Cambridge AS & A Level

CHEMISTRY

Paper 2

Topical Past Paper Questions

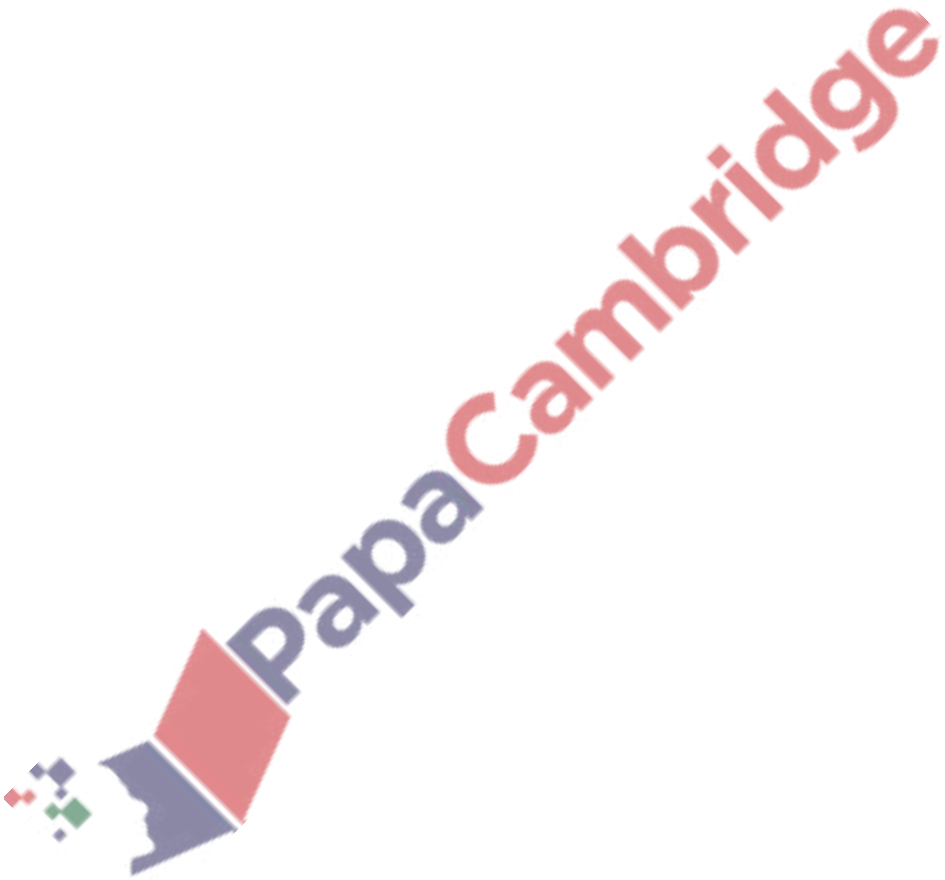
+ Answer Scheme

2015 - 2021

PapaCambridge

Chapter 13

An introduction to organic chemistry



13.1 Formulae, functional groups, the naming of organic compounds

88. 9701_w16_qp_21 Q: 4

In each section of this question an organic compound is shown. For each compound give its name and answer the questions about it.

(a) $CH_3CH_2CH(CH_3)CH{=}CHCH_3$

(i) name ..... [1]

(ii) This compound shows stereoisomerism.

Define *stereoisomerism.*

.....

.....

..... [1]

(iii) State and explain how many stereoisomers of this structure there are.

.....

.....

.....

.....

.....

..... [4]

(b) $(CH_3)_2C{=}C(CH_3)_2$

(i) name ..... [1]

(ii) Draw the **skeletal** formula of the organic product of the reaction of this compound with cold, dilute, acidified manganate(VII) ions.

[1]

(iii) Name the organic product of the reaction of this compound with hot, concentrated, acidified manganate(VII) ions.

..... [1]

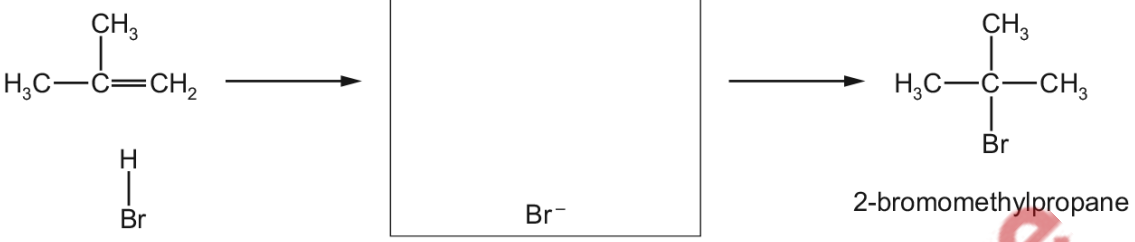
(iv) Draw the structure of part of a molecule of the addition polymer formed from this compound, showing exactly **three** repeat units.

[1]

(c) $(CH_3)_2C{=}CH_2$

(i) name ..... [1]

(ii) Complete the mechanism for the reaction of this compound with hydrogen bromide. Include all necessary curly arrows, lone pairs, charges and partial charges.



2-bromomethylpropane

[4]

(iii) Explain fully why 2-bromomethylpropane is the major product of this reaction while only relatively small amounts of 1-bromomethylpropane are produced.

.....

.....

.....

.....

.....

.....

..... [3]

[Total: 18]

13.2 Shapes of organic molecules; σ and π bonds

89. 9701_m20_qp_22 Q: 1

Group 2 metals form alkaline solutions in water.

(a) (i) Write the equation for the reaction of calcium oxide with water.

..... [1]

(ii) Identify the ion that causes an aqueous solution to be alkaline.

..... [1]

(b) The table shows the melting points of some Group 2 metal oxides.

compound	melting point/°C
MgO	2825
CaO	2613
SrO	2531
BaO	1923

Explain the trend in the melting points of the oxides down Group 2.

.....

.....

..... [2]

(c) Oxygen reacts readily with some metals, but each Group 2 metal requires strong heating to start the reaction with oxygen.

Suggest why strong heating is required to start these reactions.

.....

..... [1]

(d) Beryllium oxide reacts with hydrochloric acid to form molecules of $BeCl_2$.

Deduce the bond angle in $BeCl_2$.

..... [1]

(e) Unlike the other oxides of Group 2 metals, beryllium oxide is amphoteric.

(i) Give the meaning of the term *amphoteric*.

.....

..... [1]

(ii) Beryllium oxide and aluminium oxide have similar chemical properties.

The $Be(OH)_4^{2-}$ anion is a product of the reaction between beryllium oxide and excess concentrated $OH^-(aq)$.

Construct an equation for this reaction.

..... [1]

(f) Magnesium oxide reacts reversibly with chlorine according to the following equation.

$$2MgO(s) + 2Cl_2(g) \rightleftharpoons 2MgCl_2(s) + O_2(g)$$

Under certain conditions, a dynamic equilibrium is established.

(i) State **two** features of a reaction that is in dynamic equilibrium.

1 .....

2 .....

[2]

(ii) The equilibrium constant, K_p, is given by the following expression.

$$K_p = \frac{p_{O_2}}{p_{Cl_2}^2}$$

At 1.00×10^5 Pa and 500 K, 70% of the initial amount of $Cl_2(g)$ has reacted.

Calculate K_p and state its units.

K_p = ...

units = ...

[3]

(g) Magnesium peroxide, MgO_2, is made in the following reaction.

$$MgO(s) + H_2O_2(l) \rightarrow MgO_2(s) + H_2O(l) \qquad \Delta H = -96\,kJ\,mol^{-1}$$

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
MgO(s)	–602
$H_2O_2(l)$	–188
$H_2O(l)$	–286

(i) The peroxide ion is O_2^{2-}.

Deduce the average oxidation number of oxygen in the peroxide ion.

..... [1]

(ii) Define the term *enthalpy change of formation*.

.....

.....

..... [2]

(iii) Use the data given to calculate the enthalpy change of formation of $MgO_2(s)$.

ΔH_f $MgO_2(s)$ = ... kJ mol^{-1} [2]

(iv) Magnesium peroxide decomposes slowly to form magnesium oxide and oxygen.

$$MgO_2(s) \rightarrow MgO(s) + \tfrac{1}{2}O_2(g)$$

Use your answer to **(g)(iii)** and the data in the table to calculate the enthalpy change of this reaction.

If you were unable to obtain an answer to **(g)(iii)**, *use the value* $\Delta H_f = -550\,kJ\,mol^{-1}$. *This is* ***not*** *the correct answer.*

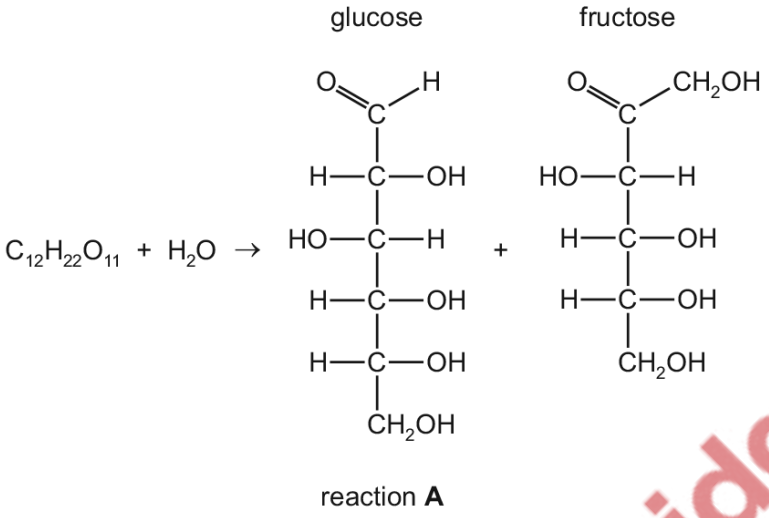
enthalpy change of reaction = ... $kJ\,mol^{-1}$ [1]

[Total: 19]

13.3 Isomerism: structural and stereoisomerism

90. 9701_s20_qp_22 Q: 3

Sucrose, $C_{12}H_{22}O_{11}$, reacts with water to form glucose and fructose in reaction **A**.



(a) Suggest a name for this type of reaction.

..... [1]

(b) Explain in detail, why glucose and fructose are a pair of structural isomers. Your answer should refer specifically to these two molecules.

.....

.....

..... [2]

(c) Reaction **A** occurs faster in the presence of an enzyme. This is reaction **B**.

(i) The activation energy for reaction **B** is +29 kJ mol^{-1}.

Predict a value for the activation energy of reaction **A**.

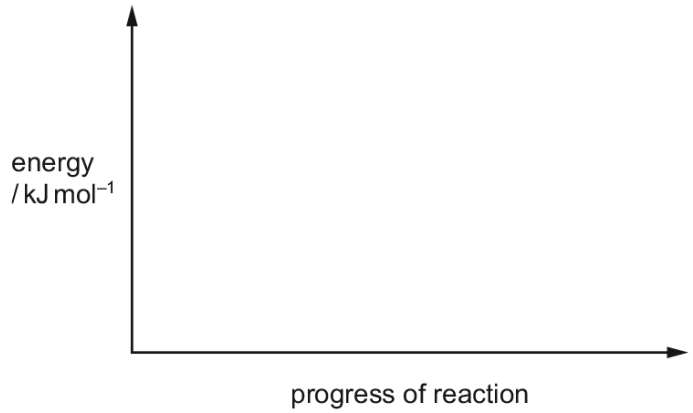
..... [1]

(ii) The enthalpy change for reaction **A** is –14 kJ mol^{-1}.

Predict a value for the enthalpy change for reaction **B**.

..... [1]

(iii) Sketch a labelled energy level diagram for reaction **B**. Use relevant values from **(c)(i)** and **(c)(ii)**.



[2]

(d) 1.00 g of sucrose, $C_{12}H_{22}O_{11}$, is completely combusted. The heat energy produced is used to increase the temperature of 250 g of water inside a calorimeter from 25.0 °C to 40.7 °C.

These data can be used to calculate the enthalpy change of combustion of sucrose.

(i) Explain what is meant by the term *enthalpy change of combustion of sucrose*.

.....

.....

..... [2]

(ii) Use the *Data Booklet* to calculate the enthalpy change, in kJ mol^{-1}, for the combustion of sucrose.
Assume that all of the heat energy produced is transferred to the water.

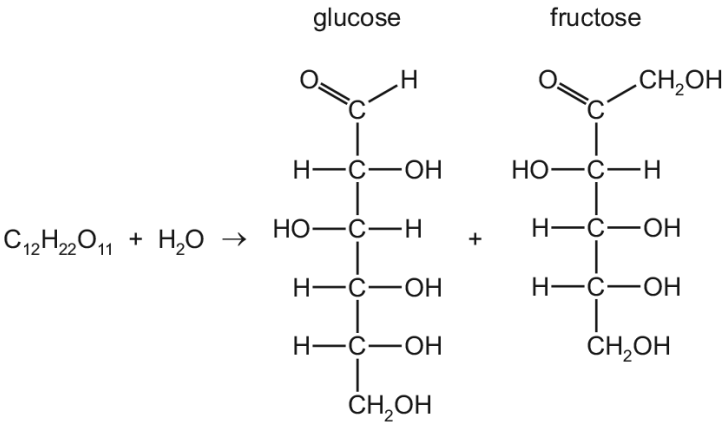
Show your working.

enthalpy change of combustion of sucrose = ... kJ mol^{-1}
[3]

[Total: 12]

91. 9701_s20_qp_23 Q: 3

Sucrose is a white crystalline solid, $C_{12}H_{22}O_{11}$. In reaction **Z**, sucrose reacts with water in the presence of a catalyst, aqueous hydrochloric acid, to form glucose and fructose.



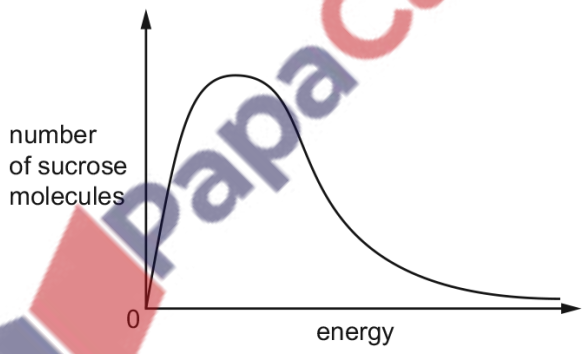
reaction **Z**

(a) (i) Suggest a name for the reaction that occurs when sucrose reacts with water to form glucose and fructose.

..... [1]

(ii) If no catalyst is added in reaction **Z**, the reaction is very slow.

Label the Boltzmann distribution to show the effect of adding a catalyst to the sample of sucrose and water molecules at constant temperature.



Explain your labelled diagram.

.....

.....

.....

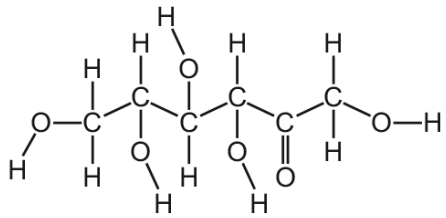
[3]

(b) Both fructose and glucose contain chiral centres.

(i) Explain what is meant by the term *chiral centre*.

..... [1]

(ii) On the diagram of the fructose molecule, label all the chiral centres with an asterisk (*).



[1]

(iii) Determine the empirical formula of fructose.

..... [1]

(c) (i) Explain what is meant by the term *enthalpy change of combustion*.

.....

..... [2]

(ii) Write the equation for the complete combustion of sucrose.

..... [1]

The enthalpy change of reaction **Z**, ΔH_r, can be calculated using the enthalpy change of combustion data given in the table.

substance	enthalpy change of combustion, ΔH_c / kJ mol^{-1}
sucrose	–5643
glucose	–2805
fructose	–2810

(iii) Use the data in the table to calculate the enthalpy change for the reaction occurring when sucrose reacts with water, ΔH_r. You should draw a labelled Hess' cycle to show your working.

ΔH_r = ... kJ mol^{-1} [2]

[Total: 12]

92. 9701_s19_qp_21 Q: 5

Ethanal reacts with a mixture of HCN and NaCN to make 2-hydroxypropanenitrile, $CH_3CH(OH)CN$.

The reaction mechanism is nucleophilic addition.

(a) Explain the meaning of the term *nucleophile* and identify the species which acts as the nucleophile during this reaction.

.....

.....

species acting as nucleophile .....

[2]

(b) $CH_3CH(OH)CN$ exists as a pair of stereoisomers.

(i) Name the type of stereoisomerism shown by $CH_3CH(OH)CN$.

..... [1]

(ii) Draw three-dimensional diagrams of this pair of stereoisomers.

Indicate with an asterisk (*) the chiral centre on one of the structures drawn.

[3]

(c) Give the structure of the organic product of the reaction of $CH_3CH(OH)CN$ with dilute sulfuric acid.

..... [1]

[Total: 7]

93. 9701_s19_qp_22 Q: 1

Methylpropane, $(CH_3)_2CHCH_3$, is an isomer of butane, $CH_3(CH_2)_2CH_3$.

(a) (i) Explain why methylpropane and butane are a pair of isomers.

.....

..... [2]

(ii) Identify the type of isomerism shown by methylpropane and butane.

..... [1]

(b) When a sample of butane is heated to 373 K, in the presence of a catalyst, and allowed to reach equilibrium the following reaction occurs.

$$CH_3(CH_2)_2CH_3(g) \rightleftharpoons (CH_3)_2CHCH_3(g) \qquad \Delta H = -8.0\,kJ\,mol^{-1}$$

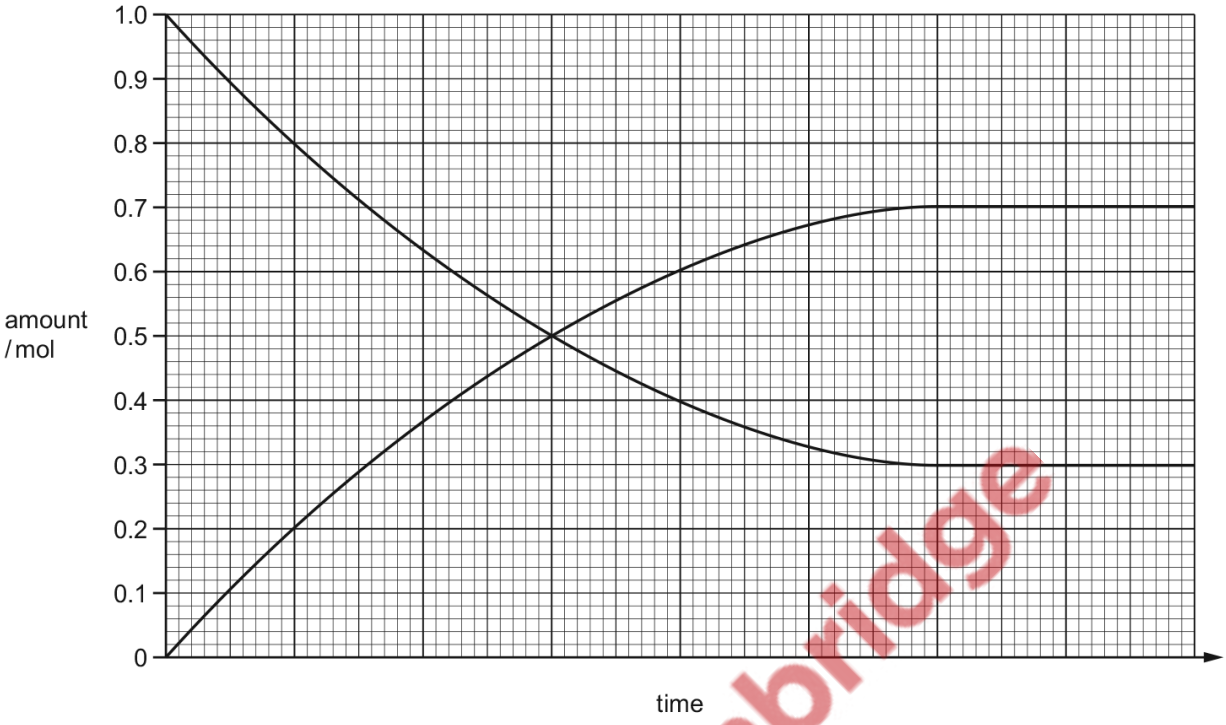
State and explain the effect on the composition of this equilibrium mixture when the temperature is increased to 473 K.

.....

.....

..... [2]

(c) 1 mole of butane gas was added to a 1 dm^3 closed system, at a constant temperature and pressure. The amount of butane and methylpropane was measured at regular time intervals.



(i) Label the graph with a *t* to show the time taken to reach dynamic equilibrium. [1]

(ii) Use the graph to find the concentration of butane and methylpropane in the mixture at equilibrium.

concentration of butane = ... mol dm^{-3}

concentration of methylpropane = ... mol dm^{-3}

[1]

(iii) Write an expression for K_c for this reaction.

[1]

(iv) Calculate a value for K_c and state its units.

K_c = ... units = ... [2]

[Total: 10]

94. 9701_s18_qp_23 Q: 2

One reason for the wide variety of organic compounds is isomerism, either structural isomerism or stereoisomerism.

(a) (i) Explain the meaning of the term *structural isomerism*.

.....

.....

..... [2]

(ii) Explain the meaning of the term *stereoisomerism*.

.....

.....

..... [2]

(b) Pent-1-ene, $CH_2=CH(CH_2)_2CH_3$, does not show stereoisomerism.

(i) Give **two** reasons why pent-1-ene does **not** show stereoisomerism.

reason 1 .....

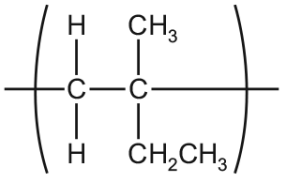
.....

reason 2 .....

.....

[2]

(ii) A structural isomer of pent-1-ene is used as the monomer to form a polymer. The repeat unit of this polymer is shown.



Draw the **displayed** formula of the monomer used to make this polymer.

Give the name of the monomer.

.....

[2]

(iii) A different structural isomer of pent-1-ene shows geometrical isomerism.

Draw the structure of **one** of the two geometrical isomers with the formula C_5H_{10}.

Give the full name of this isomer.

.....

[2]

[Total: 10]

95. 9701_s17_qp_23 Q: 3

Sulfur trioxide, SO_3, is manufactured from sulfur dioxide and oxygen by the Contact process.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196.0\,kJ\,mol^{-1}$$

(a) The enthalpy change of formation of SO_2, ΔH_f $SO_2(g)$, is $-296.8\,kJ\,mol^{-1}$.

(i) Define the term *enthalpy change of formation*.

.....

.....

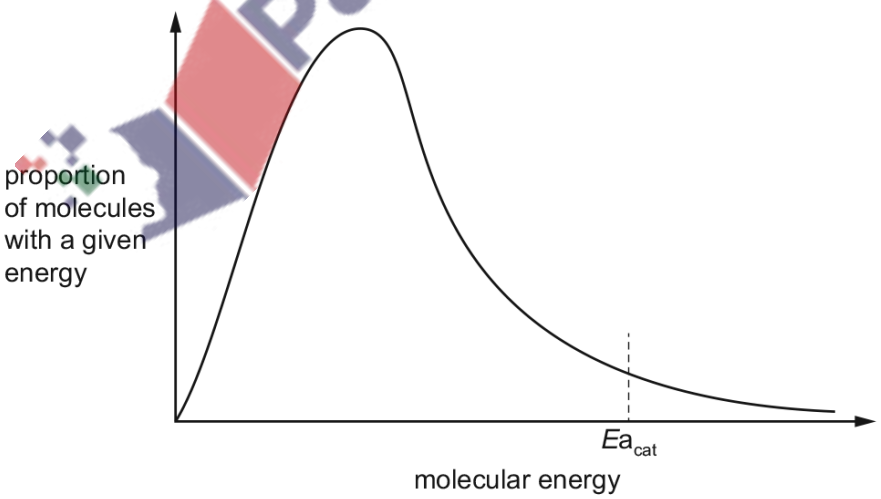
..... [2]

(ii) Use the data to calculate the enthalpy change of formation of $SO_3(g)$.

ΔH_f $SO_3(g)$ = ... $kJ\,mol^{-1}$ [2]

(b) The Contact process is usually carried out at a temperature of approximately 700 K, a pressure of approximately 150 kPa and in the presence of a vanadium(V) oxide catalyst, V_2O_5.

The Boltzmann distribution for a mixture of SO_2 and O_2 at 700 K is shown.
Ea_{cat} represents the activation energy for the reaction in the presence of the catalyst.



(i) Add a labelled mark, Ea_{uncat}, to the diagram to indicate the activation energy in the absence of the catalyst. [1]

(ii) State the benefit of using a catalyst in this reaction. Explain how it achieves this effect.

.....

.....

.....

..... [2]

(iii) State and explain how an increase in pressure would affect both the rate of reaction and the yield of SO_3 in the Contact process.

rate .....

.....

.....

.....

yield .....

.....

.....

.....

[4]

(c) At a pressure of 1.50×10^5 Pa, 1.00 mol of sulfur dioxide gas, SO_2, was mixed with 1.00 mol of oxygen gas, O_2. The final equilibrium mixture formed was found to contain 0.505 mol of O_2.

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

(i) Calculate the amount, in mol, of SO_2 and SO_3 in the equilibrium mixture.

SO_2 = ... mol

SO_3 = ... mol [1]

(ii) Calculate the partial pressure of oxygen gas, pO_2, in the equilibrium mixture.

pO_2 = ... Pa [2]

(d) In another equilibrium mixture formed from different starting amounts of SO_2 and O_2, the partial pressures of SO_2, O_2 and SO_3 were as shown.

$pSO_2 = 8.42 \times 10^2$ Pa

$pO_2 = 6.00 \times 10^4$ Pa

$pSO_3 = 9.10 \times 10^4$ Pa

(i) Write the expression for the equilibrium constant, K_p, for the production of SO_3 from SO_2 and O_2.

$K_p =$

[1]

(ii) Calculate the value of K_p for this reaction and state the units.

K_p = ...

units = ...

[2]

[Total: 17]

96. 9701_s17_qp_23 Q: 4

A, **B** and **C** all have the formula C_4H_8. They all decolourise bromine and are structural isomers of each other.

(a) State the name of the process by which **A**, **B** and **C** could be obtained from $C_{10}H_{22}$.

..... [1]

(b) Draw the structures of these three **structural** isomers.

[1]

(c) Only **A** shows geometrical isomerism.

(i) Explain the meaning of the term *geometrical isomerism*.

.....

.....

.....

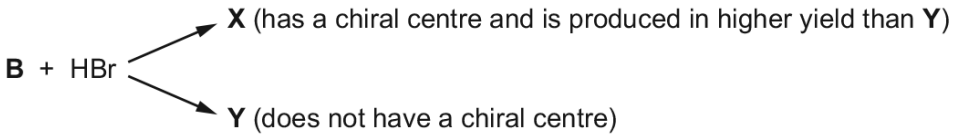
..... [2]

(ii) Draw the displayed formula of **A** and use it to show the mechanism of the reaction of **A** with HBr. Include all necessary charges, dipoles, lone pairs and curly arrows.

[4]

(d) **B** does **not** show geometrical isomerism.

B reacts with HBr to form a mixture of two structural isomers, **X** and **Y**.



(i) State the meaning of the term *chiral centre*.

.....

.....

.....

..... [1]

(ii) Name **B**.

..... [1]

(iii) **X** exists as a pair of optical isomers.

Draw these isomers using the conventional three-dimensional representation.

[2]

(iv) Explain why **X** is produced in higher yield than **Y**.

.....

.....

.....

..... [2]

(e) **C** does **not** show geometrical isomerism.

C reacts with HBr to form a mixture of two structural isomers, neither of which has a chiral centre.

(i) Name **C**.

..... [1]

(ii) Draw the **displayed** formula of each of the structural isomers produced by the reaction of **C** with HBr.

[2]

[Total: 17]

97. 9701_s16_qp_21 Q: 4

This question is about molecules with molecular formula C_4H_8.

(a) Give the structures of a pair of **positional** isomers with the formula C_4H_8.

[1]

(b) Give the structures of a pair of **chain** isomers with the formula C_4H_8, that do **not** exhibit stereoisomerism.

[1]

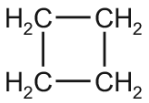
(c) Give the structures and full names of a pair of **stereoisomers** with the formula C_4H_8.

....

[2]

(d) The structure of a molecule, **A**, of formula C_4H_8 is shown.

Draw a functional group isomer of molecule **A** in box **B**. Explain how molecules **A** and **B** could be distinguished by a chemical test.



A

B

.....

.....

..... [3]

[Total: 7]

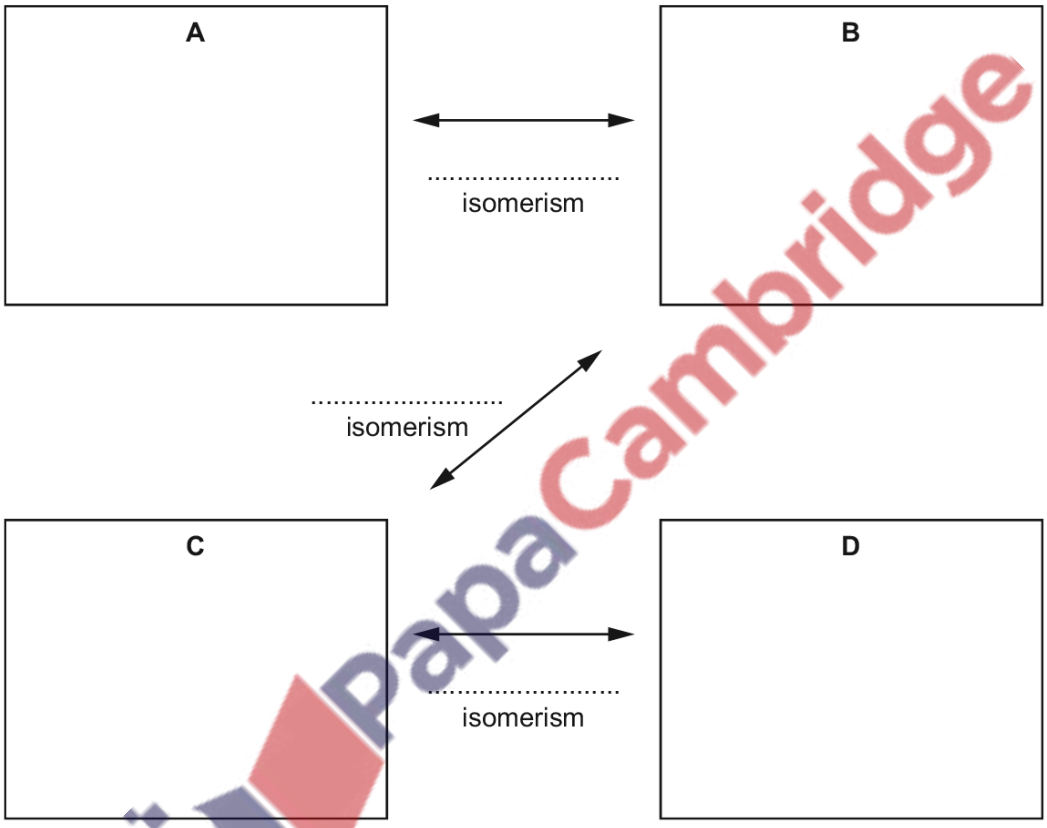
98. 9701_S15_qp_21 Q: 4

There are four alcohols, **A**, **B**, **C** and **D**, which are structural isomers with the molecular formula $C_4H_{10}O$.

Alcohol **A** does not react with acidified potassium dichromate(VI) solution but **B**, **C** and **D** do.

All four alcohols react with hot, concentrated sulfuric acid to form products with the molecular formula C_4H_8. **A**, **C** and **D** each give a single product in this reaction. **B** gives a mixture of two structural isomers, one of which shows stereoisomerism.

(a) Give the **skeletal** formula for each of the four alcohols and complete the diagram with the names of the types of structural isomerism shown by each linked pair of compounds.



[7]

(b) (i) Give the names of the two structural isomers produced by the reaction of **B** with hot, concentrated sulfuric acid

.... [2]

(ii) State which of these two isomers shows stereoisomerism. Explain why this molecule is capable of showing stereoisomerism.

.....

.....

.....

..... [2]

(iii) Draw **displayed** formulae to show the two stereoisomers.

stereoisomer 1	stereoisomer 2

[2]

[Total: 13]