



Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2022

Centre Number

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Candidate Number

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Chemistry

StemUp Model Solution

Assessment Unit AS 2

assessing

Further Physical and Inorganic
Chemistry and an Introduction to
Organic Chemistry



[SCH24]

SCH24

FRIDAY 27 MAY, AFTERNOON

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

Answer **all eighteen** questions in **Sections A and B**.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen or a pencil.**

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.

Quality of written communication will be assessed in Question **17(c)**.

The figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

A Periodic Table of Elements, containing some data, is included with this question paper.



Section A

For each of the following questions, only **one** of the lettered responses (A–D) is correct.

Select the correct response for each question and write the appropriate letter in the space provided.

- 1 6.00 g of propan-1-ol ($\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$) were used to prepare 1-bromopropane ($\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$). 4.92 g of 1-bromopropane were produced. The percentage yield is:

- A 40.0%
- B 48.8%
- C 60.0%
- D 82.0%

Answer A [1]

- 2 How many structural isomers are there with the molecular formula C_5H_{12} ?

- A 2
- B 3
- C 4
- D 5

Answer B [1]

- 3 Which one of the following isomers has the lowest boiling point?

- A 2,3-dimethylbutane
- B hexane
- C 2-methylpentane
- D 3-methylpentane

Answer A [1]



- 4 Which one of the following sets of numbers represents the numbers required to balance the equation for the complete combustion of butane?

	butane	oxygen	carbon dioxide	water
A	1	6	4	5
B	2	12	4	5
C	2	12	8	10
D	2	13	8	10

Answer D [1]

- 5 What volume of hydrogen gas, measured at 293 K and 1 atmosphere, is required to completely saturate 4.10 g of the following compound?

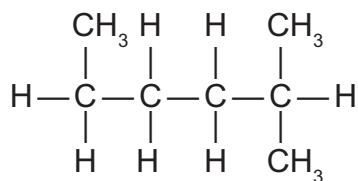


- A 600 cm³
B 1200 cm³
C 2400 cm³
D 24 dm³

Answer C [1]



6 What is the IUPAC name of the following molecule?



- A 1,1,4-trimethylbutane
- B 1,4,4-trimethylbutane
- C 2-methylhexane
- D 5-methylhexane

Answer C [1]

7 Which one of the following is a correct description of the 1-bromo-2-methylpropane obtained when methylpropene reacts with hydrogen bromide?

- | | | |
|---|---------------|---------------------------------|
| A | Major product | Formed via primary carbocation |
| B | Major product | Formed via tertiary carbocation |
| C | Minor product | Formed via primary carbocation |
| D | Minor product | Formed via tertiary carbocation |

Answer C [1]

8 Which one of the following gives the most thermally stable Group II carbonate and the most soluble Group II sulfate?

- | | | |
|---|-------------------|-------------------|
| A | BaCO ₃ | BaSO ₄ |
| B | BaCO ₃ | MgSO ₄ |
| C | MgCO ₃ | BaSO ₄ |
| D | MgCO ₃ | MgSO ₄ |

Answer B [1]



9 1,3-dibromobutane can be described as:

- A primary only
- B primary and secondary
- C primary and tertiary
- D secondary and tertiary

Answer B [1]

10 8.55 g of barium hydroxide were dissolved in water and the solution made up to 500 cm^3 in a volumetric flask. What is the concentration of hydroxide ions in the solution?

- A 0.025 mol dm^{-3}
- B 0.050 mol dm^{-3}
- C 0.100 mol dm^{-3}
- D 0.200 mol dm^{-3}

Answer D [1]



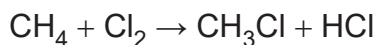
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Section B

Answer all **eight** questions in this section

- 11 An excess of methane reacts with chlorine, in the presence of UV light, to form chloromethane as one of the main products.



- (a) Name the type of mechanism for this reaction.

Radical substitution (free radical substitution) [2]

- (b) Write an equation for the initiation step.

$\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$ [1]

- (c) Write two equations for the propagation steps.

$\text{CH}_4 + \text{Cl}\cdot \rightarrow \cdot\text{CH}_3 + \text{HCl}$

$\cdot\text{CH}_3 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{Cl}\cdot$ [2]

- (d) Write an equation for the termination step which results in the formation of ethane.

$\cdot\text{CH}_3 + \cdot\text{CH}_3 \rightarrow \text{C}_2\text{H}_6$ [1]

- (e) Give the IUPAC name of one other carbon-containing product which may be formed.

dichloromethane [1]

[Turn over]



- 12 Analysis of an organic compound shows that it contains **carbon, hydrogen** and **oxygen** and it has a relative molecular mass of 88. The empirical formula of the compound can be determined using percentage composition by mass. The molecular formula can then be established using the relative molecular mass.

(a) Define the term **molecular formula**.

A formula which shows the actual number of atoms of each element in a molecule.

[1]

(b) (i) The compound contains 54.5% carbon and 9.1% hydrogen by mass. Determine the empirical formula of the compound.

$$\% O = 100 - 54.5 - 9.1 = 36.4\%$$

$$C : H : O = 54.5 \div 12 : 9.1 \div 1 : 36.4 \div 16$$

$$= 4.54 : 9.1 : 2.275$$

$$= 2 : 4 : 1 \text{ (dividing by 2.275)}$$

$$\text{Empirical formula} = C_2H_4O$$

[3]

(ii) Determine the molecular formula of the compound.

$$M_r \text{ of } C_2H_4O = (12 \times 2) + (1 \times 4) + 16 = 44$$

$$88 \div 44 = 2$$

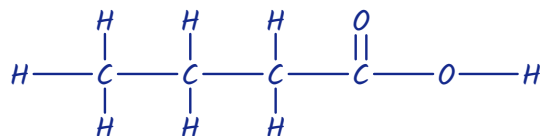
$$\text{Molecular formula} = C_4H_8O_2$$

[1]

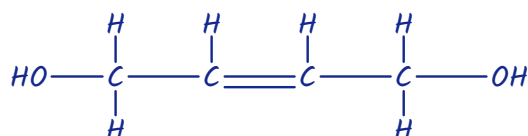


- (iii) Using your answer to (b)(ii), suggest a possible structure for the compound which contains only one functional group and another structure which contains two different functional groups.

One functional group: butanoic acid



*Two different functional groups (alkene and alcohol):
but-2-ene-1,4-diol*



[2]

[Turn over



- 13 Bromoethane and 2-bromo-2-methylpropane both react with a hot dilute aqueous solution of sodium hydroxide to form the corresponding alcohol. Both mechanisms are classified as nucleophilic substitution but the mechanisms are not identical. Aqueous hydroxide ions behave as nucleophiles and the products are formed via a transition state or an intermediate.

(a) Give the IUPAC names of the alcohols formed.

ethanol and 2-methylpropan-2-ol

[1]

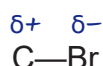
(b) (i) Define the term **nucleophile**.

An ion or molecule with a lone pair of electrons that attacks

regions of low electron density and donates the pair.

[2]

(ii) Show the polarity of the C—Br bond and explain why aqueous hydroxide ions attack bromoethane.



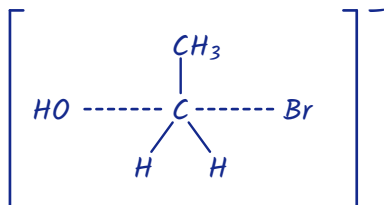
Br is more electronegative than C, so the carbon is $\delta+$.

OH^- is negative and has a lone pair, so it attacks the $\delta+$

carbon.

[2]

(iii) Draw the structure of the transition state when bromoethane reacts with aqueous sodium hydroxide and suggest why 2-bromo-2-methylpropane does not form a transition state.



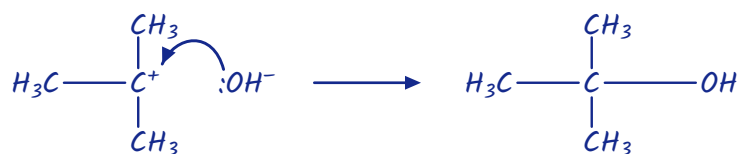
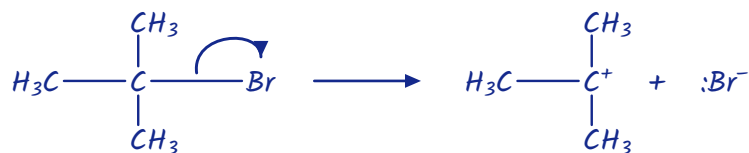
It forms a stable tertiary carbocation; attack by OH^- is hindered

by the bulky methyl groups.

[2]



(c) Draw the mechanism, using curly arrows, for the reaction of 2-bromo-2-methylpropane with aqueous sodium hydroxide.



[4]

[Turn over]



14 The standard enthalpy of combustion of ethane can be estimated using average bond enthalpies.

(a) Define the following terms:

(i) **standard enthalpy of combustion**

The enthalpy change when one mole of a substance is

completely burnt in oxygen under standard conditions (298 K,

100 kPa).

[2]

(ii) **average bond enthalpy**

The energy required to break one mole of a given covalent bond

(in the gaseous state), averaged over many different compounds.

[2]

(b) Suggest why the bond enthalpy value for $\text{O}=\text{O}$ is not an **average** value.

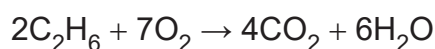
The $\text{O}=\text{O}$ bond is only present in the O_2 molecule, so there is only

one value.

[1]



(c) The complete combustion of ethane can be represented by the equation:



Use the bond enthalpies in the table below to calculate the **standard enthalpy of combustion** for ethane.

Bond	Bond enthalpy /kJ mol ⁻¹
C—H	413
C—C	348
O=O	497
C=O	803
O—H	464

Bonds broken: 12(C—H) + 2(C—C) + 7(O=O)

= 4956 + 696 + 3479 = 9131 kJ

Bonds formed: 8(C=O) + 12(O—H) = 6424 + 5568 = 11992 kJ

$\Delta H = 9131 - 11992 = -2861 \text{ kJ (for 2 mol of ethane)}$

$\Delta H_c^\ominus = -2861 \div 2 = -1430.5 \text{ kJ mol}^{-1}$

[4]

(d) Suggest why a mixture of ethane and oxygen is stable at room temperature and does not react to form carbon dioxide and water.

The reaction has a high activation energy, so at room temperature no

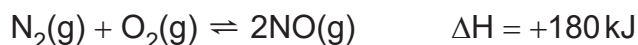
molecules have sufficient energy to react.

[1]

[Turn over]



- 15 At very high temperatures, in a closed system, nitrogen can be oxidised to form nitrogen(II) oxide in a reversible reaction:



A position of dynamic equilibrium is established and the equilibrium is described as homogeneous.

- (a) Define the term **homogeneous**.

A reaction in which all the reactants and products are in the same physical state (phase).

[1]

- (b) (i) Deduce an expression and corresponding units for the equilibrium constant, K_c , for this reaction.

$$K_c = \frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]}$$

No units (the units cancel).

[2]

- (ii) What is the significance of a small value of K_c ?

The position of equilibrium lies to the left, so only a small amount of product (NO) is formed.

[1]



- (c) Explain the effect of increasing the pressure on the equilibrium yield of nitrogen(II) oxide.

No effect on the yield.

There are the same number of moles (molecules) of gas on each side of the equation (2 on the left and 2 on the right).

[2]

- (d) Explain the effect of increasing the temperature on the equilibrium yield of nitrogen(II) oxide.

The yield of nitrogen(II) oxide increases.

The position of equilibrium moves to the right,

because the forward reaction is endothermic ($\Delta H = +180 \text{ kJ}$), so it

absorbs the heat and opposes the increase in temperature.

[3]

[Turn over



16 Strontium and magnesium are both s-block elements. The chemistry of the two elements is very similar but strontium is significantly more reactive. Strontium oxide and magnesium oxide are both basic and will neutralise dilute nitric acid to form nitrates.

- (a) (i)** Deduce the electronic configuration of a strontium atom and a strontium cation:

atom $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2$

cation $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$ [2]

- (ii)** Suggest why strontium is more reactive than magnesium.

The outer electrons in strontium are further from the nucleus

and more shielded than those in magnesium,

so the outer electrons are lost more readily. [2]

- (b)** Write an equation for the reaction of strontium with water.

$Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$ [1]

- (c)** Write an equation for the reaction of strontium oxide with dilute nitric acid.

$SrO + 2HNO_3 \rightarrow Sr(NO_3)_2 + H_2O$ [2]



(d) It is possible to distinguish between solutions of magnesium nitrate and strontium nitrate by adding a solution which contains hydroxide ions.

(i) What would be observed when a few drops of sodium hydroxide solution were added separately to a solution of magnesium nitrate and a solution of strontium nitrate?

Magnesium nitrate: a white precipitate forms.

Strontium nitrate: no precipitate, the solution stays colourless (no change).

[2]

(ii) Write an ionic equation, with state symbols, for a reaction which occurs in (d)(i).



[2]

(iii) Suggest an alternative solution which could be used, instead of a solution which contains hydroxide ions, to distinguish between solutions of magnesium nitrate and strontium nitrate.

Sodium sulfate solution (any soluble sulfate)

[1]

[Turn over]



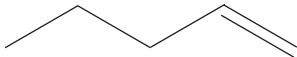
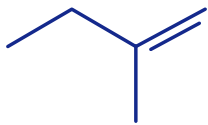
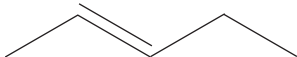
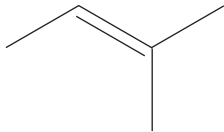
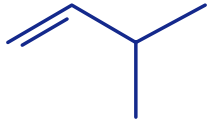
17 There are five aliphatic structural isomers with molecular formula C_5H_{10} .

(a) Define the term **structural isomers**.

Molecules which have the same molecular formula but a different structural formula.

[1]

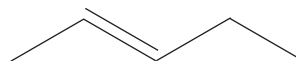
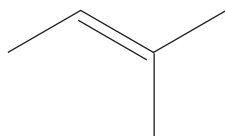
(b) Two of the aliphatic structural isomers are described as having unbranched structures and three are described as branched. Complete the table below for the five aliphatic structural isomers of C_5H_{10} .

IUPAC name of isomer	Skeletal formula
<i>pent-1-ene</i>	
2-methylbut-1-ene	
<i>pent-2-ene</i>	
<i>2-methylbut-2-ene</i>	
<i>3-methylbut-1-ene</i>	

[5]



- (c) The molecule on the left below does not exist as E–Z isomers whereas the molecule on the right does.



Draw the Z isomer of the molecule on the right and explain, in terms of priority, why the structure is classified as the Z isomer.

Explain why the molecule on the left does not exist as E–Z isomers whereas the molecule on the right does.

In this question you will be assessed on using your written communication skills including the use of specialist scientific terms.

Z isomer:



(Z)-pent-2-ene

It is the Z isomer because the higher priority groups (CH_3 and C_2H_5) are on the same side of the $\text{C}=\text{C}$.

The C of CH_3 has a higher priority than H, and the C of C_2H_5 has a higher priority than H (higher atomic number).

E–Z isomers exist due to restricted rotation about the $\text{C}=\text{C}$.

The molecule on the left has two identical methyl groups attached to one of the carbon atoms of the $\text{C}=\text{C}$, so it cannot exist as E–Z isomers.

The molecule on the right has two different atoms or groups attached to each carbon atom of the $\text{C}=\text{C}$, so it exists as E and Z isomers.

[6]

[Turn over



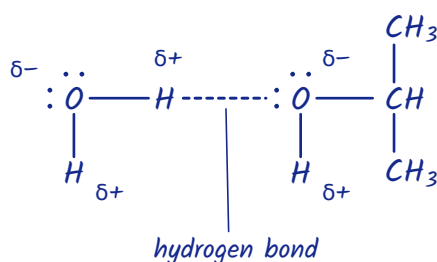
18 Propan-2-ol is a secondary alcohol which has a relatively high boiling point. It is soluble in water and can be oxidised to form a ketone.

- (a) (i) Why does propan-2-ol have a much higher boiling point than a hydrocarbon of similar relative molecular mass?

*Propan-2-ol has hydrogen bonds between its molecules,
which are stronger than the van der Waals' forces between
hydrocarbon molecules.*

[2]

- (ii) Draw a diagram to show the strongest type of attraction which forms between a propan-2-ol molecule and a water molecule. Show lone pairs of electrons and partial charges.



[2]



- (b) (i) Name a reagent which can be used to oxidise propan-2-ol. Give the condition(s) required and the observations which are made.

Reagent

potassium dichromate(VI)

Condition(s)

acidified (with dilute sulfuric acid)

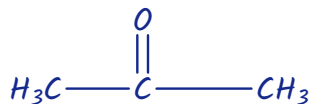
heat (under reflux)

Observations

The solution changes colour from orange to green.

[4]

- (ii) Draw the structure of the ketone formed on oxidation of propan-2-ol and give its IUPAC name.



propanone

[2]

- (iii) State two differences between the infrared spectrum of propan-2-ol and the ketone formed.

Only propan-2-ol has a broad O-H peak (3200 to 3600 cm⁻¹).

Only the ketone has a C=O peak (1650 to 1800 cm⁻¹).

[2]



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General Information

1 tonne = 10^6 g

1 metre = 10^9 nm

One mole of any gas at 293 K and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm³

Avogadro Constant = 6.02×10^{23} mol⁻¹

Planck Constant = 6.63×10^{-34} Js

Specific Heat Capacity of water = $4.2 \text{ J g}^{-1} \text{ K}^{-1}$

Speed of Light = $3 \times 10^8 \text{ m s}^{-1}$

Characteristic absorptions in IR spectroscopy

Wavenumber/cm ⁻¹	Bond	Compound
550–850	C–X (X = Cl, Br, I)	Haloalkanes
750–1100	C–C	Alkanes, alkyl groups
1000–1300	C–O	Alcohols, esters, carboxylic acids
1450–1650	C=C	Arenes
1600–1700	C=C	Alkenes
1650–1800	C=O	Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides
2200–2300	C≡N	Nitriles
2500–3200	O–H	Carboxylic acids
2750–2850	C–H	Aldehydes
2850–3000	C–H	Alkanes, alkyl groups, alkenes, arenes
3200–3600	O–H	Alcohols
3300–3500	N–H	Amines, amides

Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

Chemical Shift	Structure	
0.5–2.0	–CH	Saturated alkanes
0.5–5.5	–OH	Alcohols
1.0–3.0	–NH	Amines
2.0–3.0	–CO–CH	Ketones
	–N–CH	Amines
	C ₆ H ₅ –CH	Arene (aliphatic on ring)
2.0–4.0	X–CH	X = Cl or Br (3.0–4.0) X = I (2.0–3.0)
4.5–6.0	–C=CH	Alkenes
5.5–8.5	RCONH	Amides
6.0–8.0	–C ₆ H ₅	Arenes (on ring)
9.0–10.0	–CHO	Aldehydes
10.0–12.0	–COOH	Carboxylic acids

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

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Data Leaflet

Including the Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and
Advanced Level Examinations

Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations

gce a/as examinations chemistry



THE PERIODIC TABLE OF ELEMENTS																	
Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen																	4 He Helium
7 Li Lithium	9 Be Beryllium											11 B Boron	12 C Carbon	14 N Nitrogen	16 O Oxygen	19 F Fluorine	20 Ne Neon
23 Na Sodium	24 Mg Magnesium											27 Al Aluminium	28 Si Silicon	31 P Phosphorus	32 S Sulfur	35.5 Cl Chlorine	40 Ar Argon
39 K Potassium	40 Ca Calcium	45 Sc Scandium	48 Ti Titanium	51 V Vanadium	52 Cr Chromium	55 Mn Manganese	56 Fe Iron	59 Co Cobalt	59 Ni Nickel	64 Cu Copper	65 Zn Zinc	70 Ga Gallium	73 Ge Germanium	75 As Arsenic	79 Se Selenium	80 Br Bromine	84 Kr Krypton
85 Rb Rubidium	88 Sr Strontium	89 Y Yttrium	91 Zr Zirconium	93 Nb Niobium	96 Mo Molybdenum	98 Tc Technetium	101 Ru Ruthenium	103 Rh Rhodium	106 Pd Palladium	108 Ag Silver	112 Cd Cadmium	115 In Indium	119 Sn Tin	122 Sb Antimony	128 Te Tellurium	127 I Iodine	131 Xe Xenon
133 Cs Caesium	137 Ba Barium	139 La [*] Lanthanum	178 Hf Hafnium	181 Ta Tantalum	184 W Tungsten	186 Re Rhenium	190 Os Osmium	192 Ir Iridium	195 Pt Platinum	197 Au Gold	201 Hg Mercury	204 Tl Thallium	207 Pb Lead	209 Bi Bismuth	210 Po Polonium	210 At Astatine	222 Rn Radon
223 Fr Francium	226 Ra Radium	227 Ac [†] Actinium	261 Rf Rutherfordium	262 Db Dubnium	266 Sg Seaborgium	264 Bh Bohrium	277 Hs Hassium	268 Mt Meitnerium	271 Ds Darmstadtium	272 Rg Roentgenium	285 Cn Copernicium						
			140 Ce Cerium	141 Pr Praseodymium	144 Nd Neodymium	145 Pm Promethium	150 Sm Samarium	152 Eu Europium	157 Gd Gadolinium	159 Tb Terbium	162 Dy Dysprosium	165 Ho Holmium	167 Er Erbium	169 Tm Thulium	173 Yb Ytterbium	175 Lu Lutetium	
			232 Th Thorium	231 Pa Protactinium	238 U Uranium	237 Np Neptunium	242 Pu Plutonium	243 Am Americium	247 Cm Curium	245 Bk Berkelium	251 Cf Californium	254 Es Einsteinium	253 Fm Fermium	256 Md Mendelevium	254 No Nobelium	257 Lr Lawrencium	

a

X

b

a = relative atomic mass (approx)

x = atomic symbol

b = atomic number

* 58 – 71 Lanthanum series
† 90 – 103 Actinium series

^a
X
_b

a = relative atomic mass (approx)
x = atomic symbol
b = atomic number