Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2022

Centre Number

Candidate Number

Chemistry

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.

13147

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 ($CH_3CH_2CH_2OH$) were used to prepare 1-bromopropane ($CH_3CH_2CH_2Br$). 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 _____ [1]

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

A 2

B 3

C 4

D 5

Answer _____ [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 _____ [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 _____ [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 $600\,cm^3$

B $1200\,cm^3$

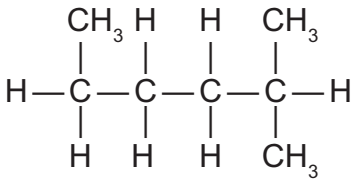
C $2400\,cm^3$

D $24\,dm^3$

Answer _____ [1]

[Turn over

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 _____ [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 _____ [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 _____ [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 _____ [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 _____ [1]

[Turn over

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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.

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

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

_____ [2]

(b) Write an equation for the initiation step.

_____ [1]

(c) Write two equations for the propagation steps.

_____

_____ [2]

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

_____ [1]

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

_____ [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**.

_____

_____ [1]

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

_____

_____

_____

_____

_____ [3]

(ii) Determine the molecular formula of the compound.

_____

_____

_____ [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.

[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.

_____

_____ [1]

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

_____

_____ [2]

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

C—Br

_____

_____

_____ [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.

_____

_____ [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

_____

_____

_____ [2]

(ii) average bond enthalpy

_____

_____

_____ [2]

(b) Suggest why the bond enthalpy value for O═O is not an **average** value.

_____

_____ [1]

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

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

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

[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.

[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:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H = +180\,kJ$$

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

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

_____

_____

_____ [1]

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

_____ [2]

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

_____

_____ [1]

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

[2]

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

[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 _____

cation _____ [2]

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

_____

_____

_____ [2]

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

_____ [1]

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

_____ [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?

_____

_____

_____

_____ [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.

_____ [1]

[Turn over

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

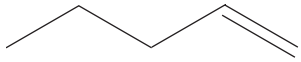
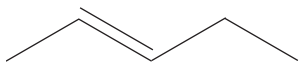
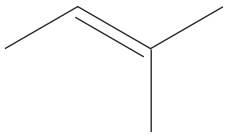
(a) Define the term **structural isomers**.

_____

_____

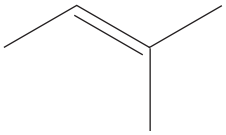
_____ [1]

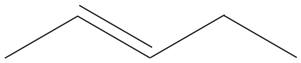
(b) Two of the aliphatic structural isomers are described as having unbranched structures and three are described as branched. Complete the table below for the five aliphatic structural isomers of C_5H_{10}.

IUPAC name of isomer	Skeletal formula
	
2-methylbut-1-ene	
	
	

[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:

[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?

_____

_____

_____ [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

Condition(s)

Observations

[4]

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

[2]

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

[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 dm^3
Avogadro Constant = 6.02×10^{23} mol^{-1}
Planck Constant = 6.63×10^{-34} J s
Specific Heat Capacity of water = 4.2 J g^{-1} K^{-1}
Speed of Light = 3×10^8 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	–C**H**	Saturated alkanes
0.5–5.5	–O**H**	Alcohols
1.0–3.0	–N**H**	Amines
2.0–3.0	–CO–C**H**	Ketones
	–N–C**H**	Amines
	C_6H_5–C**H**	Arene (aliphatic on ring)
2.0–4.0	X–C**H**	X = Cl or Br (3.0–4.0)
		X = I (2.0–3.0)
4.5–6.0	–C=C**H**	Alkenes
5.5–8.5	RCON**H**	Amides
6.0–8.0	–C_6**H**$_5$	Arenes (on ring)
9.0–10.0	–C**H**O	Aldehydes
10.0–12.0	–COO**H**	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

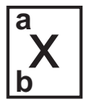
chemistry

THE PERIODIC TABLE OF ELEMENTS

I	II											III	IV	V	VI	VII	0
Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1																	4 He Helium 2
7 Li Lithium 3	9 Be Beryllium 4											11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
23 Na Sodium 11	24 Mg Magnesium 12											27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulfur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	98 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
133 Cs Caesium 55	137 Ba Barium 56	139 La* Lanthanum 57	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	210 Po Polonium 84	210 At Astatine 85	222 Rn Radon 86
223 Fr Francium 87	226 Ra Radium 88	227 Ac† Actinium 89	261 Rf Rutherfordium 104	262 Db Dubnium 105	266 Sg Seaborgium 106	264 Bh Bohrium 107	277 Hs Hassium 108	268 Mt Meitnerium 109	271 Ds Darmstadtium 110	272 Rg Roentgenium 111	285 Cn Copernicium 112						

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	145 Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	162 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
232 Th Thorium 90	231 Pa Protactinium 91	238 U Uranium 92	237 Np Neptunium 93	242 Pu Plutonium 94	243 Am Americium 95	247 Cm Curium 96	245 Bk Berkelium 97	251 Cf Californium 98	254 Es Einsteinium 99	253 Fm Fermium 100	256 Md Mendelevium 101	254 No Nobelium 102	257 Lr Lawrencium 103

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



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

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