Shenzhen College of International Education
Cambridge International AS & A Level

CANDIDATE NAME			
CHEMISTRY TEACHER		CANDIDATE NUMBER	

CHEMISTRY 9701/22

Paper 2 AS Level Structured Questions **March 2025**

1 hour 15 minutes

You must answer on the question paper.

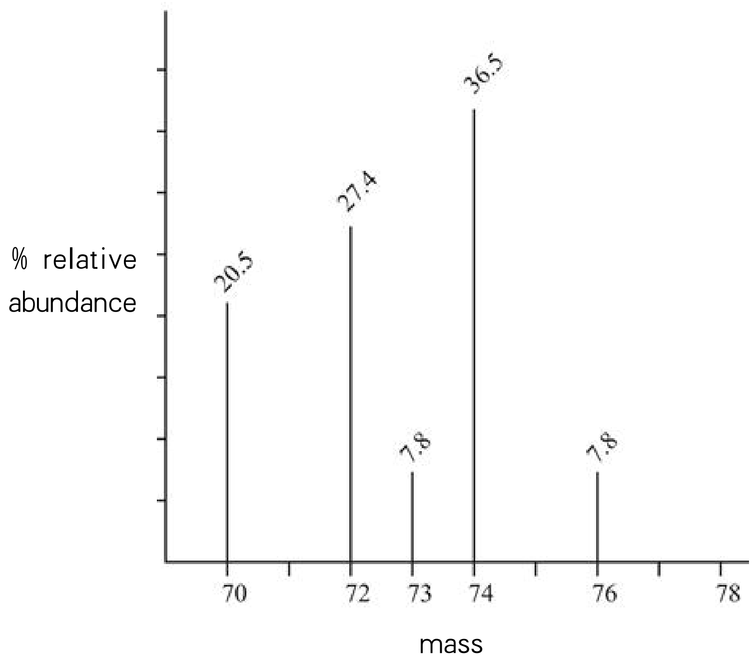
No additional materials are needed.

INSTRUCTIONS
- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, teacher's name and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION
- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

1 Germanium is an element in Group 14. It is used as a semiconductor in transistors and various other electronic devices.

(a) A sample of germanium is analysed using a mass spectrometer. The mass spectrum produced is shown.



(i) Explain what is meant by the term relative atomic mass.

the (weighted) average mass of one atom of an element (1)

compared to 1/12 the mass of an atom of carbon–12 (1)

[2]

(ii) Calculate the relative atomic mass of gallium in this sample.

Give your answer to one decimal place.

Show your working.

$$\frac{(70 \times 20.5) + (72 \times 27.4) + (73 \times 7.8) + (74 \times 36.5) + (76 \times 7.8)}{100} \quad (1)$$

$= 72.7$ (1)

relative atomic mass = ...
[2]

(b) Complete the table which describes a gaseous atom of germanium.

isotope	nucleon number	total number of electrons in **lowest** energy level	type of orbital which contains the electron in the **highest** energy level
^{74}Ge	74	2	p

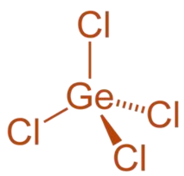
[3]

(c) When germanium is heated in excess chlorine, germanium tetrachloride, $GeCl_4$, is made.

Draw the shape of the ~~gallium trichloride~~ germanium tetrachloride molecule and suggest the Cl – Ge – Cl bond angle.

shape of molecule

name from the original question was left on the paper, but students told of the correction – so accept either a Ge or Ga – but must be tetrahedral



bond angle ....109^0 ....

[2]

(d) Gemanium oxide, GeO_2, will react with hot concentrated acids and molten alkalis.

(i) Suggest the equation for the reaction between GeO_2 and HNO_3.

$GeO_2 + 4\ HNO_3 \rightarrow Ge(NO_3)_2 + 2\ H_2O$

[1]

(ii) Suggest an equation for the reaction between germanium oxide and NaOH.

M1 *Identity of correct germanium containing product*
Na_4GeO_4 / Na_2GeO_3

M2 *correctly balance equation*
$GeO_2 + 4\ NaOH \rightarrow Na_4GeO_4 + 2\ H_2O$
OR $GeO_2 + 2\ NaOH \rightarrow Na_2GeO_3 + H_2O$

[2]

[Total : 12]

2 Nitric acid can be made from ammonia in a 3–stage process.

Stage 1 Ammonia is oxidised by oxygen from the air, to form nitrogen monoxide and water. This

reaction is carried out at 8 kPa and 900 °C in the presence of a platinum catalyst.

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O \qquad \Delta H = -905\ kJ\ mol^{-1}$$

Stage 2 Nitrogen monoxide is cooled to 250 °C and reacts with more oxygen to form nitrogen dioxide.

$$2NO + O_2 \rightarrow 2NO_2 \qquad \Delta H = -114\ kJ\ mol^{-1}$$

Stage 3 Nitrogen dioxide reacts with water to make nitric acid and nitrogen monoxide.

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO \qquad \Delta H = -117\ kJ\ mol^{-1}$$

(a) (i) Construct an overall balanced equation for the production of nitric acid from ammonia and oxygen.

$4\ NH_3 + 8\ O_2 \rightarrow 4\ H_2O + 4\ HNO_3$

$NH_3 + 2\ O_2 \rightarrow H_2O + HNO_3$

[1]

(ii) Calculate the overall enthalpy change for the production of 1 mole of nitric acid.

$(-905) + (-114 \times 3) + (-117 \times 2) = -1364\ kJ\ mol^{-1}$ for the equation

$-1364/4 = -341 kJ\ mol^{-1}$ per mol HNO_3

[1]

(b) Draw a 'dot–and–cross' diagram to show the arrangement of outer electrons in a molecule of ammonia.

```
      xx
H o x N o x H
      xo
      H
```

[1]

[Turn over

(c) (i) Give the oxidation numbers of nitrogen in the nitrogen-containing species for the reaction in **stage 3**.

NO_2 +4

HNO_3 +5

NO +2 (1) any two correct
(2) all three correct

[2]

(ii) Explain why the reaction in stage 3 is described as a disproportionation reaction. Include reference to transfer of electrons in your answer.

relates the term disproportionation to the reaction described
M1 nitrogen /N (in nitrogen dioxide) is both gaining electrons and losing electrons during the reaction
M2 *refer to relevant transfer of electrons when NO_2 reacts to form HNO_3 and NO*
NO_2 to HNO_3 involves loss of electron(s)
AND
NO_2 to NO involves gain of electron(s)

[2]

(d) Identify one natural and one man-made occurrence of nitrogen oxides in the atmosphere.

natural thunderstorms

man-made power stations / cars

[2]

(e) Ammonia is a basic gas.

Describe how ammonia is able to act as a base.

the lone pair can form a dative bond with a proton (owtte)

[1]

[Total: 10]

3 The Group 16 elements show a change from non-metallic to metallic character down the group.

(a) Table 3.1 shows some properties of two Group 16 elements, O and Te, in their standard states. The table is incomplete.

Table 3.1

	oxygen	tellurium
state and appearance in standard state	colourless gas	silvery solid
electrical conductivity	poor	good
type of bonding	covalent	metallic
type of structure	simple	giant

(iii) Complete table 3.1.
[3]

(iv) Explain why tellurium has good electrical conductivity.

as a metal it has delocalised electrons

[1]

(v) Tellurium has two allotropes. Define allotrope.

the same element but different structure (owtte)

[1]

(b) Fig. 3.2 shows the boiling points of the simplest hydrides of the Group 16 elements, O to Te.

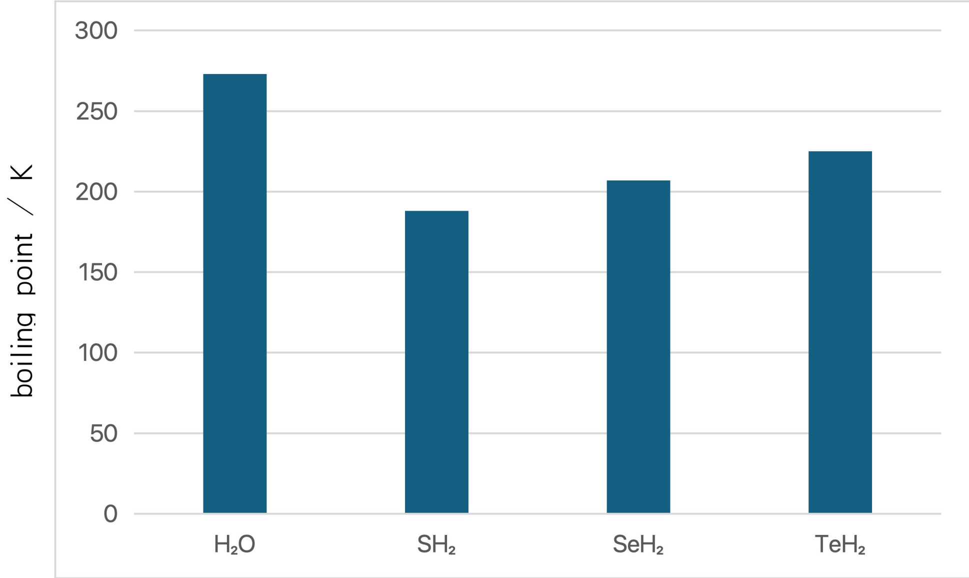


Figure 3.2

(i) Explain the trend in the boiling points of the Group 16 hydrides shown in Fig. 3.2.

water is the highest due to hydrogen bonding (1)

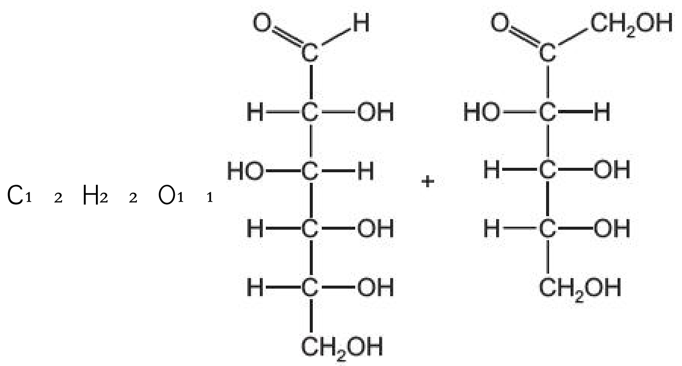
the rest increase in boiling point due to increased van der Waals / London dispersion forces (with increasing electron number) (1)

[2]

[Total: 7]

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

reaction **A**



glucose fructose

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

hydrolysis

[1]

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

M1 both have molecular formula – $C_6H_{12}O_6$

M2 *idea that in glucose and fructose there are the same number and type of atoms present but the atoms are arranged in a different order* ie one has a carbonyl group at the end of the chain/molecule and the other has a carbonyl group in the middle of the chain/molecule

[2]

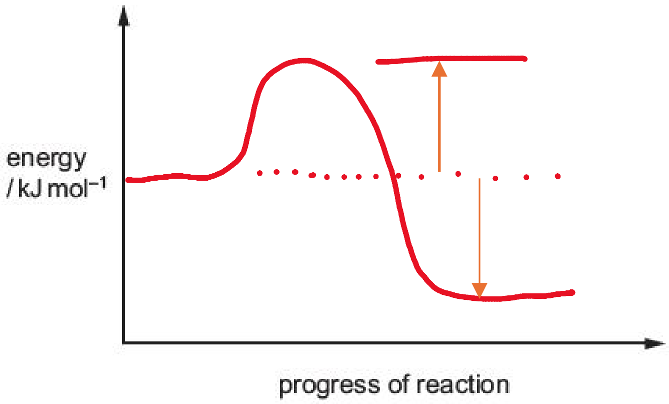
(c) Reaction **A** occurs faster in the presence of an enzyme. This is reaction **B**.

(i) Estimate values for the activation energy for reaction **A** and the enthalpy change for reaction **B**.

	activation energy /kJ mol⁻¹	enthalpy change /kJ mol⁻¹
reaction A	*more than +29*	−14
reaction B	+29	−14

[2]

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



M1 show the energy of the reactants > products AND label ΔH using the predicted value given in (i)

M2 show the energy of the reactants > products AND label ΔH using the predicted value given in (i)

[2]

(d) 1.00g of glucose, $C_6H_{12}O_6$, 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 32.8 °C.

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

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

M1 (enthalpy change) when 1 mole of glucose

M2 burns/combusts/reacts in excess air/oxygen
OR
completely burns/combusts/reacts in air/oxygen

[2]

(ii) Calculate the enthalpy change, in kJ mol^{-1}, for the combustion of glucose.

Assume that all of the heat energy produced is transferred to the water.

Show your working.

M1 *for finding amount of energy released per gram of sucrose using* ΔH / Q = mcΔT = (–)250 x 4.18 x (32.8–25) = (–)8151 J per gram **OR** (–)8.151 kJ / g

M2 for finding amount (mol) glucose in1g = 1/180 mol

M3 = M1 / (M2 x1 000)

$\Delta H = -1470\ kJ\ mol^{-1}$ (3 sig figs) OR $-1467\ kJ\ mol^{-1}$ (4 sig figs)

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

(iii) Estimate a value for the enthalpy change of combustion of fructose.

same value as (ii)

[1]

[Total: 13]

5 An unlabelled bottle contains a straight–chain halogenoalkane, **P**. The molecular formula of **P** is C_4H_9X, where **X** is a halogen; bromine, chlorine or iodine.

(a) A test is carried out to identify the halogen present in **P**.

A sample of **P** is added to NaOH(aq) and warmed. Dilute nitric acid is then added followed by
a few drops of aqueous silver nitrate. A cream precipitate is observed.

(i) Suggest the identity of **X**.

bromine / Br

[1]

(ii) Write an ionic equation to describe the formation of the cream precipitate. Include state symbols.

$Ag^+(aq) + X^-(aq) \rightarrow AgX(s)$ **OR** $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$

[1]

(iii) Describe a further test which would confirm the identity of **X**.

M1 *reagent*
Add (aqueous) ammonia

M2 *expected result*
EITHER (Dilute ammonia) – partial amount precipitate dissolves OR not much precipitate dissolves
OR add concentrated ammonia – precipitate dissolves

[2]

(b) The reaction of **P** with NaOH(aq) tends to proceed via an S_N2 mechanism.

(ii) Suggest the structure of the straight–chain halogenoalkane **P**.

$CH_3-CH_2-CH_2-CH_2-Br$

[1]

(iii) Explain why the reaction tends to proceed via an S_N2 mechanism rather than an S_N1 mechanism.

M1 primary / 1^0 (carbo)cation formed is not very stable

M2 EITHER (as) only one alkyl group exerting an inductive effect
OR only one alkyl group so the charge is (more) localised on the C+

[2]

(iv) Draw a labelled mechanism of the reaction between P and hydroxide ions. Include all relevant dipoles, lone pairs and curly arrows in your answer.

M1 $\delta+$C—Br$\delta-$ dipole AND hydroxide lone pair AND hydroxide charge shown

M2 curly arrow from HO: to C$\delta+$ AND from C—Br bond to Br atom shown

M3 butan—1—ol and Br^- shown as products

[3]

(c) Two different halogenoalkanes, **Q** and **R**, both with the molecular formula C_4H_9Cl, are separately dissolved in ethanol and heated under reflux with sodium hydroxide.

The major organic product of each of these reactions is methylpropene.

(i) Name the type of reaction occurring.

elimination

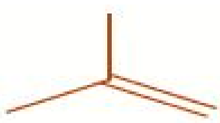
[1]

(ii) Write an equation, using molecular formulae, to represent the reaction occurring.

$C_4H_9Cl + NaOH \rightarrow C_4H_8 + NaCl + H_2O$

[1]

(iii) Draw the structure of methylpropene.



ONLY

[1]

(iv) Give the names of P and R. (this should have been Q and R, so accept any two answers)

Q/R 2—chloro(—2—)methylpropane / 1—chloro(—2—)methylpropane
P 1—bromobutane

[2]

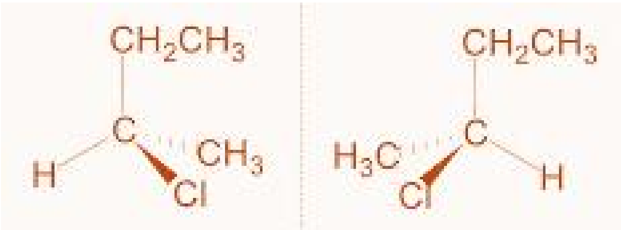
(d) There is a structural isomer, **S**, of C_4H_9Cl which displays optical isomerism.

(i) Explain what is meant by optical isomerism.

two compounds which contain the same number and kinds of atoms, and bonds (i.e., the connectivity between atoms is the same), and different spatial arrangements of the atoms, but which have non–superimposable mirror images

[1]

(ii) Draw the two optical isomers of **S**.



[2]

[Total: 18]

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Important values, constants and standards

molar gas constant	$R = 8.31\ J\ K^{-1}\ mol^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\ C\ mol^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23}\ mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\ C$
molar volume of gas	$V_m = 22.4\ dm^3\ mol^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\ dm^3\ mol^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\ mol^2\ dm^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\ kJ\ kg^{-1}\ K^{-1}$ ($4.18\ J\ g^{-1}\ K^{-1}$)

The Periodic Table of Elements

Key

atomic number atomic symbol name relative atomic mass

Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3											13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –