OCR
Oxford Cambridge and RSA

Tuesday 12 October 2021 – Morning

AS Level Chemistry B (Salters)

H033/02 Chemistry in depth

Time allowed: 1 hour 30 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 **70**.
- 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 **20** pages.

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

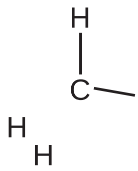
Answer **all** the questions.

1 Crude oil is fractionally distilled and the fractions are cracked to form small-chain alkenes. These can be used to make addition polymers.

(a) One such alkene is propene, $CH_3CH{=}CH_2$.

(i) Complete the diagram below to show the 3-D shape around the carbon atom in the CH_3 group. Use the notation of solid and dashed wedges.

Give the H–C–H bond angle around this carbon atom.

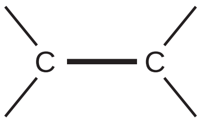


bond angle = ... ° **[2]**

(ii) The C=C bond consists of a sigma(σ)-bond and a pi(π)-bond.

The diagram below shows a representation of the σ-bond.

Complete the diagram to show a representation of the π-bond.



▬▬ representation of σ-bond

[1]

(b) Propene can be polymerised to produce poly(propene).

(i) Draw a section of a poly(propene) chain that shows two monomers joined together.

[1]

(ii) A chemist dissolves a sample of poly(propene) in a suitable solvent.
The chemist wants a quick and simple way to check whether the polymer contains any unreacted monomer.

Suggest what the chemist should do.

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.... **[1]**

(c) When propene is bubbled into a solution containing chlorine and sodium iodide, a mixture of products is obtained, including CH_3CHICH_2Cl.

Draw the structure of the carbocation that leads to the formation of CH_3CHICH_2Cl.

[1]

(d) Other alkenes can also be used in addition polymerisation reactions.

One such alkene is but-2-ene, $CH_3CH=CHCH_3$.

(i) The groups attached to the carbons in a C=C double bond are in fixed positions because there is no rotation about the C=C bond.

Explain why but-2-ene exhibits *E*/*Z* isomerism but propene does not do so.

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.... **[1]**

(ii) But-2-ene has the molecular formula C_4H_8. There are two other structural isomers with this molecular formula that are both alkenes.

Draw (in the boxes) **skeletal** formulae for these two isomers.

[2]

2 Hydrochloric acid is an important chemical both in industry and in the laboratory. The acid can be made by dissolving hydrogen chloride gas in water.

(a) Hydrogen chloride gas can be prepared in the laboratory using the reaction between solid sodium chloride and concentrated sulfuric acid.

(i) Write the chemical equation for this reaction.

[1]

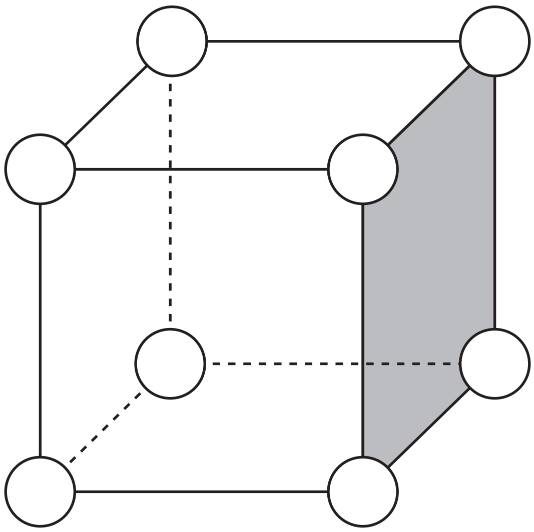
(ii) Hydrogen iodide can be similarly prepared from sodium iodide but an acid different from sulfuric acid must be used.

Name the acid.

.... **[1]**

(iii) Sodium chloride, sodium bromide and sodium iodide have the same giant ionic lattice structures.

Part of this giant lattice structure is shown in the diagram below.
Show the positions of the positive sodium ions and the negative halide ions.
Use + and – symbols inside the circles.



[1]

(b) **(i)** **X** is a hydrogen halide that gives a red/brown vapour on heating.
Suggest, with a reason, the name of **X**.

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.... **[2]**

(ii) Give a test on a solution of **X** that would verify your choice in **(b)(i)**.

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.... **[2]**

(c) A student wishes to determine the concentration of a sample of hydrochloric acid by titrating the acid with a standard solution of sodium carbonate.

The student records the procedure for making up the standard solution as follows.

1 About 240 cm^3 of de-ionised water is placed in a clean 250 cm^3 beaker.

2 A sample of anhydrous sodium carbonate is weighed in a weighing bottle. The sample is tipped slowly, with stirring, into the water in the 250 cm^3 beaker. The weighing bottle is re-weighed.

3 The water is stirred with a glass rod until all of the solid has dissolved. The glass rod is then removed.

4 The solution is poured from the beaker through a funnel into a 250 cm^3 volumetric flask. The beaker and the funnel are rinsed into the flask with de-ionised water.

5 De-ionised water is poured into the volumetric flask until it is just below the graduation mark.

6 Further de-ionised water is added using a dropping pipette until the bottom of the meniscus reaches the graduation mark.

7 A stopper is put into the flask and the solution is now ready to use.

The student has made mistakes in the procedure above.
Describe **two** of them and explain why they lead to lack of accuracy.

Mistake 1 ....

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Mistake 2 ....

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[4]

(d) The equation for the reaction between sodium carbonate and hydrochloric acid is shown below.

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$ **Equation 2.1**

(i) A student titrates 25.0 cm^3 of a solution of sodium carbonate with 0.100 mol dm^{-3} hydrochloric acid in order to find the concentration of the sodium carbonate.

The student's results are shown below.

	Trial Titration	**Titration 1**	**Titration 2**	**Titration 3**
Titre / cm^3	24.0	23.50	23.80	23.60

Calculate the concentration of the sodium carbonate solution.

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

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

(ii) Another student is asked to determine the value of *x* in hydrated sodium carbonate, $Na_2CO_3{\bullet}xH_2O$.

The student dissolves 1.46 g of the hydrated salt in water and makes it up to 250.0 cm^3 in a volumetric flask.

A titration shows that the concentration of the sodium carbonate is 2.51×10^{-2} mol dm^{-3}.

Use these data to determine the value of *x*.

Give your answer to the nearest whole number.

x = ... **[4]**

(e) The relative reactivities of the halogens can be investigated using displacement reactions.

For example, bromine will displace iodine from a solution of potassium iodide.
The ionic equation for this reaction is shown below.

$Br_2(aq) + 2I^-(aq) \longrightarrow 2Br^-(aq) + I_2(aq)$ **Equation 2.2**

(i) Write the ionic half-equation for the **oxidation** reaction.

[1]

(ii) Explain, in terms of electrons, why a bromine atom is more reactive than an iodine atom.

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.... **[1]**

(iii) The reaction in **Equation 2.2** is carried out in a test tube. Some of the colourless organic solvent cyclohexane is added to the reaction mixture.
The tube is shaken and the mixture allowed to settle.
The cyclohexane layer is now a pink/purple colour.

What causes the colour in the cyclohexane layer?

.... **[1]**

3 The manufacture of chlorofluorocarbons (CFCs) has been banned because they cause the depletion of ozone in the stratosphere. CFCs like CCl_3F have been replaced by a range of compounds including hydrochlorofluorocarbons (HCFCs) which are mainly broken down before they reach the stratosphere.

(a) HCFCs can react in the troposphere with OH radicals.

OH radicals are formed from water molecules in the stratosphere.

What **type** of bond breaking occurs when OH radicals are formed from water molecules?

.... **[1]**

(b) The bond enthalpy of the O–H bond in water is $+463\,\text{kJ mol}^{-1}$.

Calculate the minimum frequency of radiation, in Hz, needed to break a single O–H bond.

frequency = ... Hz **[3]**

(c) **(i)** CCl_3F breaks down in the stratosphere by the reaction shown below.

$$CCl_3F \rightarrow CCl_2F + Cl$$

Chlorine radicals catalyse the breakdown of ozone in the stratosphere.

Complete the following equations to show this.

$$\text{............} + O_3 \rightarrow \text{............} + O_2$$

$$\text{............} + O \rightarrow \text{............} + O_2$$

[1]

(ii) Give the systematic name of CCl_3F.

.... **[1]**

(d)* Chloromethane, CH_3Cl, also breaks down in the stratosphere.
Two related compounds are methane, CH_4, and methanol, CH_3OH.

Describe and explain the origin of the intermolecular bonds in CH_3Cl, CH_4 and CH_3OH and predict their relative boiling points.

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Additional answer space if required

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(e) Chloromethane and bromomethane from the atmosphere dissolve in the oceans where both compounds undergo hydrolysis.

(i) Write the equation for the hydrolysis of chloromethane, CH_3Cl, by water.

[1]

(ii) Explain which of chloromethane and bromomethane would undergo hydrolysis more rapidly.

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.... **[1]**

(iii) Give **two** words that describe the mechanism of the hydrolysis reaction in **(e)(i)**.

.... **[1]**

(f) The estimated annual global emissions of chloromethane, CH_3Cl, are 8.0×10^2 tonnes.

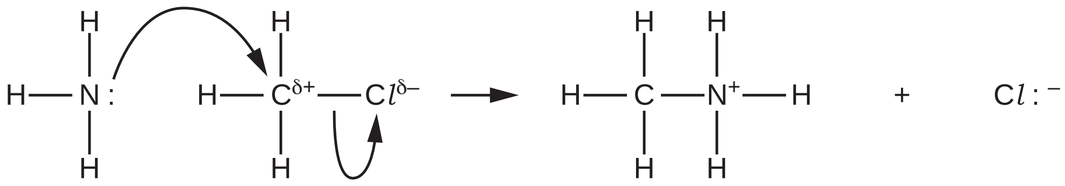
Calculate the volume of this chloromethane, in dm^3, at a pressure of 1.00×10^5 Pa and a temperature of 16 °C.

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

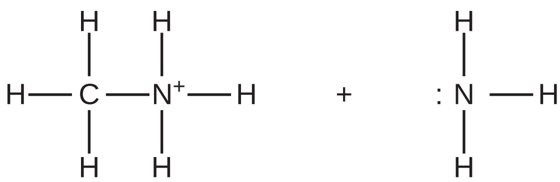
(g) Chloromethane also reacts with ammonia to produce methylamine, CH_3NH_2.

$CH_3Cl + 2NH_3 \rightarrow CH_3NH_2 + NH_4^+ Cl^-$

The mechanism for the **first stage** of this reaction is shown below.



(i) Use ‘curly arrows’ to complete the mechanism for the **second stage** of this reaction.



[2]

(ii) This reaction also produces dimethylamine, $(CH_3)_2NH$, in a mixture of organic products.

Use the mechanism for the **first stage** of the reaction to help you suggest how dimethylamine is formed.

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.... **[1]**

4 Methanol can be used as a fuel. It can be made industrially by the catalysed reaction between carbon monoxide and hydrogen as shown in **Equation 4.1**.

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -91\,kJ\,mol^{-1}$ **Equation 4.1**

(a) The reaction represented by **Equation 4.1** can reach a position of dynamic equilibrium.

A student says that a position of dynamic equilibrium is reached when the concentrations of reactants and products remain constant because both the forward and reverse reactions have stopped.

Comment on the student's statement, giving the correct chemistry where necessary.

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.... **[3]**

(b) (i) Write an expression for the equilibrium constant, K_c, for the reaction shown in **Equation 4.1**.

[1]

(ii) At a temperature of 480 K, the reaction shown in **Equation 4.1** has the following equilibrium concentrations.

Substance	**Equilibrium concentration / mol dm^{-3}**
CH_3OH	0.039
CO	0.090

The numerical value of K_c for the reaction in **Equation 4.1** at 480 K is 33.9.

Calculate a value for the equilibrium concentration of hydrogen under these conditions.
Use your answer to **(b)(i)** and the data provided.

equilibrium concentration of hydrogen = ... mol dm^{-3} **[2]**

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -91\,kJ\,mol^{-1}$ **Equation 4.1**

(c)* A company suggests operating the industrial process in **Equation 4.1** at a relatively low temperature of 300 °C and a relatively high pressure of 100 atmospheres.

Consider whether these are the best conditions in terms of both yield and rate of production of methanol, giving the background chemistry.

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Additional answer space if required

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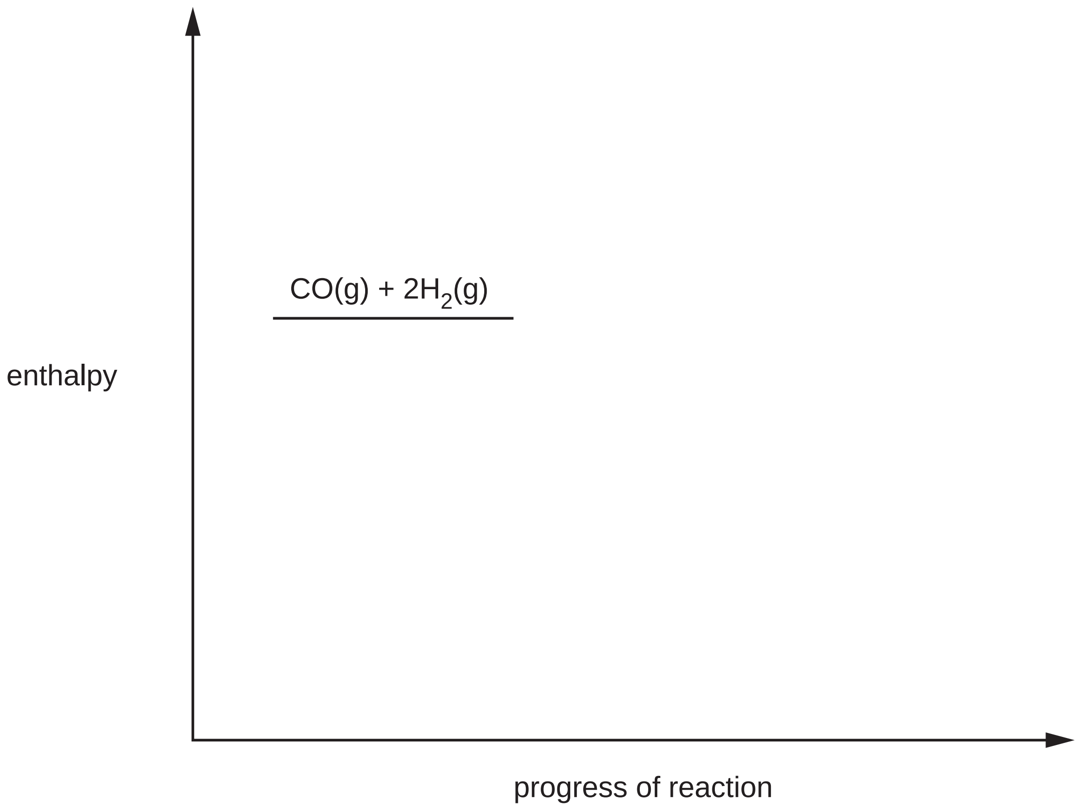
$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ $\Delta H = -91\,kJ\,mol^{-1}$ **Equation 4.1**

(d) A mixture of solid copper and solid zinc oxide is used as a catalyst in the industrial process.

(i) Complete the enthalpy level diagram below to show the effect of a catalyst on the activation enthalpy for this exothermic reaction.

You should draw and label enthalpy profiles for both catalysed and uncatalysed reactions.



[3]

In the type of catalysis in part **(d)(i)**, the process begins with the adsorption of the reactants onto the surface of the catalyst. It ends with the desorption of the product from the surface.

(ii) Name the **type** of catalysis provided by the mixture of solids.

.... **[1]**

(iii) Describe the stages that occur between adsorption and desorption to allow the reaction to occur.

1. Adsorption

2. ....

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3. ....

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4. Desorption **[2]**

END OF QUESTION PAPER

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).