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ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2019

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



[SCH22]

SCH22

THURSDAY 23 MAY, MORNING

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 fourteen** questions.

Answer **all ten** questions in **Section A**. Record your answers by marking the appropriate letter on the answer sheet provided. Use only the spaces numbered 1 to 10. Keep in sequence when answering.

Answer **all four** questions in **Section 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.**

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.

Quality of written communication will be assessed in Question **13(a)(ii)**.

In Section A all questions carry equal marks, i.e. **one** mark for each question.

In Section B 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.

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24SCH2201

Section A – Multiple Choice

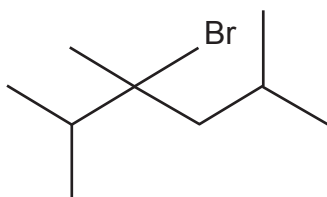
Select the correct response in each case and mark its code letter by connecting the dots as illustrated on the answer sheet.

Each multiple choice question is worth 1 mark.

- 1 How many carbon to carbon bonds are there in 3,3-dichloro-2-methylbutan-2-ol?
- A 3
- ☒ B 4
- C 5
- D 6
- 2 Which sequence of elements is arranged in order of increasing bond strength?
- ☒ A F_2 O_2 N_2
- B N_2 O_2 F_2
- C O_2 F_2 N_2
- D O_2 N_2 F_2
- 3 0.005 mole of a chloride of an element Z was mixed with water and the resulting solution required 25 cm^3 of 0.6 M aqueous silver nitrate for complete precipitation of silver chloride. Element Z is in Group
- ☒ A III.
- B IV.
- C V.
- D VI.



- 4 The bromoalkane below reacts with ethanolic potassium hydroxide and eliminates hydrogen bromide.



What is the number of alkenes formed and how many pairs of E/Z isomers exist?

	number of alkenes	pairs of E/Z isomers
A	2	1
B	2	2
C	3	1
D	3	2

- 5 The Williamson synthesis of an ether (ROR') is summed up by the following two steps:



Using propan-2-ol and 2-chlorobutane the ether formed is

- A $\text{CH}_3\text{CH}_2\text{CH}_2\text{OCH}(\text{CH}_3)\text{CH}_2\text{CH}_3$.
- B $\text{CH}_3\text{CH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{CH}_2\text{CH}_3$.
- C $\text{CH}_3\text{CH}(\text{CH}_3)\text{OCH}_2\text{CH}_2\text{CH}_2\text{CH}_3$.
- D** $\text{CH}_3\text{CH}(\text{CH}_3)\text{OCH}(\text{CH}_3)\text{CH}_2\text{CH}_3$.

[Turn over



6 Which of the following describes a dynamic equilibrium?

	concentration of reactants and products	forward and reverse reaction rates
☒ A	constant	equal
B	constant	not equal
C	not constant	equal
D	not constant	not equal

7 A mixture of potassium bromide and potassium carbonate contains 0.6 moles of bromide ion and 0.2 moles of carbonate ion. How many moles of potassium ions are present?

A 0.4

B 0.5

C 0.8

☒ D 1.0

8 The total pressure is increased in each of the following reactions. For which reaction would the yield of product(s) **not** change?

☒ A $\text{CO(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{CO}_2\text{(g)} + \text{H}_2\text{(g)}$

B $\text{CO(g)} + 2\text{H}_2\text{(g)} \rightleftharpoons \text{CH}_3\text{OH(g)}$

C $2\text{H}_2\text{(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{H}_2\text{O(g)}$

D $3\text{H}_2\text{(g)} + \text{CO(g)} \rightleftharpoons \text{CH}_4\text{(g)} + \text{H}_2\text{O(g)}$



9 One molecule of cuprimine contains one sulfur atom. The percentage, by mass, of sulfur in cuprimine is 21.47%. The relative molecular mass of cuprimine is

- A 85.
- B 101.
- C 125.
- ☒ D 149.

10 The general formula of an alkyl group is

- A C_nH_{n+1}
- B C_nH_{n-1}
- ☒ C C_nH_{2n+1}
- D C_nH_{2n-1}



Section B

Answer all **four** questions in this section

- 11** Group II metal nitrates are formed when either the metal, the metal oxide or the metal carbonate are reacted with nitric acid. Metal nitrates are very soluble in water and all of the reactions proceed normally, apart from magnesium with nitric acid, because nitric acid is an oxidising agent and causes other reactions to take place.

(a) Write equations for the reactions of calcium, calcium oxide and calcium carbonate with dilute nitric acid.

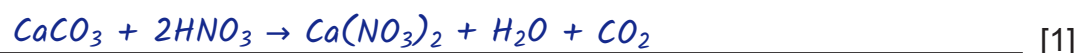
(i) calcium:



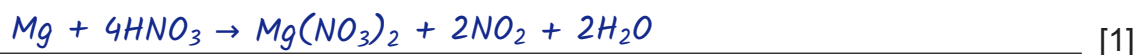
(ii) calcium oxide:



(iii) calcium carbonate:



(b) Magnesium does not react with most concentrations of nitric acid to give hydrogen. Instead, nitrogen(IV) oxide together with magnesium nitrate and water are produced. Write the equation for the reaction.



(c) Group II metal nitrates increase in thermal stability as the Group is descended.

(i) Explain what is meant by the term **thermal stability**.

The resistance of a compound to decomposition when it is heated to a high temperature.

[1]

(ii) Explain why thermal stability increases down the Group.

The metal cation is larger (lower charge density) down the Group, so it polarises (distorts) the nitrate ion less.

[1]

(d) When heated, the Group II nitrates, $M(\text{NO}_3)_2$, decompose according to the following equation:



(i) Explain why the residue left after the reaction gives an alkaline solution when dissolved in water.

The residue is the metal oxide, which is basic: it reacts with water to form a soluble hydroxide (OH^- ions).

[1]

(ii) If 3.6 g of strontium nitrate is heated and completely decomposes, what is the total volume of gases collected at 20°C and a pressure of one atmosphere?

$$M_r, \text{Sr}(\text{NO}_3)_2 = 88 + 28 + 96 = 212; n = 3.6 \div 212 = 0.0170$$

$$2 \text{ mol nitrate} \rightarrow 5 \text{ mol gas}; n(\text{gas}) = 0.0170 \times 2.5 = 0.0425$$

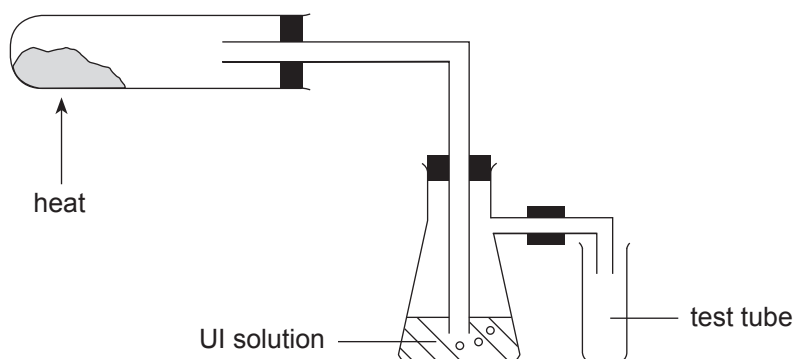
$$\text{volume} = 0.0425 \times 24 = 1.02 \text{ dm}^3 = 1.0 \text{ dm}^3$$

[3]

[Turn over]



- (iii) The diagram below shows the gases from the decomposition of a nitrate passing through Universal Indicator (UI) solution and one gas being collected in a test tube. Explain why the UI solution goes red and name the gas collected in the test tube.

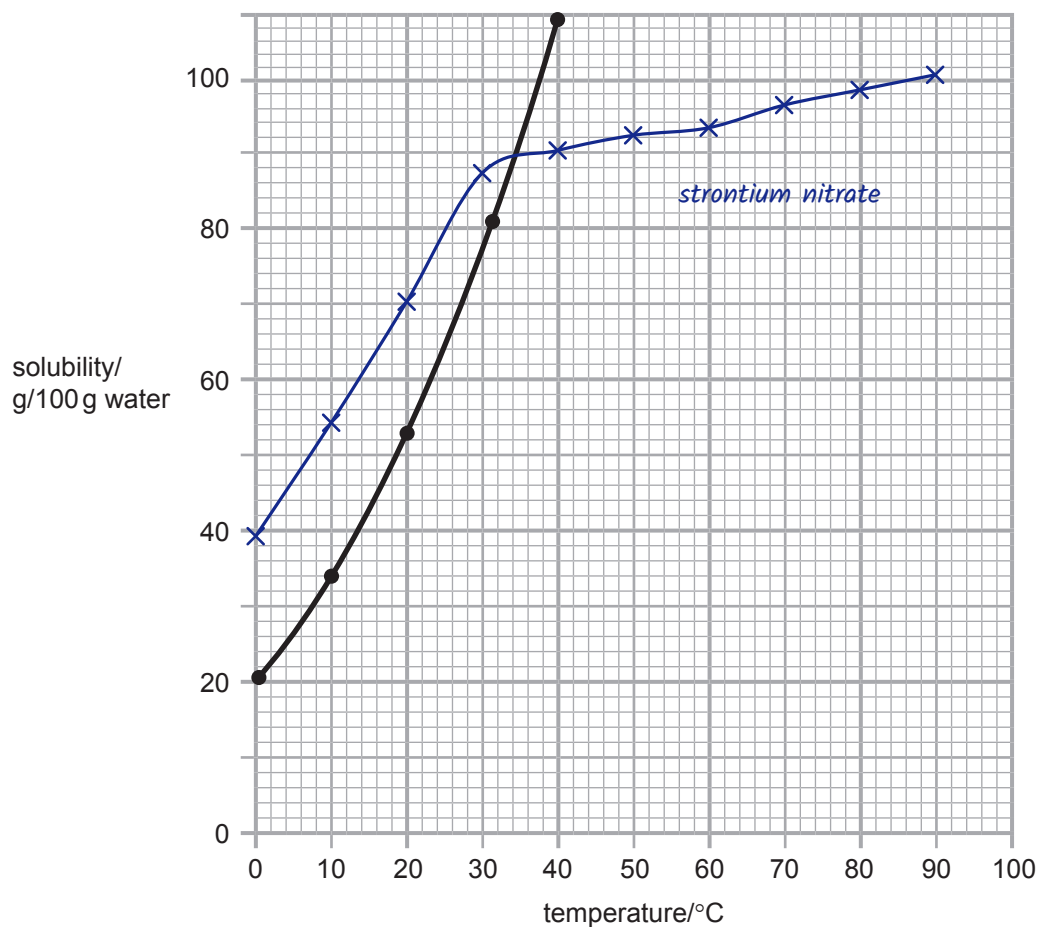


Nitrogen(IV) oxide is a strongly acidic oxide which dissolves in the water to form acids. The gas collected is oxygen.

[2]



- (e) Group II metal nitrates are soluble in water. The solubility curve for the Group I nitrate, rubidium nitrate, is shown below.



The following data refers to the solubility of strontium nitrate with temperature.

Solubility/ g/100 g water	40	55	71	88	91	93	94	97	99	101
Temperature/°C	0	10	20	30	40	50	60	70	80	90

- (i) Plot the solubility curve for strontium nitrate on the axes above. [1]

- (ii) Determine the temperature at which rubidium nitrate and strontium nitrate have the same solubility.

34 °C (where the two curves cross)

[1]

[Turn over]



12 Hypochlorous acid has the formula HOCl. It adds to alkenes to form chlorohydrins.



- (a) (i) Calculate the enthalpy change for the reaction between ethene and hypochlorous acid using the following average bond enthalpies.

bond	enthalpy/ kJ mol^{-1}
C=C	612
C—C	347
Cl—O	272
C—Cl	346
C—O	358

Bonds broken: $\text{C}=\text{C} + \text{Cl}-\text{O} = 612 + 272 = +884 \text{ kJ}$

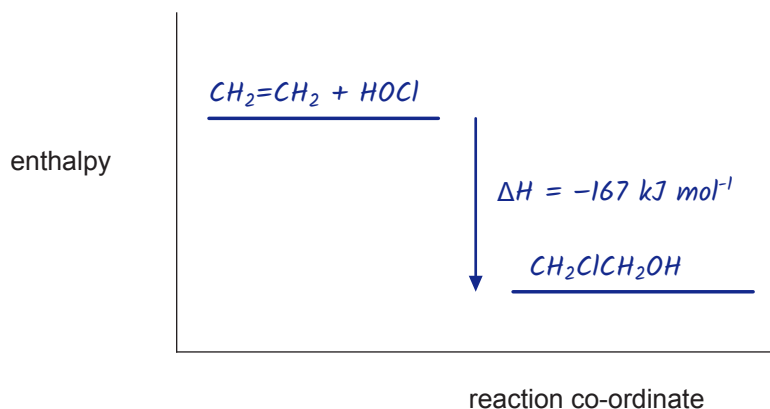
Bonds formed: $\text{C}-\text{C} + \text{C}-\text{Cl} + \text{C}-\text{O} = 347 + 346 + 358 =$

-1051 kJ

$\Delta H = +884 - 1051 = -167 \text{ kJ mol}^{-1}$

[3]

- (ii) Construct a simple labelled enthalpy level diagram for the reaction between ethene and hypochlorous acid. Insert the enthalpy value calculated in part (i) onto the diagram.



[2]



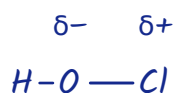
(b) Hypochlorous acid adds to alkenes because it has a polar bond, HO—Cl.

(i) Explain what is meant by the term **polar bond**.

A covalent bond in which the bonding pair of electrons is shared

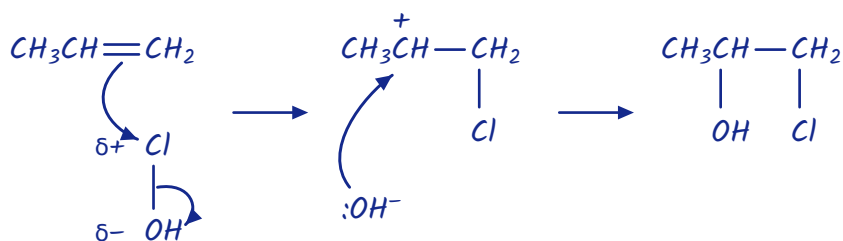
unequally, because the atoms have different electronegativities. [2]

(ii) Draw the polarity of a hypochlorous acid molecule.



[1]

(iii) Draw the mechanism, using curly arrows, for the reaction of hypochlorous acid with propene to form CH₂ClCHOHCH₃.



lone pair on O of OH⁻ attacks the carbocation

[4]

(iv) Name the compound CH₂ClCHOHCH₃.

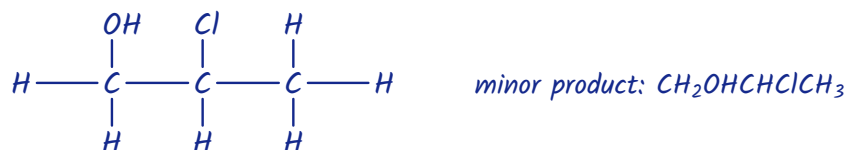
1-chloropropan-2-ol

[2]

[Turn over]



- (v) The compound $\text{CH}_2\text{ClCHOHCH}_3$ is the major product. Draw the structure of the minor product and explain why it is the minor product.



It is the minor product because it forms via a primary carbocation, which is less stable than the secondary carbocation that leads to the major product.

[2]

- (vi) If the reaction in part (iii) is carried out in the presence of sodium nitrite, NaNO_2 , some $\text{CH}_2\text{ClCHNO}_2\text{CH}_3$ is formed. Suggest how this compound is formed.

The nitrite ion, NO_2^- , acts as a nucleophile and reacts with the carbocation intermediate (in competition with OH^-).

[1]

- (c) Chlorohydrins are useful in synthetic chemistry because they are bifunctional.

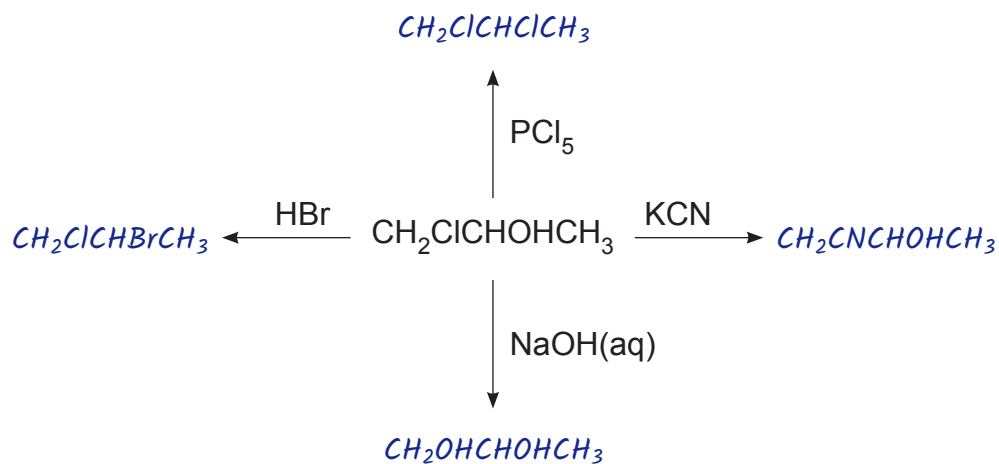
- (i) Suggest the meaning of the term **bifunctional**.

The molecule has two different reactive functional groups (Cl and OH).

[1]



- (ii) Complete the following reaction scheme for $\text{CH}_2\text{ClCHOHCH}_3$ by drawing the organic products.

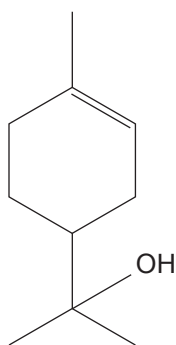


[4]

[Turn over]



13 α -Terpineol is a terpene which is the main ingredient in pine oil.



α -terpineol

It is a colourless liquid with a smell of violets. The boiling point of α -terpineol is $214\text{--}216^\circ\text{C}$ and its density is 0.93 g cm^{-3} . α -Terpineol is slightly soluble in water; 2.42 g dissolves in 1 dm^3 of water at room temperature.

- (a) (i) Describe and explain, using calculated values, what you would observe if you added 1.1 g of α -terpineol to 200 cm^3 of water in a beaker at room temperature and stirred the mixture.

$$\text{Mass that dissolves in } 200\text{ cm}^3 = 2.42 \times 200 \div 1000 = 0.484$$

g, so only about half of the 1.1 g dissolves.

$$\text{Mass undissolved} = 1.1 - 0.484 = 0.616\text{ g}; \text{ volume} = 0.616 \div$$

$$0.93 = 0.66\text{ cm}^3.$$

α -Terpineol (0.93 g cm^{-3}) is less dense than water, so the

undissolved 0.66 cm^3 forms a separate colourless layer floating

on top of the water.

[4]



- (ii) Explain, with full experimental detail, how you would separate α -terpineol from a mixture of 50 cm³ of α -terpineol and 10 cm³ of water. Your method should include separating with a funnel, distillation and drying.

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

Pour the mixture into a separating funnel, stopper and allow the layers to settle. Run off the lower water layer through the tap.

Put the upper α -terpineol layer in a distillation flask with anti-bumping granules, distil off the remaining water, then collect the α -terpineol that distils at 214 to 216 °C.

Add anhydrous sodium sulfate to the distillate, swirl and leave until clear, then decant or filter off the dry α -terpineol.

[6]

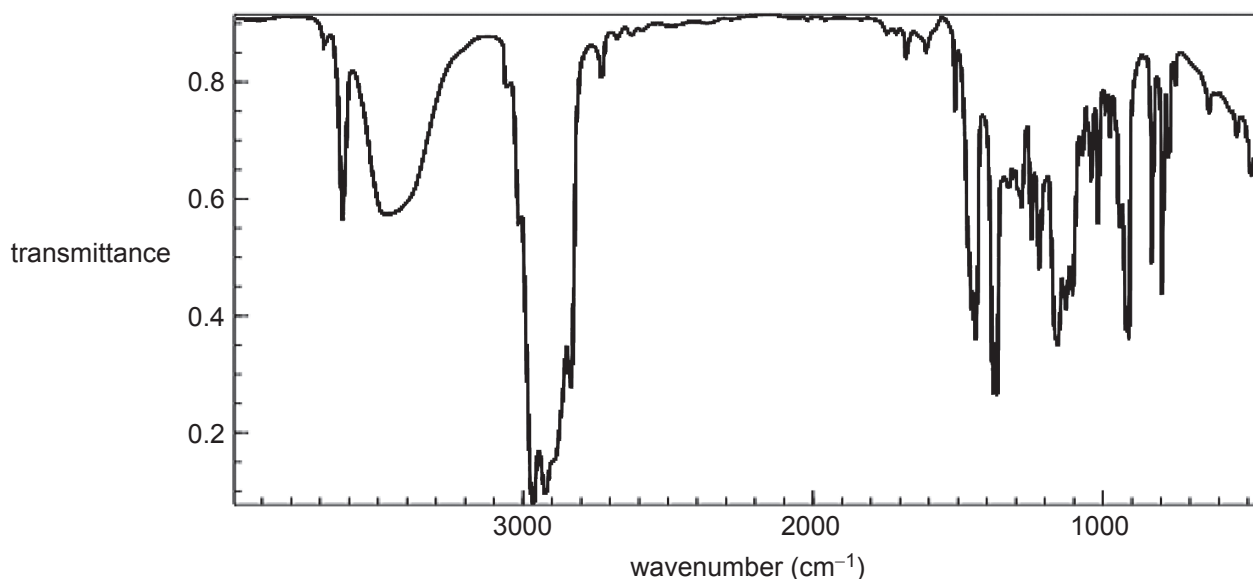
[Turn over

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- (b) The purity of the α -terpineol obtained from part (a) may be determined by the infrared spectrum which is shown below.



"Data from NIST Standard Reference Database 69: NIST Chemistry WebBook
© National Institute of Standard and Technology. U.S. Department of Commerce"

- (i) Explain why molecules absorb infrared radiation producing infrared spectra.

Bonds (groups of atoms) within the molecule vibrate at characteristic frequencies, so they absorb infrared radiation of the frequency that matches their vibration (molecular vibrations).

[2]

- (ii) Identify the peaks, by stating the range of wavenumbers in the spectrum, which correspond to the functional groups in the molecule.

1600 to 1700 cm⁻¹: C=C (alkene)

3200 to 3600 cm⁻¹: O-H (alcohol)

[2]



- (iii) Explain how you could use infrared spectrometry to determine that a sample of α -terpineol is pure and free from all impurities.

Compare its spectrum with that of pure α -terpineol: if they are

identical, with no extra peaks, the sample is pure. [1]

- (c) (i) Explain, using the structure of α -terpineol, whether the alcohol is primary, secondary or tertiary.

It is tertiary: the carbon attached to the OH group is bonded to

three other carbon atoms. [2]

- (ii) State what would be observed when a few drops of α -terpineol are added to acidified potassium dichromate(VI) and the mixture is heated.

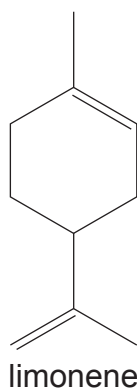
The orange colour remains; there is no change.

[1]

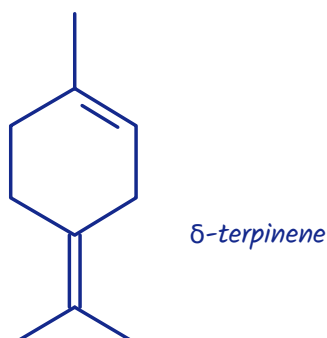
[Turn over



(d) When α -terpineol is dehydrated it forms a mixture of limonene and δ -terpinene.



Suggest the structure of δ -terpinene.



[1]

(e) Limonene is an unsaturated hydrocarbon which reacts with bromine and hydrogen.

(i) Define the term **unsaturated**.

Contains at least one carbon to carbon double (or triple) bond,

C=C or C $\equiv$ C.

[1]



- (ii) Explain, giving experimental detail, how you would use bromine water to test for unsaturation.

Add a few drops of bromine water to the sample in a test tube,

stopper it and shake.

The orange bromine water is decolourised (turns colourless),

showing the compound is unsaturated.

[3]

- (iii) Explain, naming the catalyst, what is meant by catalytic hydrogenation.

Hydrogen is added across a C=C double bond to form a saturated

compound, using a nickel catalyst (heated, about 150 °C).

[2]

- (iv) Cadinene, $C_{15}H_{24}$, reacts with hydrogen and becomes completely saturated. 0.34 g of cadinene reacts with 80 cm^3 of hydrogen at 20°C and a pressure of one atmosphere. Calculate the number of double bonds in a molecule of cadinene.

$$M_r C_{15}H_{24} = 180 + 24 = 204; n = 0.34 \div 204 = 0.00167 \text{ mol}$$

$$\text{moles } H_2 = 80 \div 24000 = 0.00333 \text{ mol}$$

$$\text{ratio } H_2 : \text{cadinene} = 0.00333 : 0.00167 = 2 : 1$$

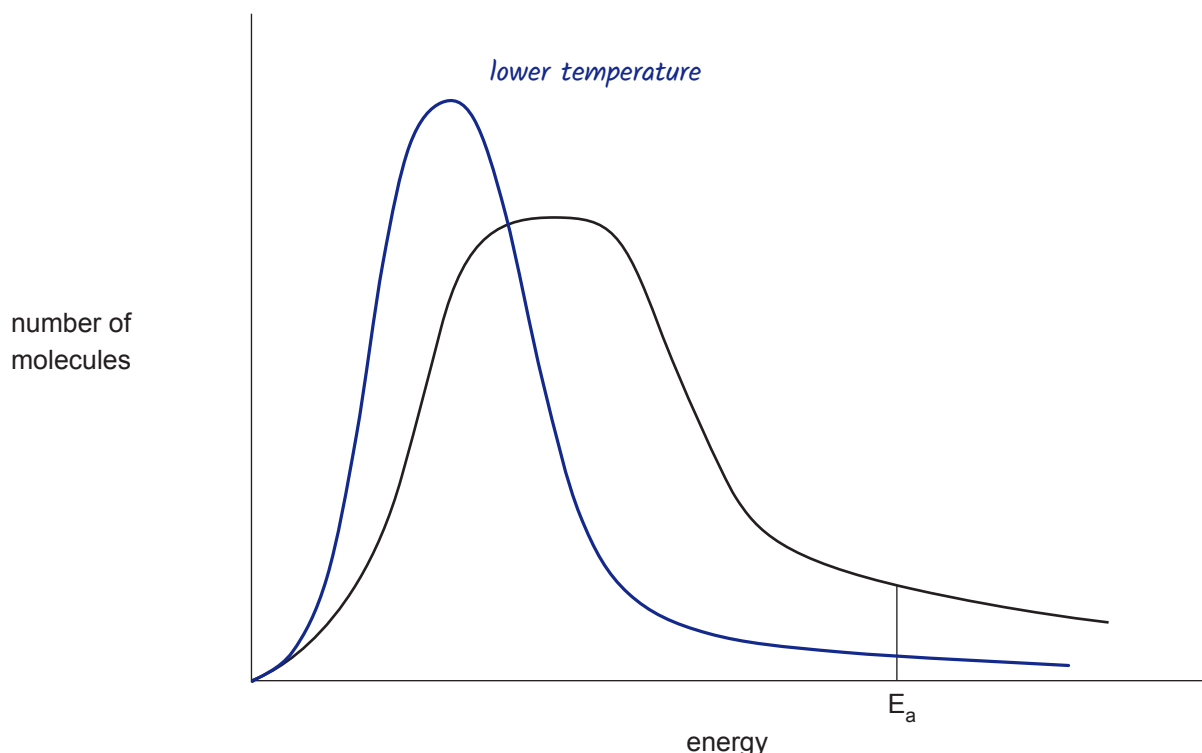
so there are 2 C=C double bonds in each molecule of cadinene.

[3]

[Turn over



- 14 The Maxwell–Boltzmann distribution curve below shows the distribution of molecular energies in a mixture of the gases sulfur dioxide and oxygen at 25 °C.



The x-axis can either be labelled as energy or speed. The distribution curve starts at the point 0,0 and at the end approaches the x-axis but does not touch it. The symbol E_a is the activation energy.

- (a) Draw, on the axes above, the Maxwell–Boltzmann distribution curve for a mixture of sulfur dioxide and oxygen, at a *lower* temperature.

[2]

- (b) Explain why the x-axis can either be labelled as energy or speed.

A moving molecule has kinetic energy, which depends on its speed

$(E_k = \frac{1}{2}mv^2)$.

[1]



- (c) Explain what it means if the distribution curve starts at the point 0,0.

There are no molecules with zero energy (zero molecules have zero energy).

[1]

- (d) Explain what it would mean if the Maxwell–Boltzmann curve touched the x-axis at a final energy value.

No molecules would have an energy greater than this final value.

[1]

- (e) Activation energy varies from reaction to reaction.

- (i) Explain the term **activation energy**.

The minimum amount of energy that colliding particles need for a reaction to occur.

[2]

- (ii) Comment on the reaction speed between silver ions and chloride ions in aqueous solution and how it relates to activation energy.

The reaction is very fast (instant precipitate) because its activation energy is very low.

[2]

- (iii) State the effect of a catalyst on the activation energy of a reaction.

It lowers the activation energy.

[1]

[Turn over



(f) The reaction between sulfur dioxide and oxygen is part of the process to manufacture sulfuric acid.

(i) What is the name of this industrial process?

Contact process

[1]

(ii) Describe and explain the conditions used in this process for the reaction between sulfur dioxide and oxygen referring to temperature, pressure and catalyst.

temperature

About 450 °C. The reaction is exothermic, so a low temperature

would give a higher yield, but a high enough temperature is

needed for a fast rate: a compromise.

[2]

pressure

1 to 2 atm. High pressure would increase the yield (fewer moles

of gas on the right), but the conversion is already high (about

99%), so high pressure is not needed.

[2]

catalyst

Vanadium(V) oxide, V_2O_5 : effective and not poisoned by arsenic.

[1]





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24SCH2224

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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COUNCIL FOR THE CURRICULUM, EXAMINATIONS AND ASSESSMENT

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New
Specification



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

For first teaching from September 2016
For first award of AS Level in Summer 2017
For first award of A Level in Summer 2018
Subject Code: 1110

I II THE PERIODIC TABLE OF ELEMENTS 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						

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

^a
X
_b

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

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