Write your name here

Surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number | | | | | |

Candidate Number | | | | |

Chemistry

Advanced Subsidiary
Unit 2: Application of Core Principles of Chemistry

Wednesday 18 January 2017 – Morning
Time: 1 hour 30 minutes

Paper Reference
WCH02/01

Candidates may use a calculator.

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed
  – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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6/5/6/5/5/

P 4 8 3 6 8 A 0 1 2 4

Pearson

SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Which is a disproportionation reaction?

☒ **A** $Cl_2 + 2KBr \rightarrow 2KCl + Br_2$

☒ **B** $Cl_2 + 2Na \rightarrow 2NaCl$

☒ **C** $8Cl_2 + P_4 \rightarrow 2PCl_3 + 2PCl_5$

☒ **D** $Cl_2 + 2NaOH \rightarrow NaCl + NaClO + H_2O$

(Total for Question 1 = 1 mark)

2 In which of the following would you expect the paired species to have **different** bond angles?

☒ **A** H_2O NH_2^-

☒ **B** NH_4^+ CH_4

☒ **C** BF_3 NH_3

☒ **D** $BeCl_2$ CO_2

(Total for Question 2 = 1 mark)

3 Global warming is an environmental concern and results from greenhouse gases trapping radiation from the Earth.

Identify the type of radiation involved and its effect on greenhouse gases.

	Type of radiation	Effect
☒ **A**	Infrared	Bond breaking
☒ **B**	Infrared	Bond vibration
☒ **C**	Ultraviolet	Bond breaking
☒ **D**	Ultraviolet	Bond vibration

(Total for Question 3 = 1 mark)

4 The ozone layer is depleted by a series of reactions involving trichlorofluoromethane, $CFCl_3$. Some of the possible reactions are

Reaction 1 $O_3 + O \rightarrow 2O_2$

Reaction 2 $CFCl_3 \rightarrow CFCl_2^{\bullet} + Cl^{\bullet}$

Reaction 3 $O_3 + Cl^{\bullet} \rightarrow ClO^{\bullet} + O_2$

Reaction 4 $ClO^{\bullet} + O \rightarrow Cl^{\bullet} + O_2$

(a) Which is an initiation reaction?

(1)

☒ **A** Reaction 1

☒ **B** Reaction 2

☒ **C** Reaction 3

☒ **D** Reaction 4

(b) In the reactions shown above, what best describes the role of the chlorine free radical in the depletion of ozone?

(1)

☒ **A** Catalyst

☒ **B** Inhibitor

☒ **C** Initiator

☒ **D** Terminator

(c) Which of the following is a possible termination reaction?

(1)

☒ **A** $Cl^{\bullet} + O_2 \rightarrow ClO^{\bullet} + O$

☒ **B** $O + Cl^{\bullet} \rightarrow ClO^{\bullet}$

☒ **C** $ClO^{\bullet} + ClO^{\bullet} \rightarrow Cl_2O_2$

☒ **D** $CFCl_2^{\bullet} + O_3 \rightarrow CFCl_2O^{\bullet} + O_2$

(Total for Question 4 = 3 marks)

5 At room temperature, iodine is a solid and bromine is a liquid.
The best explanation for this is that

(1)

☒ **A** bromine has weaker permanent dipoles between the molecules.

☒ **B** bromine is more volatile.

☒ **C** iodine has stronger covalent bonds.

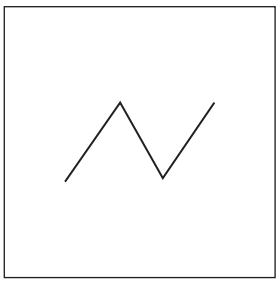
☒ **D** iodine has stronger London forces.

(Total for Question 5 = 1 mark)

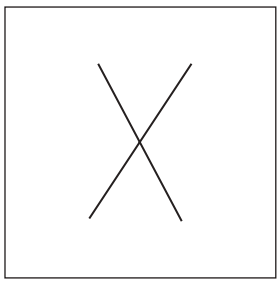
6 Which molecule will have the **highest** boiling temperature?

(1)

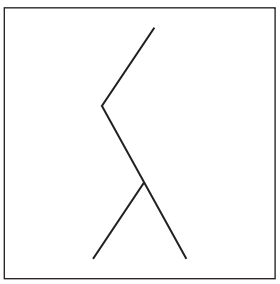
☒ **A**



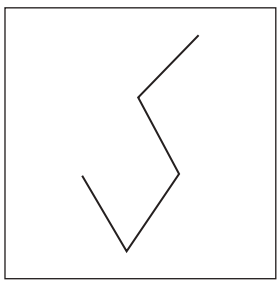
☒ **B**



☒ **C**



☒ **D**



(Total for Question 6 = 1 mark)

7 Covalent bond length is defined as the

(1)

☒ **A** distance from the nucleus of one atom to the outermost electron of the other atom.

☒ **B** distance from the nucleus of one atom to the nucleus of the other atom.

☒ **C** shortest distance from the outermost electron of one atom to the outermost electron of the other atom.

☒ **D** longest distance from the outermost electron of one atom to the outermost electron of the other atom.

(Total for Question 7 = 1 mark)

8 Hydrogen peroxide decomposes forming water and oxygen.

$$H_2O_2(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$

Which change does **not** increase the reaction rate?

☒ **A** Adding the powdered catalyst, MnO_2

☒ **B** Increasing the concentration of the hydrogen peroxide from 2 mol dm^{-3} to 4 mol dm^{-3}

☒ **C** Increasing the pressure from 2 atm to 4 atm

☒ **D** Increasing the temperature from 20 °C to 40 °C

(Total for Question 8 = 1 mark)

9 Consider the following reaction:

$$X_2(g) + 3Y_2(g) \rightleftharpoons 2XY_3(g)$$

Increasing the pressure increases the reaction **rate** because it

☒ **A** increases molecular energies.

☒ **B** shifts the position of equilibrium to the right.

☒ **C** increases the collision frequency.

☒ **D** decreases the activation energy.

(Total for Question 9 = 1 mark)

10 Which type of radiation is often used in the pharmaceutical industry to heat reaction mixtures?

☒ **A** Gamma

☒ **B** Microwave

☒ **C** Ultraviolet

☒ **D** X-ray

(Total for Question 10 = 1 mark)

11 The potassium halides, KCl, KBr and KI, can all react with concentrated sulfuric acid to produce

☒ **A** hydrogen halides.

☒ **B** hydrogen sulphide.

☒ **C** sulfur dioxide.

☒ **D** sulfur.

(Total for Question 11 = 1 mark)

12 The reaction between a potassium halide and silver nitrate in solution is

$$KX(aq) + AgNO_3(aq) \rightarrow KNO_3(aq) + AgX(s)$$

The ionic equation for this reaction is

☒ **A** $K^+(aq) + NO_3^-(aq) \rightarrow KNO_3(aq)$

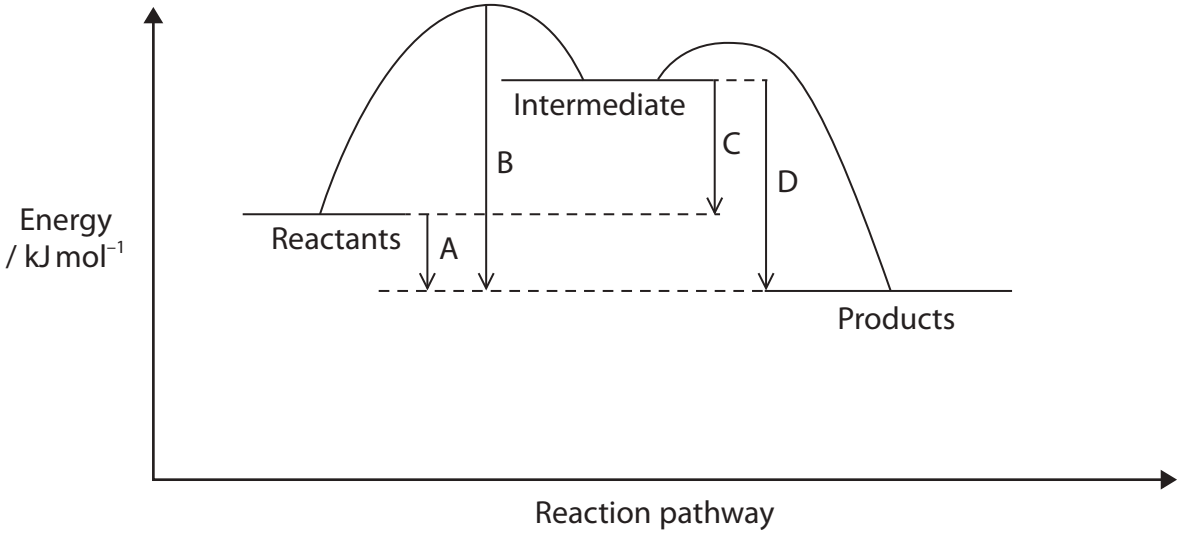
☒ **B** $KX(aq) + Ag^+(aq) \rightarrow K^+(aq) + AgX(s)$

☒ **C** $X^-(aq) + Ag^+(aq) \rightarrow AgX(s)$

☒ **D** $K^+(aq) + X^-(aq) + Ag^+(aq) + NO_3^-(aq) \rightarrow K^+(aq) + NO_3^-(aq) + AgX(s)$

(Total for Question 12 = 1 mark)

13 An energy level diagram for a reaction with an intermediate can be drawn as shown.



Which arrow indicates the enthalpy change for this reaction?

☒ **A**

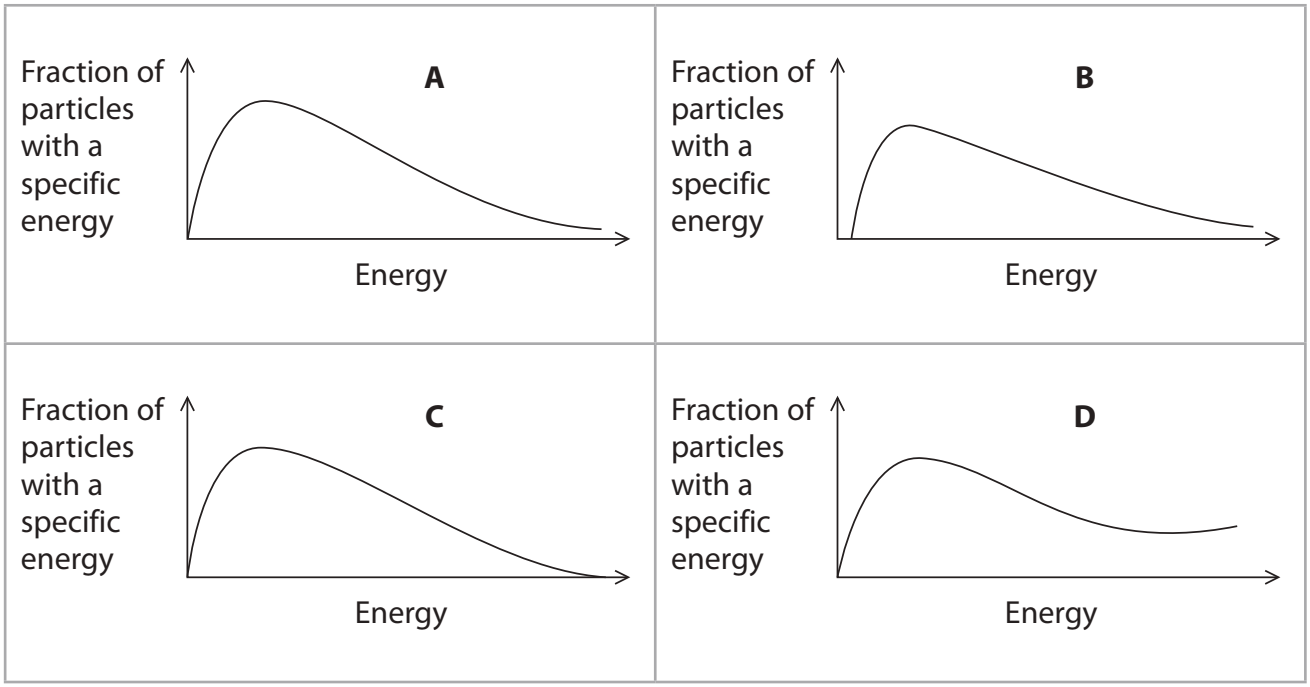
☒ **B**

☒ **C**

☒ **D**

(Total for Question 13 = 1 mark)

14 Which graph correctly shows the Maxwell-Boltzmann energy distribution?



☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 14 = 1 mark)

Use this space for rough working. Anything you write in this space will gain no credit.

15 Use the Pauling electronegativity values given in the table to answer the following questions.

H 2.1						
Li 1.0	Be 1.5	B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2	Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0

(a) Which compound has **covalent** bonds with the greatest polarity?

(1)

☒ **A** H_2O

☒ **B** CF_4

☒ **C** MgF_2

☒ **D** Al_2O_3

(b) Which compound is most ionic?

(1)

☒ **A** Li_2O

☒ **B** MgO

☒ **C** AlF_3

☒ **D** NaF

(Total for Question 15 = 2 marks)

Use this space for rough working. Anything you write in this space will gain no credit.

16 The table gives some data on fuels.

Fuel	Energy density / MJ l^{-1}	CO_2 produced on combustion / kg l^{-1}
Biodiesel	33	2.5
LPG	24	1.5
Petrol	32	2.3
Wood	10	0.9

Which fuel produces the smallest mass of carbon dioxide on combustion to generate 100 MJ of energy?

☒ **A** Biodiesel

☒ **B** LPG

☒ **C** Petrol

☒ **D** Wood

(Total for Question 16 = 1 mark)

17 Which combustion of ethanol produces no change in the volume of gas present at room temperature?

☒ **A** $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

☒ **B** $C_2H_5OH(l) + O_2(g) \rightarrow 2C(s) + 3H_2O(l)$

☒ **C** $C_2H_5OH(l) + 2O_2(g) \rightarrow 2CO(g) + 3H_2O(l)$

☒ **D** $C_2H_5OH(l) + 1½O_2(g) \rightarrow CO(g) + C(s) + 3H_2O(l)$

(Total for Question 17 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

18 Sulfur dioxide, SO_2, is added to commercial wine to act as an antioxidant and inhibitor of microbial growth. The SO_2 that is dissolved in the wine is called 'free' SO_2. However, there is also SO_2 combined with compounds in the wine; this 'bound' SO_2 can be released by the addition of sodium hydroxide. The 'free' SO_2 and 'bound' SO_2 give the 'total' SO_2 present in the wine.
The amount of sulfur dioxide can be determined by titration with an iodine solution. The equation is

$$SO_2 + I_2 + 2H_2O \rightarrow 2I^- + 4H^+ + SO_4^{2-}$$

Free SO_2 determination
A 50.00 cm^3 sample of white wine was pipetted into a conical flask. The sample was acidified with 5 cm^3 of dilute sulfuric acid and 2 cm^3 of starch solution was added. This mixture was titrated with 0.00100 mol dm^{-3} iodine solution. The end-point was taken when a dark blue colour persisted for about two minutes. The procedure was repeated and the following burette readings obtained.

	1	2
Final volume / cm^3	25.60	41.20
Initial volume / cm^3	10.00	25.60
Volume added / cm^3	15.60	15.60

(a) (i) Calculate the number of moles of iodine added in each 15.60 cm^3 titre.

(1)

(ii) Hence deduce the number of moles of free SO_2 in 50 cm^3 of the wine.

(1)

(iii) Calculate the concentration in mg dm^{-3} of free SO_2 in the wine. This is equivalent to the concentration in ppm.
Give your answer to **three** significant figures.

(2)

Total SO_2 determination

Another 50.00 cm^3 sample of the white wine was pipetted into a conical flask. To release the bound SO_2, excess sodium hydroxide was added. After swirling, the mixture was left to stand for 15 minutes.

This mixture was acidified with 10 cm^3 of dilute sulfuric acid and 2 cm^3 of starch solution was added. This mixture was then titrated with 0.00100 mol dm^{-3} iodine solution. The following burette readings were obtained.

Final volume / cm^3	23.40
Initial volume / cm^3	0.00
Volume added / cm^3	23.40

(iv) Calculate the concentration in mg dm^{-3} (ppm) of total SO_2 in the wine.

(1)

(v) Calculate the percentage uncertainty in the volume measured using the burette in the determination of both the free SO_2 and the total SO_2. Each time a burette is read the uncertainty is ±0.05 cm^3.

Also calculate the percentage uncertainty in measuring 50 cm^3 using a 50 cm^3 pipette. Each time the pipette is used the uncertainty is ±0.10 cm^3.

(2)

Burette uncertainty for free SO_2 .....

Burette uncertainty for total SO_2 .....

Pipette uncertainty .....

(vi) State in which of these SO_2 determinations you have the greater confidence.

Justify your answer.

(1)

(b) The recommended total concentration of SO_2 in wine is 20–40 ppm but the European Union has set a legal limit of 200 ppm for white wines.

Suggest one possible problem with the total concentration of SO_2 in white wine being outside each of these limits.

(2)

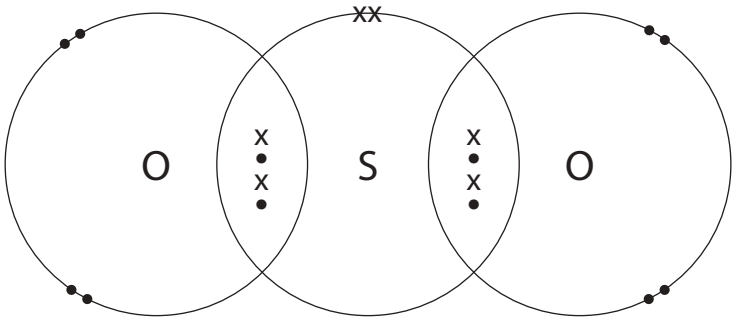
Less than 20 ppm

More than 200 ppm

(c) Suggest why it is more difficult to get an accurate titre with red wine, using the method described above.

(1)

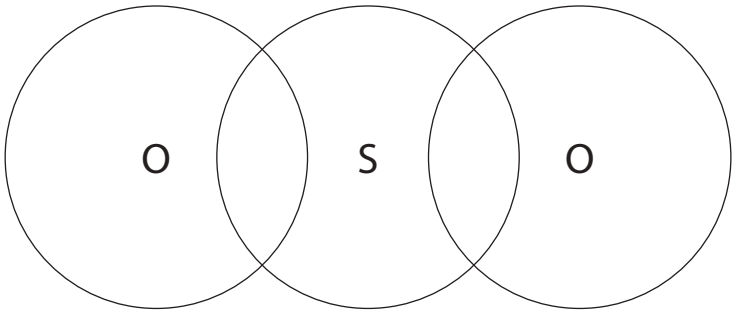
(d) The dot and cross diagram for sulfur dioxide can be drawn as shown. The sulfur atom has expanded its octet by having ten electrons in the outer energy level.



(i) Draw the dot and cross diagram for sulfur dioxide which shows the sulfur atom with only eight electrons in its outer energy level.

Use dots to represent the oxygen electrons and crosses to represent the sulfur electrons.

(1)



(ii) A sulfur atom can expand its octet but an oxygen atom cannot.

Suggest why this is so.

(1)

.....

.....

(iii) Deduce the shape of the sulfur dioxide molecule and suggest the O—S—O bond angle.

(2)

Shape .....

Bond angle .....

(Total for Question 18 = 15 marks)

19 This is a question about some elements of Group 2 and their compounds.

(a) Magnesium reacts slowly with cold water but rapidly when heated in steam.

For each reaction, name the magnesium compound formed.

Identify the other product formed in both reactions.

(2)

Magnesium compound formed with cold water .....

Magnesium compound formed with steam .....

Other product .....

(b) Calcium chloride can be formed in two ways by reacting calcium with different reagents.

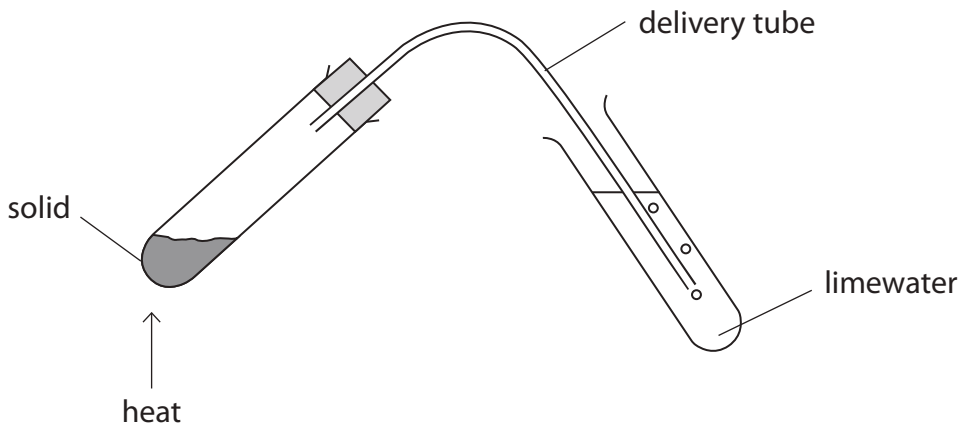
Write the equation, with state symbols, for each of these reactions.

(3)

Reaction 1

Reaction 2

(c) The thermal decomposition of Group 2 carbonates can be investigated using the apparatus shown.



(i) State why it is necessary to remove the delivery tube from the limewater as soon as heating is stopped.

(1)

.....

.....

(ii) Give the **formula** of the chemical compound in limewater that reacts with carbon dioxide.

(1)

(iii) Identify the chemical compound that is responsible for the cloudiness of the limewater.

(1)

*(iv) Magnesium carbonate took two minutes of heating to produce enough carbon dioxide to make a sample of limewater go cloudy.

State and explain the trend in the time taken for decomposition as Group 2 is descended.

(4)

Trend

Explanation

(d) Explain why a saturated solution of barium hydroxide is more alkaline than a saturated solution of magnesium hydroxide.

(1)

*(e) The colour seen in a flame test is characteristic of the metal ion involved. For example, barium ions give a green colour whilst calcium ions give a yellow-red colour.

Explain, with reference to the electronic transitions involved, how these flame colours are formed and why the flame colours are different.

(4)

(Total for Question 19 = 17 marks)

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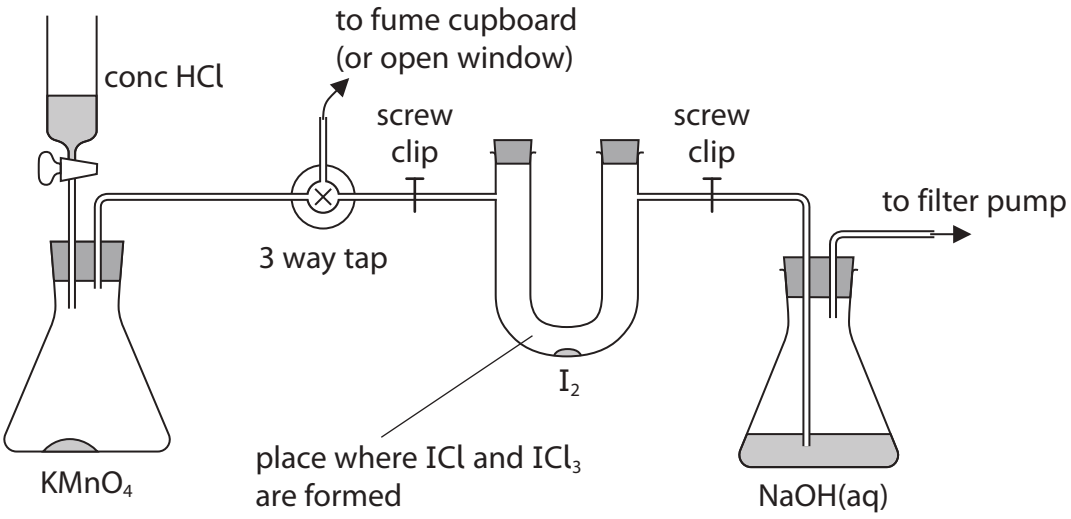
20 The effect of changing conditions on a system at equilibrium can be illustrated by the reaction involving ICl and ICl_3 which may be studied using the apparatus shown.



The equilibrium is

$$ICl(l) + Cl_2(g) \rightleftharpoons ICl_3(s) \qquad \Delta H = -105.9 \text{ kJ mol}^{-1}$$

brown pale green yellow

(a) Explain the effect of increasing the amount of chlorine on the system at equilibrium. State what you would see.

(2)

(b) Explain the effect of placing the U-tube in a beaker of warm water on the system at equilibrium. State what you would see.

(2)

(c) The chlorine gas is generated in the apparatus by the reaction between concentrated hydrochloric acid and potassium manganate(VII).

$$16H^+ + 10Cl^- + 2MnO_4^- \rightarrow 5Cl_2 + 2Mn^{2+} + 8H_2O$$

Show by the use of all relevant oxidation numbers that this is a redox reaction.

(2)

.....

.....

.....

(d) Suggest the purpose of the sodium hydroxide solution in the flask on the right hand side of the apparatus.

(1)

.....

.....

.....

(Total for Question 20 = 7 marks)

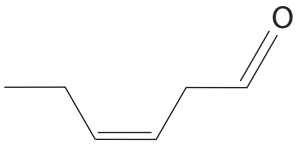
TOTAL FOR SECTION B = 39 MARKS

SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

21 Grass is similar to many other plants in naturally releasing mixtures of volatile organic compounds. Freshly-cut grass has a characteristic aroma because of the increased release of these compounds, which are known as green leaf volatiles (GLVs). The most important contributors to this aroma are alcohols and aldehydes containing six carbon atoms.

The main compound giving freshly-cut grass its smell is *Z*-hex-3-enal.



The human nose can detect *Z*-hex-3-enal at levels as low as 1.0 ng dm^{-3} or 1.0×10^{-9} g dm^{-3}. However, this compound is relatively unstable and rearranges to form the *E* isomer.

Some other GLVs are methanol, ethanol, *Z*-hex-3-en-1-ol and *E*-hex-2-enal.

It has been suggested that the release of these GLVs is part of a defence response by the plant. In one study of plants attacked by caterpillars, the chemical composition of the GLVs changed to attract the natural insect predators of these caterpillars.

(a) Give the molecular formula of *Z*-hex-3-enal.

(1)

.....

(b) Draw the **skeletal** formula of the *E*-isomer of hex-3-enal.

(1)

(c) An average nasal cavity has a volume of 30 cm^3. Calculate the minimum number of molecules of *Z*-hex-3-enal that could be detected in this volume.

Data: Avogadro constant = 6.02×10^{23} mol^{-1}
Molar mass of *Z*-hex-3-enal = 98 g mol^{-1}

(2)

(d) Complete the table with saturated, straight-chain alcohols having six carbon atoms that could be GLVs by giving one example in each case.

(4)

Classification of alcohol	Structural formula	Name
Primary		
Secondary		

(e) The compound 2-chloro-2-methylpentane has six carbon atoms.

(i) It can be converted into a tertiary alcohol with aqueous sodium hydroxide. Complete the equation for this reaction.

(1)

(ii) What class of reagent is the hydroxide ion in this reaction?

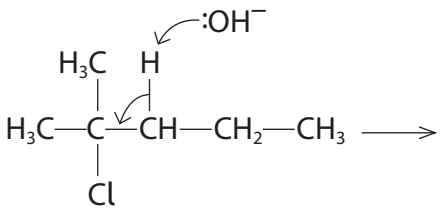
(1)

.....

(iii) In different conditions, 2-chloro-2-methylpentane undergoes an elimination reaction that produces an alkene.

Complete the reaction mechanism with the appropriate curly arrow.
State the essential condition for this reaction.

(4)



Essential condition for reaction .....

(f) Methanol and ethanol are both GLVs. There are a number of fragment peaks which appear in the mass spectra of both compounds but, somewhat surprisingly, the OH^+ peak at $m/e = 17$ is not one of them.

(i) Suggest the formulae and m/e values of two fragment ions that you would expect to occur in both spectra.

(2)

First fragment ion .....

Second fragment ion .....

(ii) Give the formula of one fragment ion that you would expect to be present in the mass spectrum of ethanol but absent from that of methanol.

(1)

*(g) *Z*-hex-3-en-1-ol is only sparingly soluble in water but completely miscible with ethanol. By reference to intermolecular forces, fully explain this difference in solubility.

Detailed explanations of the forces involved are **not** required.

(4)

(Total for Question 21 = 21 marks)

TOTAL FOR SECTION C = 21 MARKS
TOTAL FOR PAPER = 80 MARKS

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] 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							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
* Actinide series	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