r value of the organic molecule whose mass spectrum is shown below?



A 75

B 74

C 45

D 28

Your answer ☐ **[1]**

16 What is correct about the linking of DNA strands?

A Adenine forms three hydrogen bonds with thymine.

B Guanine forms three hydrogen bonds with cytosine.

C Guanine forms two hydrogen bonds with adenine.

D Uracil forms two hydrogen bonds with adenine.

Your answer ☐ **[1]**

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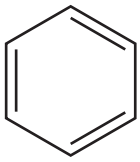
17 The Kekulé structure of benzene (C_6H_6) is shown below.



What is a correct statement about benzene if the Kekulé structure represented the actual structure and bonding in benzene?

A The molecule would have a regular hexagonal shape.

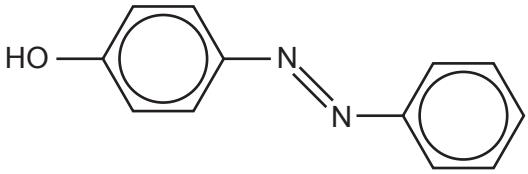
B The molecule would undergo electrophilic substitution reactions.

C The molecule would form several different compounds of formula $C_6H_4Br_2$.

D The molecule would decolorise bromine water.

Your answer ☐ **[1]**

18 A dye molecule is shown below.



What is correct about this dye molecule?

A Delocalisation extends over the whole dye molecule.

B The dye molecule will attach itself to fibres mainly by covalent bonds.

C Substitution of CH_3 groups onto a ring will increase the solubility of the dye in water.

D Substitution of NO_2 groups onto a ring will not affect the chromophore.

Your answer ☐ **[1]**

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19 What is correct about a 0.1 mol dm^{-3} solution of a strong base?

A $[OH^-] << 0.1\,mol\,dm^{-3}$.

B The solution is weaker than a 0.5 mol dm^{-3} solution of the same base.

C The pH of the solution is given by $pH = 14 + \log_{10}(0.1)$ at 298 K.

D The solution will not react with weak acids.

Your answer ☐ **[1]**

20 GCC is a mRNA triplet code for alanine.

What is correct?

A Alanine has a transfer RNA with the code CGG.

B GCC is the only code for alanine.

C Other amino acids as well as alanine are coded by GCC.

D The mRNA sequence is produced by GCC on a DNA strand.

Your answer ☐ **[1]**

21 In the absence of water the following reaction occurs.

$$CH_3COOH + H_2SO_4 \rightarrow CH_3C(OH)_2^+ + HSO_4^-$$

What is correct about this reaction?

A CH_3COOH is a proton donor.

B CH_3COOH is acting as a base.

C $CH_3C(OH)_2^+$ is the conjugate base of CH_3COOH.

D HSO_4^- is the conjugate acid of H_2SO_4.

Your answer ☐ **[1]**

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22 What is correct?

A A 0.10 mol dm^{-3} solution of a strong acid has a pH of 2.

B A 0.10 mol dm^{-3} solution of a strong base has a pH of 14.

C A 0.10 mol dm^{-3} solution of an acid with $K_a = 1.0 \times 10^{-5}$ mol dm^{-3} has a pH of 3.

D A half-neutralised solution of a weak acid has pH = 0.5 pK_a.

Your answer ☐ **[1]**

23 10 cm^3 of 0.10 mol dm^{-3} HC*l*(aq) is added to 5 cm^3 of 0.10 mol dm^{-3} NaOH(aq).

What is the pH of the resulting solution?

A 1.0

B 1.2

C 1.3

D 1.5

Your answer ☐ **[1]**

24 Ethanoic acid is a weak acid and hydrochloric acid is a strong acid.

What is correct about 10 cm^3 of 0.1 mol dm^{-3} solutions of each acid?

A They both fizz at the same rate with equal sized pieces of magnesium.

B They both fizz at the same rate with equal sized pieces of $CaCO_3$.

C They both have the same effect on pH indicator paper.

D They both neutralise 10 cm^3 of 0.1 mol dm^{-3} NaOH(aq).

Your answer ☐ **[1]**

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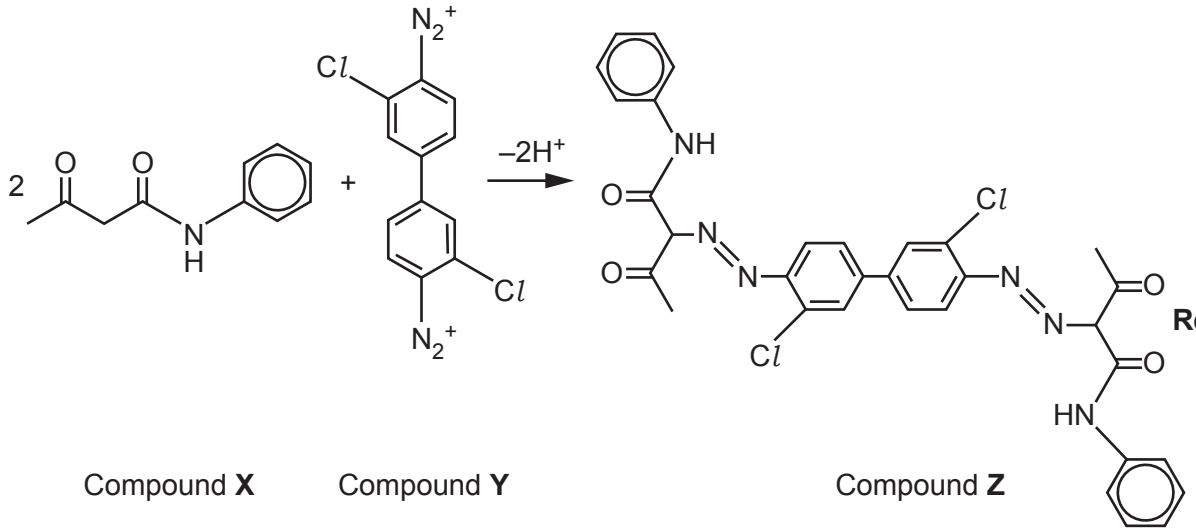
25 The formation of an azo dye is shown in **Reaction 25.1** below.

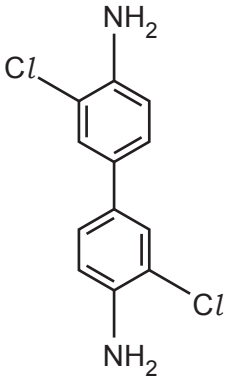


Reaction 25.1

Compound **X** Compound **Y** Compound **Z**

What is correct about this reaction and the compounds involved?

A Compound **Y** can be formed by a diazotisation reaction on the compound below.



B **Reaction 25.1** is a coupling reaction between diazonium groups and NH groups.

C **Reaction 25.1** is an addition reaction.

D **Reaction 25.1** needs cold HNO_2.

Your answer ☐ **[1]**

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26 Manganate(VII) ions react with sulfate(IV) ions as shown in the **unbalanced** equation below.

$MnO_4^-(aq) + SO_3^{2-}(aq) + H^+(aq) \rightarrow Mn^{2+}(aq) + SO_4^{2-}(aq) + H_2O(l)$

What is the ratio of $SO_4^{2-}(aq) : H_2O(l)$ in the balanced equation?

A 1:1

B 1:3

C 3:4

D 5:3

Your answer ☐ **[1]**

27 Iodine is formed from iodide ions by reaction with copper(II) ions as shown in the following ionic equation.

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

The iodine formed can be titrated with sodium thiosulfate as shown in the following ionic equation.

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

25.0 cm^3 of a copper(II) solution forms iodine that reacts with 22.5 cm^3 of 1.50×10^{-2} mol dm^{-3} sodium thiosulfate solution.

What is the concentration of copper(II) ions (in mol dm^{-3}) in the solution?

A 3.38×10^{-4}

B 6.75×10^{-3}

C 1.35×10^{-2}

D 2.70×10^{-2}

Your answer ☐ **[1]**

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28 Which statement(s) is/are correct about an orange dye?

1 Blue light is absorbed when electrons rise to higher energy levels.

2 Orange light is emitted when electrons drop to lower energy levels.

3 The dye absorbs orange light.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

29 Two half-cell equations are shown with their standard electrode potentials.

$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$ $E^{\ominus} = -0.26\,V$

$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$ $E^{\ominus} = +0.34\,V$

Which statement(s) is/are correct?

1 A solution of V^{3+} will change into V^{2+} and VO^{2+}.

2 The cell made from these two half-cells has an $E^{\ominus}_{cell}$ value of 0.60 V.

3 $VO^{2+}(aq)$ will not oxidise $V^{2+}(aq)$ unless acid is present.

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 nitrogen chemistry?

1 Ammonium compounds give off ammonia when warmed with alkalis.

2 The oxide N_2O is brown.

3 Nitrate(V) ions can be oxidised to nitrate(III) ions.

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 Bromine is currently extracted from the Dead Sea.

(a) Bromine is made from the sodium bromide present in sea water.

Complete the table showing the structure, bonding and properties of bromine and sodium bromide.

Substance	Structure	Bonding	Melting point	Electrical conductivity in liquid state
Bromine	simple molecules			poor
Sodium bromide			high	

[2]

(b) The extraction process for bromine involves bubbling chlorine gas through sea water.

The equation for the reaction is shown below.

$2Br^-(aq) + Cl_2(g) \rightarrow Br_2(aq) + 2Cl^-(aq)$

Explain in terms of electrons why chlorine can displace bromine from bromide ions.

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

(c) Bromine can also be produced by the electrolysis of aqueous sodium bromide.

Write the ionic half-equation for the production of bromine at the anode.

[1]

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(d) A solution contains 2.57 g dm^{-3} of sodium bromide.

Calculate the minimum volume of chlorine gas (in cm^3) required at 20 °C and 101 kPa to displace all the bromine from 100 cm^3 of this solution.

$2Br^-(aq) + Cl_2(g) \rightarrow Br_2(aq) + 2Cl^-(aq)$

volume = ... cm^3 **[4]**

(e) Three test-tubes, labelled as **A**, **B** and **C**, contain solutions of sodium chloride, sodium bromide and sodium iodide but not necessarily in that order.
A student adds an equal volume of silver nitrate solution to each tube.

Tubes **A** and **B** both give precipitates that are not white but are not clearly distinguishable from each other. Tube **C** gives a white precipitate.

(i) Write an ionic equation for the reaction that has occurred in tube **C**.

Show state symbols.

[1]

(ii) Describe what the student would do to the precipitates to distinguish between the halide ions in tubes **A** and **B**.

State the expected results.

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

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(f) Another student tries to prepare a sample of pure hydrogen bromide by adding concentrated sulfuric acid to solid sodium bromide. A brown vapour is produced as well as fumes of HBr.

(i) Write an equation to show why a brown vapour is produced when hydrogen bromide reacts with sulfuric acid.

[1]

(ii) State how the student can produce pure hydrogen bromide.

.....

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

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32 The Montreal Protocol was established to phase out ozone-depleting CFCs. CFC molecules contain carbon, fluorine and chlorine atoms only. When CFCs reach the stratosphere they decompose, releasing atoms that cause ozone to break down.

(a) A student says that when CFCs decompose they release F atoms. This is because the C–F bond is more polar than the C–C*l* bond and breaks more easily.

Comment on the statements made by the student. Give and explain the correct chemistry where necessary.

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

(b) Nitrogen oxides from aircraft exhausts can also play a part in ozone depletion.

Nitrogen dioxide undergoes photodissociation by homolytic bond fission according to the following equation.

$NO_2(g) \longrightarrow NO(g) + O(g)$

Photodissociation occurs with ultraviolet radiation with a wavelength of 3.96×10^{-7} m.

Calculate the enthalpy of the N–O bond (in $kJ\,mol^{-1}$) that breaks in NO_2.

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

enthalpy of N–O bond = ... $kJ\,mol^{-1}$ **[4]**

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(c) The NO radical can act as a homogeneous catalyst in a catalytic cycle that depletes ozone.

(i) Explain what is meant by the term **homogeneous** as applied to a catalyst.

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

(ii) The NO radical depletes ozone in a catalytic cycle.
The first reaction in the cycle is shown below.

Suggest an equation to complete the cycle.

$NO + O_3 \rightarrow NO_2 + O_2$

[1]

(iii) Explain how a catalyst increases the rate of a reaction.

.....

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

(d) Radical reactions are also important in making haloalkanes.

The reaction between methane and chlorine to make chloromethane occurs according to the following equation:

$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ **Reaction 32.1**

The product mixture is also found to contain other compounds, including small amounts of a chloroalkane **D** with M_r = 85 and a hydrocarbon **E** with M_r = 30.

(i) Identify the compounds **D** and **E**.

D is ..... **E** is ..... **[1]**

(ii) Use your knowledge of the stages of the mechanism of **Reaction 32.1** to suggest equations showing how **D** and **E** are formed.

[3]

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33 Parabens are used as antifungal preservatives in cosmetic products like shaving gel. Parabens are esters of 4-hydroxybenzoic acid, HOC_6H_4COOH (4-HBA).

4-HBA is a white solid.

(a) The antifungal properties of parabens are linked to their solubility in fats (esters of propane-1,2,3-triol).

Suggest the intermolecular bonds that cause parabens (esters of 4-HBA) to be soluble in fats.

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

(b) A student shakes some 4-HBA with sodium hydroxide solution.

A reaction occurs forming a soluble product.

Write the equation for the reaction of solid 4-HBA, HOC_6H_4COOH, with excess sodium hydroxide solution.

Show state symbols.

[2]

(c) The student places some aqueous sodium carbonate into a test-tube and adds small quantities of 4-HBA.

(i) Describe **two** things that the student would observe.

1 .....

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2 .....

.....

[1]

(ii) Write a formula for the organic product that is formed when 4-HBA reacts with aqueous sodium carbonate.

[1]

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(d) The student prepares an impure sample of ethyl paraben by reacting 4-HBA with ethanol.

Describe how the student could purify the ethyl paraben.

You should make use of the solubility data for ethyl paraben in **Table 33.1** below.

Solvent	Solubility in solvent at room temperature	Solubility in solvent when hot
Water	Insoluble	Slightly soluble
Propanone	Very slightly soluble	Moderately soluble
Ethanol	Very slightly soluble	Very soluble

Table 33.1

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..... **[5]**

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(e) 4-HBA reacts with thionyl chloride to make HOC_6H_4COCl.

(i) Give the name of the functional group $COCl$ that is formed in this reaction.

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

(ii) Give the structural formula of the aromatic product formed in the reaction between HOC_6H_4COCl and CH_3NH_2.

[1]

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34 Methanol is an important alcohol that can be used for making various plastics and it can also be used as a fuel. It can be produced industrially by reacting carbon monoxide with hydrogen according to the equilibrium in **Equation 34.1**.

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ $\Delta H = -91\,kJ\,mol^{-1}$ **Equation 34.1**

(a) Student **F** says that dynamic equilibrium is reached when the forward and back reactions are still occurring and the concentrations of the reactants and products are equal.

Student **G** says that equilibrium is reached when the forward and back reactions have stopped.

Evaluate these two statements giving correct chemistry where necessary.

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

(b) **(i)** Write the expression for the equilibrium constant K_c for the reaction in **Equation 34.1**.

$K_c =$

[1]

(ii) The value of K_c at 657 K is $4.75 \times 10^3\,dm^6\,mol^{-2}$.

The reaction in **Equation 34.1** is carried out at 657 K in a flask of volume $9.40 \times 10^3\,cm^3$.

An equilibrium mixture is found to contain 0.452 mol of CO and 0.273 mol CH_3OH.

Calculate the amount (in mol) of H_2 in this equilibrium mixture.

amount of H_2 = ... mol **[4]**

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(c)* The most economic operating conditions for the manufacture of methanol are a temperature of 525 K and a pressure of 40 atm with a copper-based catalyst.

Discuss these conditions.

Use the principles of equilibrium and rates of reaction and give the supporting chemistry.

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..... **[6]**

Additional answer space if required

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(d) Another important industrial process is the one that produces hydrogen from methane as shown in **Equation 34.2**.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\,kJ\,mol^{-1}$$ **Equation 34.2**

(i) State and explain the sign of $\Delta_{sys}S$ for the reaction in **Equation 34.2**.

.....

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

(ii) Calculate the temperature (in K) at which the reaction in **Equation 34.2** is just feasible.

You should make use of the data in **Table 34.1** below.

Substance	**$\Delta S°$/J K^{-1} mol^{-1}**
$CH_4(g)$	+186.2
$H_2O(g)$	+188.7
$CO(g)$	+197.6
$H_2(g)$	+130.7

Table 34.1

temperature = ... K **[4]**

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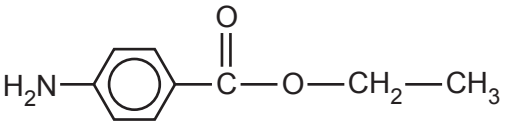
35 Benzocaine is a local anaesthetic used to relieve toothache.

Benzocaine has the following structure:



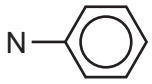
benzocaine

(a) Local anaesthetics work by binding to certain receptors in cells in order to inhibit pain.

Name the part of a molecule that binds to a receptor in a cell in the body.

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

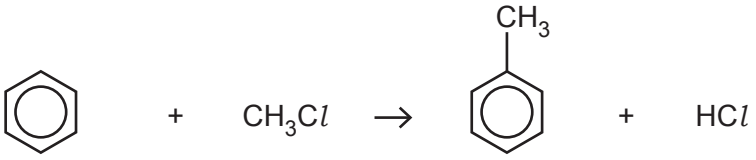
(b) Complete the diagram below to show the molecular shape around the nitrogen atom in the part of benzocaine shown. Use lines and wedges as appropriate.



[1]

(c) A synthesis of benzocaine occurs in several stages.

A first step involves the conversion of benzene into methylbenzene as shown in the equation below:



The benzene is heated with chloromethane and aluminium(III) chloride as a catalyst in anhydrous conditions.

(i) Explain why this reaction must be carried out in anhydrous conditions.

.....

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

(ii) Name the mechanism of the reaction involved in this first step.

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

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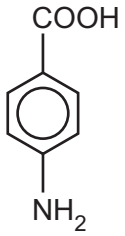
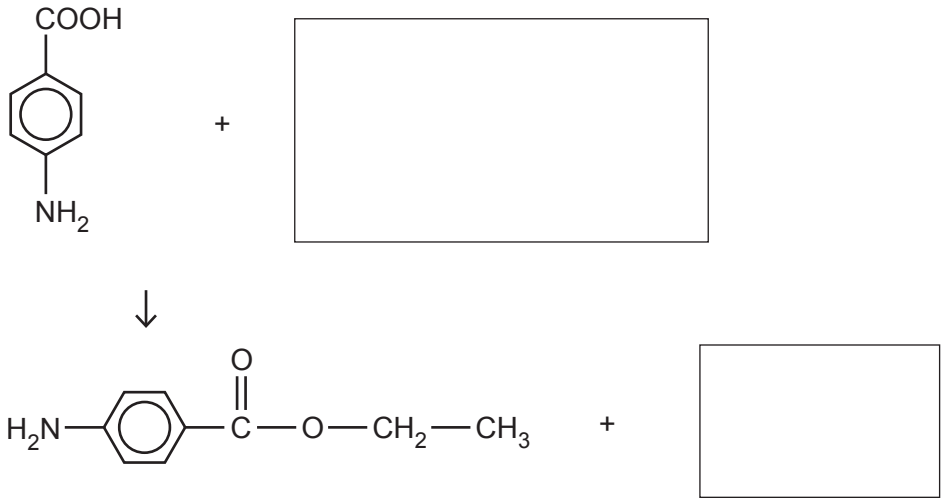
(d) Further reactions are then carried out to convert methylbenzene into 4-aminobenzoic acid.



4-aminobenzoic acid

Complete the following equation to show a synthesis of benzocaine from 4-aminobenzoic acid.



[2]

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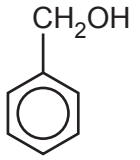
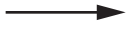
(e) An alternative route to 4-aminobenzoic acid involves the following three-step reaction sequence.

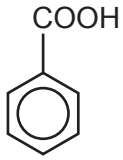


phenylmethanol

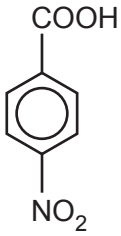


benzoic acid

Step 1

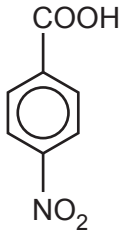


benzoic acid

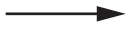


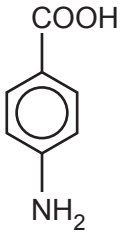
4-nitrobenzoic acid

Step 2



4-nitrobenzoic acid





4-aminobenzoic acid

Step 3

(i) Give the reagents and conditions that a student could use to bring about the reaction in **Step 1**.

.....

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

(ii) The conversion in **Step 1** occurs through the intermediate formation of benzaldehyde.

benzaldehyde

Describe a test-tube reaction that a student could carry out to test for the aldehyde group in benzaldehyde.

.....

.....

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

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(iii) The reaction of benzaldehyde with hydrogen cyanide can be written as follows:

$C_6H_5CHO + HCN \rightarrow C_6H_5CH(OH)CN$

Write out the two-step mechanism for this reaction.

Use 'curly arrows' and partial and full charges.

[3]

(iv) In **Step 2**, the benzoic acid is reacted with a nitrating mixture of concentrated nitric and concentrated sulfuric acids.

Write an equation to show the formation of the electrophile in this reaction.

[1]

(v) The conversion in **Step 3** is brought about by heating 4-nitrobenzoic acid with tin and concentrated hydrochloric acid under reflux.

Explain why the heating is carried out under reflux.

.....

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

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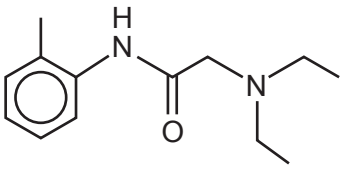
(f) The skeletal formula for another local anaesthetic, lidocaine, is shown below.



lidocaine

Draw the skeletal formulae of the two products formed from the alkaline hydrolysis of the amide group in lidocaine.

Product 1

Product 2

[2]

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Question 35 continues on page 34

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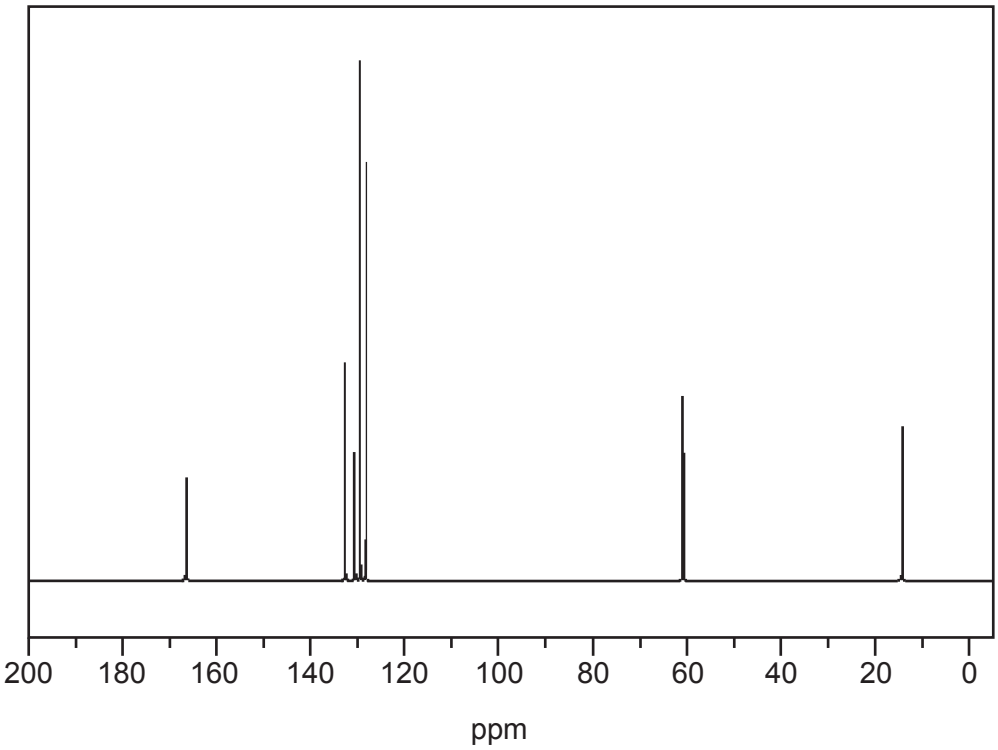
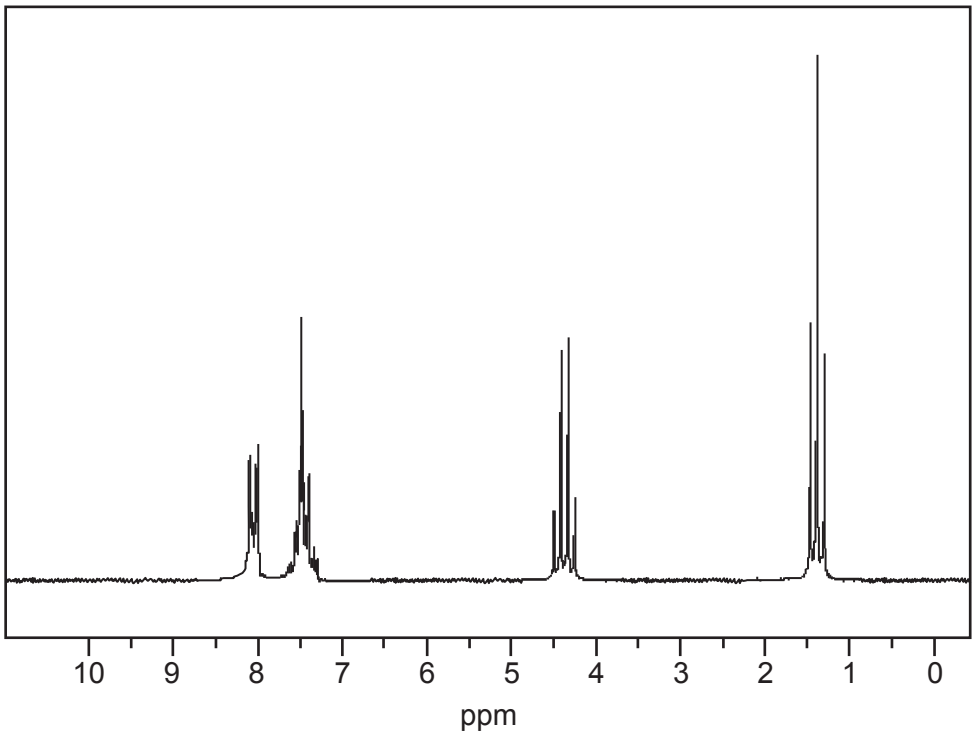
(g)* A molecule of another aromatic compound **H** is found to contain 72.0% carbon, 6.67% hydrogen and 21.3% oxygen by mass.

The M_r of **H** is 150.

The ^{13}C NMR spectrum of **H** is shown below.



The ^{1}H NMR spectrum of **H** is shown below.



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Use the data on page 34 to identify compound **H**.

Give evidence from the percentage composition and the two spectra.

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..... **[6]**

Additional answer space if required

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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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