Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

6887091367

CHEMISTRY **9701/21**

Paper 2 AS Level Structured Questions **May/June 2023**

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, centre number 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.

This document has **16** pages. Any blank pages are indicated.

1 Tellurium is an element in Group 16. The most common isotope of tellurium is ^{130}Te. Its electronic configuration is [Kr] $4d^{10}$ $5s^{2}$ $5p^{4}$.

(a) Complete Table 1.1.

Table 1.1

	nucleon number	number of neutrons	number of electrons
^{130}Te			

[3]

(b) Identify the sub-shell in an atom of Te that contains electrons with the lowest energy.

.... [1]

(c) Construct an equation to represent the first ionisation energy of Te.

.... [1]

(d) **(i)** The radius of Te ions decreases after each successive ionisation.

State **two** factors that are responsible for the increase in the first six ionisation energies of Te.

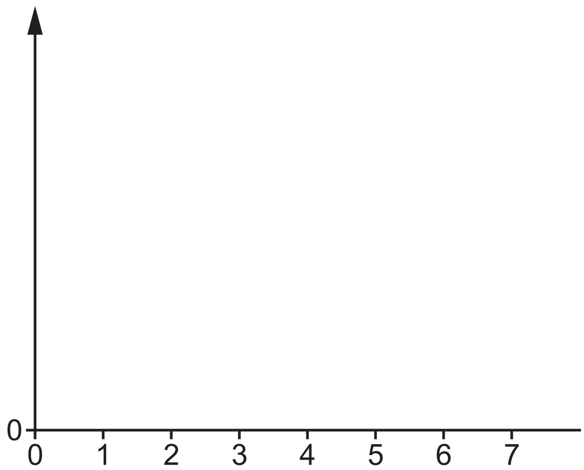
....

....

.... [2]

(ii) Sketch a graph in Fig. 1.1 to show the trend in the first **seven** ionisation energies of Te.

ionisation energy / $kJ\,mol^{-1}$



successive ionisation

Fig. 1.1

[2]

(e) Te reacts with F_2 at 150 °C to form TeF_x. Molecules of TeF_x are octahedral with bond angles of 90°.

Explain why TeF_x is octahedral with bond angles of 90°.

....

....

.... [2]

(f) TeF_x reacts with water to form tellurium hydroxide and HF. The oxidation number of tellurium does **not** change during this reaction.

(i) Construct an equation for the reaction of TeF_x with water.

.... [1]

(ii) Name the type of reaction that occurs when TeF_x reacts with water.

.... [1]

[Total: 13]

2 A neutralisation reaction occurs when NaOH(aq) is added to H_2SO_4(aq).

equation 1 $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

(a) Define enthalpy change of neutralisation, ΔH_{neut}.

....

....

.... [2]

(b) An experiment is carried out to calculate ΔH_{neut} for the reaction between NaOH(aq) and H_2SO_4(aq).

$100\,cm^3$ of $1.00\,mol\,dm^{-3}$ NaOH(aq) is added to $75\,cm^3$ of $1.00\,mol\,dm^{-3}$ H_2SO_4(aq) in a polystyrene cup and stirred. Results from the experiment are shown in Table 2.1.

Table 2.1

initial temperature of NaOH(aq) / °C	20.0
initial temperature of H_2SO_4(aq) / °C	20.0
maximum temperature of mixture / °C	27.8

(i) Use equation 1 to calculate the amount, in mol, of H_2SO_4(aq) that is neutralised in the experiment.

amount of H_2SO_4(aq) neutralised = ... mol [1]

(ii) Calculate ΔH_{neut} using the results in Table 2.1. Include units in your answer.

Assume that:
- the specific heat capacity of the final solution is $4.18\,J\,g^{-1}\,K^{-1}$
- $1.00\,cm^3$ of the final solution has a mass of 1.00 g
- there is no heat loss to the surroundings
- full dissociation of H_2SO_4(aq) occurs
- the experiment takes place at constant pressure.

Show your working.

ΔH_{neut} = ... units .... [3]

(c) **(i)** Complete the equation for the reaction that occurs when a solution of $Ba(OH)_2$ is added to aqueous sulfuric acid. Include state symbols.

.......$H_2SO_4(aq)$ + ...$Ba(OH)_2(aq) \rightarrow$ ....

[2]

(ii) Suggest why the enthalpy change of neutralisation cannot be determined using the addition of dilute sulfuric acid to aqueous barium hydroxide.

....

.... [1]

[Total: 9]

3 Chlorine is a very reactive element.

(a) Chlorine reacts with silicon to form silicon(IV) chloride.
Describe the appearance of silicon(IV) chloride at room temperature and pressure. State its structure and bonding.

appearance ....

structure and bonding ....
[2]

(b) Samples of magnesium chloride and phosphorus(V) chloride are added to separate beakers of cold water.

Complete Table 3.1. Ignore temperature changes when considering observations for these reactions.

Table 3.1

	magnesium chloride	phosphorus(V) chloride
appearance at room temperature		
one similarity in observation on addition to cold water		
one difference in observation on addition to cold water		
pH of final solution		

[4]

(c) **(i)** State the reagent and conditions required for the formation of sodium chlorate(V) from Cl_2(g).

.... [1]

(ii) Explain why the reaction in **(c)(i)** is described as a disproportionation reaction.
Your answer should refer to relevant species and their oxidation numbers.

....

.... [1]

(d) Chlorine reacts with methane in a series of reactions to produce chloroalkanes.

(i) State the conditions required for chlorine to react with methane.

.... [1]

(ii) One of the products of the reaction is CH_2Cl_2 which reacts further to produce $CHCl_3$.

Complete Table 3.2 to show details of the mechanism that forms $CHCl_3$ from CH_2Cl_2.

Table 3.2

name of step	equation
initiation	....
propagation	$CH_2Cl_2 + Cl\bullet \rightarrow$ ....
termination	.... $\rightarrow CHCl_3$

[3]

(e) $CHCl_3$ and HF are used to form $CHClF_2$ in a substitution reaction.

Construct an equation for this reaction.

.... [1]

(f) **X** is a product of the substitution reaction that occurs when $CHClF_2$ reacts with Br_2.

There is only one naturally occurring isotope of fluorine, ^{19}F.

The mass spectrum of **X** shows molecular ion peaks at m/e = 164, 166 and 168.

Complete Table 3.3 to show **all** the molecular ions responsible for each peak.

Table 3.3

m/e	formulae of molecular ions
164	
166	
168	$(CF_2{}^{37}Cl{}^{81}Br)^+$

[2]

[Total: 15]

4 **V** is a colourless liquid.

V

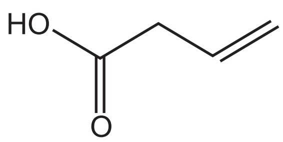


Fig. 4.1

(a) **V** reacts with an excess of $LiAlH_4$ to form **W**.

(i) Draw the structure of **W** in the box.

W

[1]

(ii) Identify the role of $LiAlH_4$ in the reaction with **V**.

.... [1]

(b) **V** reacts to form **Z** in a single reaction, as shown in Fig. 4.2.

V **Z**

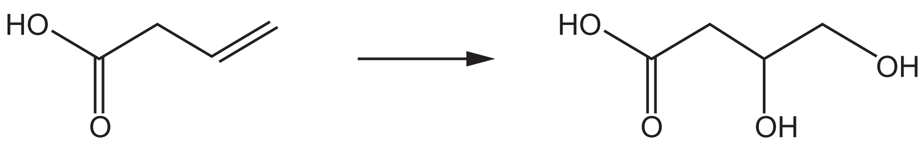


Fig. 4.2

(i) Suggest the reagent and conditions needed to form **Z** from **V**.

.... [1]

(ii) Deduce the empirical formula of **Z**.

.... [1]

(iii) Complete Table 4.1 to show the number of sp^2 and sp^3 hybridised carbon atoms that are present in a molecule of **V**.

Table 4.1

type of hybridisation	sp^2	sp^3
number of carbon atoms in **V**		

[2]

(c) **Q** contains the elements carbon, hydrogen and oxygen only. It is a saturated molecule with no branching in its carbon backbone.
Q contains only one functional group.
The relative molecular mass of **Q** is 88.
No effervescence is seen when Na_2CO_3 is added to **Q**.
Effervescence is seen when sodium is added to **Q**.
Q reacts with alkaline I_2(aq) to form a yellow precipitate.

Draw the structure of **Q** in the box.

Q

[2]

[Total: 8]

5 **(a)** Molecule **M** is present in petrol, a fuel used in cars. **M** is a saturated, non-cyclic hydrocarbon. **M** contains eight carbon atoms.

(i) Construct an equation for the complete combustion of **M**.

.... [2]

(ii) Describe how the composition of products differs when incomplete combustion of **M** occurs.

....

.... [2]

(b) When petrol is burned in an internal combustion engine, oxides of nitrogen are released into the atmosphere. Oxides of nitrogen are responsible for the formation of acid rain.

(i) Suggest the conditions required for the production of oxides of nitrogen during combustion of **M** in an internal combustion engine. Use an appropriate equation in your answer.

....

....

....

.... [2]

(ii) Describe how acid rain is formed in the atmosphere in the presence of oxides of nitrogen and SO_2. Identify the role of the oxides of nitrogen in this process. Include **all** relevant equations.

....

....

....

.... [3]

(iii) State **one** other type of air pollution that is caused by the production of oxides of nitrogen in an internal combustion engine.

.... [1]

(c) Biodiesel **T** is a fuel made from vegetable oil **R**. Fig. 5.1 shows the production of **T** from **R** in a two-step process.

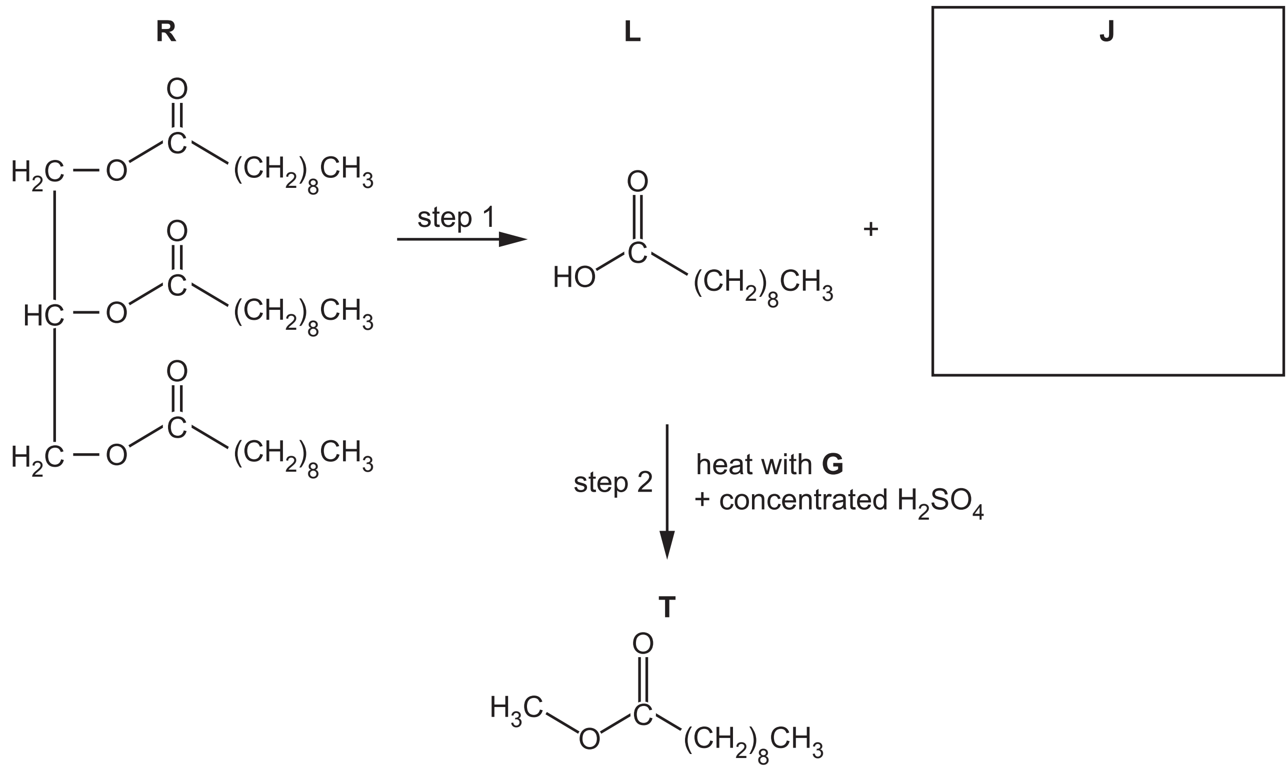


Fig. 5.1

(i) In step 1 all three ester groups in **R** react. Suggest a suitable reagent and conditions for step 1.

.... [1]

(ii) Draw the structural formula of **J** in the box in Fig. 5.1. [1]

(iii) Name the type of reaction that occurs in step 2.

.... [1]

(iv) Name organic reagent **G** used in step 2.

.... [1]

(v) **L** is called decanoic acid. Use systematic nomenclature to deduce the name of **T**.

.... [1]

[Total: 15]

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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 × 10^4 C mol^{-1}
Avogadro constant	L = 6.022 × 10^{23} mol^{-1}
electronic charge	e = –1.60 × 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 × 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

Group																	
1	2											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			**Key** atomic number atomic symbol name relative atomic mass								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	3	4	5	6	7	8	9	10	11	12	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 144.4	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 –