ANDERSON JUNIOR COLLEGE

2017 JC 2 PRELIMINARY EXAMINATIONS

CHEMISTRY   **8872/01**

Paper 1 Multiple Choice   **18 September 2017**

50 minutes

Additional Materials: Multiple Choice Answer Sheet

Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, PDG and NRIC / FIN number on the Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

Multiple Choice Answer Sheet

Write your name, PDG and NRIC / FIN number, **including** the reference letter.

Shade the NRIC / FIN number.

Exam Title: JC2 Prelim

Exam Details: H1 Chemistry / Paper 1

Date: 18/09/2017

This document consists of **14** printed pages.

Section A

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1   *Use of the Data Booklet is relevant to this question.*

How many atoms are present in 1 cm^3 of oxygen gas under room conditions?

A $\dfrac{2 \times 6.02 \times 10^{23}}{24000}$

B $\dfrac{1 \times 24000}{6.02 \times 10^{23}}$

C $\dfrac{1 \times 6.02 \times 10^{23}}{24000}$

D $\dfrac{6.02 \times 10^{23} \times 24000}{1 \times 1000}$

2   Cyanogen, a highly toxic gas, is composed of 46.2% carbon and 53.8% nitrogen by mass. At standard temperature and pressure, 1.16 g of cyanogen occupies 0.500 dm^3.

What is the molecular formula of cyanogen?

A   CN   B CN_2 C C_2N_2 D C_2N

3   Gases given off during volcanic eruptions include CO, H_2S and CS_2.

A mixture of these gases was analysed by combustion in an excess of oxygen.

If the gases were in a CO : H_2S : CS_2, 1 : 3 : 1 mole ratio, what would be the SO_2 : CO_2 mole ratio in the mixture after combustion?

A   5 : 2   B   3 : 2   C   5 : 1   D   1 : 1

4 When passed through an electric field, the ^{1}H nucleus is deflected as shown below.
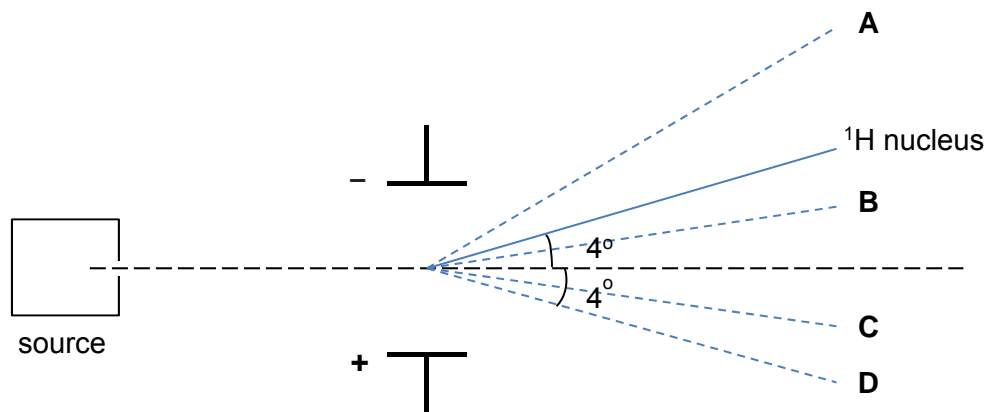
Which of the above beams represents the deflection for an ion $^2X^{2-}$?

5 Boron nitride is found to exist in two possible forms, hexagonal boron nitride and cubic boron nitride as shown below. Hexagonal boron nitride is found to be similar in structure and bonding to graphite.
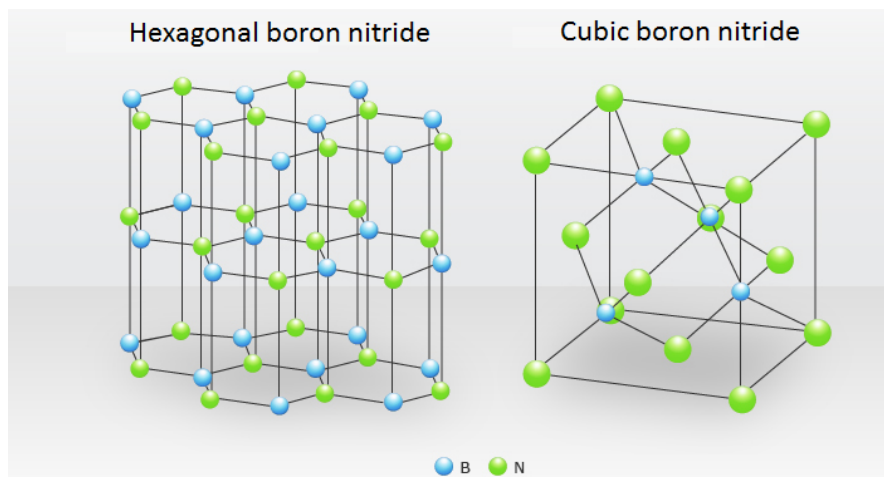

Based on the structures of the two forms of boron nitride, which of the following statements about boron nitride is true?

A Hexagonal boron nitride has a giant covalent structure whereas cubic boron nitride has a simple covalent structure.

B Hexagonal boron nitride has strong covalent bonds between its layers of atoms.

C Both forms of boron nitride are soft and slippery.

D Only the hexagonal form of boron nitride is a good conductor of electricity.

6 Which of the following isomers is likely to have the highest boiling point?

    A $CH_3CH_2CH_2CH_2CH_2CH_3$

    B $(CH_3)_2CHCH_2CH_2CH_3$

    C $(CH_3)_2CHCH(CH_3)_2$

    D $(CH_3)_3CCH_2CH_3$

7 Which of the following pairs of compounds shows the same shape and similar bond angles?

    A $AlCl_3$ and PCl_5

    B $BeCl_2$ and H_2O

    C $POCl_3$ and CCl_4

    D SO_2 and CO_2

8 Which arrow on the reaction pathway diagram shows the enthalpy change of reaction for the reverse reaction?
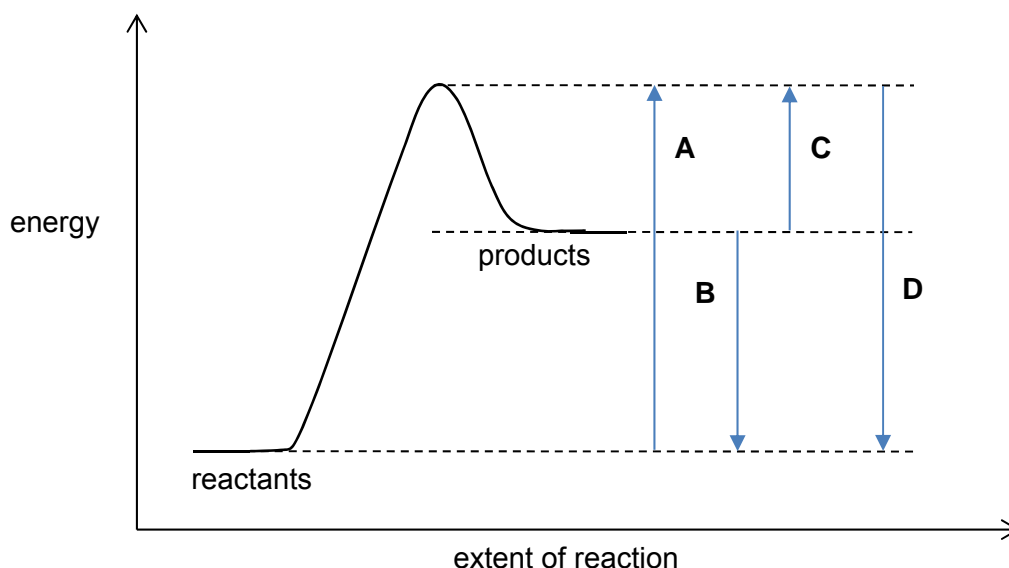
9 The values for the standard enthalpy changes of formation of hydrogen peroxide and of water are -187.8 kJ mol^{-1} and -285.8 kJ mol^{-1} respectively.

$$2H_2O_2(l) \longrightarrow 2H_2O(l) + O_2(g)$$
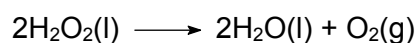
What is the enthalpy change of reaction for the decomposition of hydrogen peroxide?

    A -98 kJ mol^{-1} **B** -196 kJ mol^{-1} **C** -398 kJ mol^{-1} **D** -451 kJ mol^{-1}

10 In an experiment to measure the enthalpy change of neutralisation of hydrochloric acid, 20 cm³ of solution containing 0.04 mol of HCl was placed in a plastic cup of negligible heat capacity.

A 20 cm³ sample of aqueous sodium hydroxide containing 0.04 mol of NaOH, at the same initial temperature, was added and the temperature rose by 15 °C.

If the heat capacity per unit volume of the final solution is 4.2 J K⁻¹cm⁻³, what is the enthalpy change of neutralisation of hydrochloric acid?

A   40 x 4.2 x 288 x 0.08 J mol⁻¹

B $\dfrac{20 \text{ x } 4.2 \text{ x } 15}{0.04}$ J mol⁻¹

C $\dfrac{40 \text{ x } 4.2 \text{ x } 15}{0.04}$ J mol⁻¹

D $\dfrac{40 \text{ x } 4.2 \text{ x } 288}{0.08}$ J mol⁻¹

11 At a temperature T K, 0.60 mol dm⁻³ of CO and 0.30 mol dm⁻³ of O₂ were introduced into a 5 dm³ vessel and allowed to reach equilibrium.

$$2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g) \qquad\qquad \Delta H < 0$$

The graph below shows the changes in the concentration of CO and CO₂ in the system with time. A change was made to the system at time, t₁ and t₂.

Concentration / mol dm⁻³
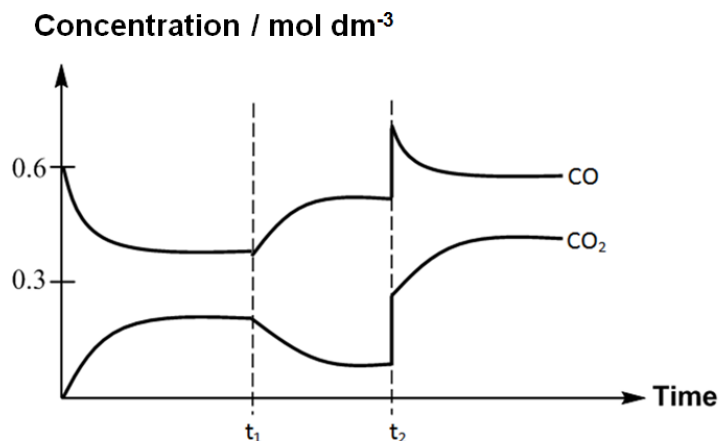
What were the changes made at time, t₁ and t₂?

	t₁	t₂
A	a catalyst was added	volume of the system is increased
B	more CO₂ was added	the temperature was decreased
C	the temperature was decreased	more O₂ was added
D	the temperature was increased	volume of the system is decreased

12 Pure carbon dioxide can be made to react with hot graphite, according to the following equation.

$$CO_2(g) + C(s) \rightleftharpoons 2CO(g) \qquad \Delta H > 0$$

A mixture containing 0.10 mol of carbon dioxide and 0.20 mol of graphite was placed in a sealed 0.10 dm^3 container and heated to a fixed temperature. At equilibrium, 69% of graphite remained unreacted.

What is the value of K_c for this reaction?

A   2.9   **B**   3.3   **C**   4.0   **D**   7.6

13 The value of the ionic product of water, K_w, varies with temperature.

Temperature / °C	K_w / $mol^2\,dm^{-6}$
25	1.0×10^{-14}
62	1.0×10^{-13}

What can be deduced from this information?

A   Water is not a neutral liquid at 62 °C.

B   The ionic dissociation of water is an endothermic process.

C   The ionic dissociation of water increases by a factor of 5 between 25 °C and 62 °C.

D   The association of water molecules by hydrogen bonding increases as temperature rises.

14 The following equilibrium exists in a mixture of concentrated nitric acid and concentrated sulfuric acid.

$$HNO_3 + H_2SO_4 \rightleftharpoons H_2NO_3^+ + HSO_4^-$$
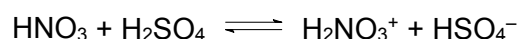
Which of the statements is correct?

A HNO_3 is a stronger acid than H_2SO_4.

B   The nitric acid acts as an oxidising agent.

C   The sulfuric acid acts as a dehydrating agent.

D HNO_3 and $H_2NO_3^+$ are a conjugate acid–base pair.

15 The Maxwell–Boltzmann distribution for gas **E** at a given temperature is shown below.

n = number of molecules
with a given energy
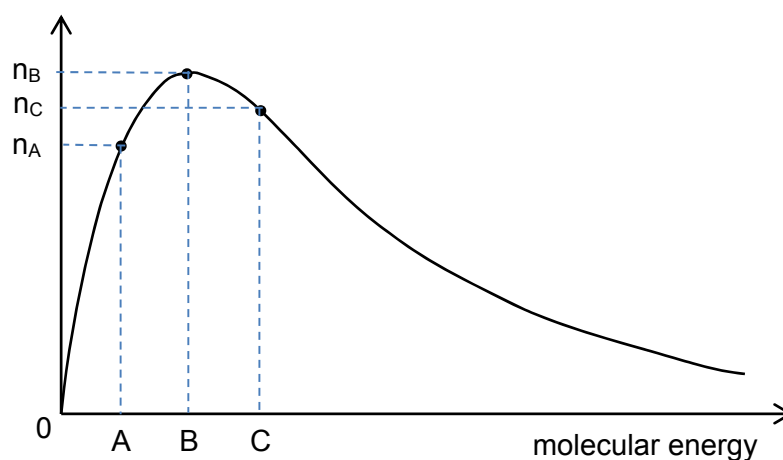
Which statement is correct for the number of molecules with molecular energies A, B and C?

A n_C decreases when more gas **E** is added at the same temperature.

B n_A decreases when temperature is lowered.

C n_A and n_B increases when temperature is increased.

D Addition of catalyst at the same temperature has no effect on n_A, n_B and n_C.

16 A radioactive element has two isotopes, **F** and **G**, with half–lives of 3 min and 9 min respectively.

An experiment starts with h times as many atoms of **F** as of **G**. After 9 min, the number of atoms of **F** and **G** are both equal.

Given that radioactive decay is a first order reaction, what is the value of h?

A 0.5 **B** 2 **C** 4 **D** 8

17 The following graph shows the first ionisation energy of eight consecutive elements, from **A** to **H** in the Periodic Table with atomic number between 3 and 20.
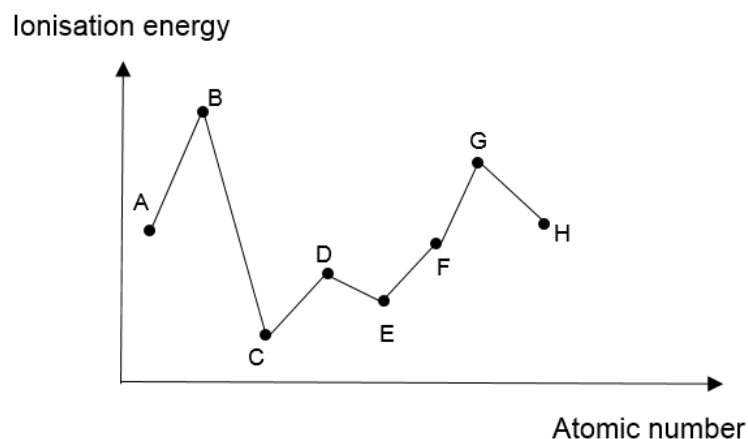
Which of the following statements is correct?

A   The chloride of **D** does not conduct electricity in the molten state.

B   **A** reacts with **C** to form a compound with giant ionic lattice structure.

C   The melting points of **A** to **H** follow the trend as shown by the graph.

D   The oxide of **H** gives a neutral pH when dissolved in water.

18 **X**, **Y** and **Z** are elements in Period 3 of the Periodic Table.

A mixture containing the oxides of **X**, **Y** and **Z** was dissolved in excess dilute sulfuric acid and filtered. The oxide of **Z** was collected as a residue. When excess dilute sodium hydroxide was added to the filtrate, only a white precipitate of the hydroxide of **Y** was formed.

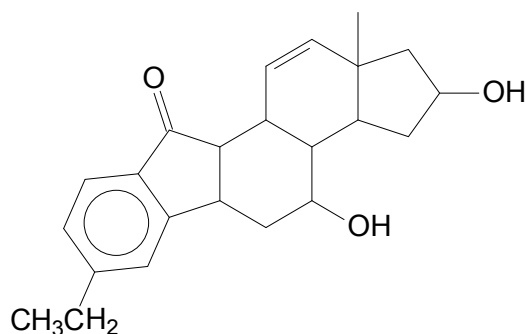What are the possible identities of **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	A*l*	Mg	Si
B	A*l*	Mg	P
C	Mg	A*l*	Si
D	Mg	A*l*	P

19   When alkane **N**, C_7H_{16}, was reacted with bromine under ultraviolet light, it produced **six** isomeric monobromo compounds, with the formula $C_7H_{15}Br$.

What is the likely identity of alkane **N**?

A $CH_3(CH_2)_5CH_3$

B $(CH_3)_2CH(CH_2)_3CH_3$

**C** $(CH_3)_3CCH_2CH_2CH_3$

D $(CH_3)_3CCH(CH_3)_2$

20

After heating the molecule above with steam and concentrated phosphoric acid, followed by subsequent heating with acidified potassium dichromate(VI), how many carboxylic acid groups are present in the resultant compound?

**A**   0   **B**   1   **C**   3   **D**   6

21   The compound, $CH_2=CHCH_2OH$, undergoes a sequence of reactions as follows:

$$CH_2=CHCH_2OH \xrightarrow{\text{X}} CH_2=CHCOOH \xrightarrow{\text{Y}} CH_3CH_2COOH$$
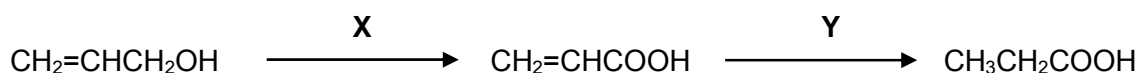
What could be the reagents for **X** and **Y**?

|	**X**	**Y**
A	acidified $K_2Cr_2O_7$	$NaBH_4$
B	acidified $K_2Cr_2O_7$	$H_2(g)$ with Ni catalyst
C	acidified $KMnO_4$	LiA/H_4 in dry ether
D	acidified $KMnO_4$	$H_2(g)$ with Pt catalyst

22 In the presence of a dilute alkali, some aldehydes and ketones undergo the 'aldol reaction' where they dimerises to form a hydroxylcarbonyl compound (an aldol). For example, ethanal dimerises in this way to form 3–hydroxybutanal.

$$2\ CH_3CHO \xrightarrow{\ OH^-\ } CH_3\underset{\underset{OH}{|}}{CH}CH_2CHO$$
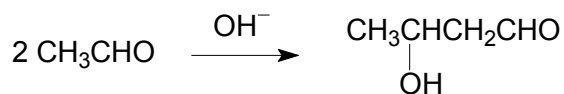
Which of the following compounds will undergo the aldol reaction to produce the aldol shown below?

$$CH_3-\underset{\underset{OH}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_2-\overset{\overset{CH_3}{|}}{C}=O$$
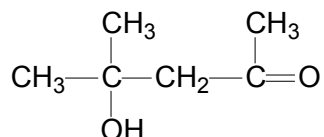
A CH_3COCH_3

B CH_3CH_2CHO

C $(CH_3)_2CHCHO$

D $CH_3CH_2COCH_3$

23 Which of the following will **not** be obtained when the molecule below is heated with NaOH in ethanol?

A

B

C

D
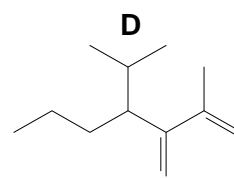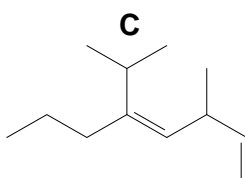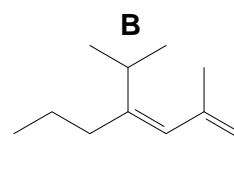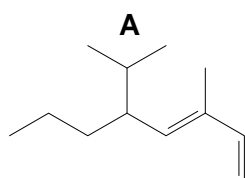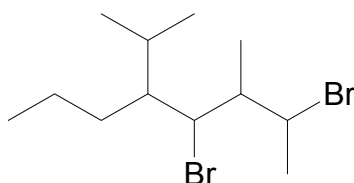
24 **Q** gives a yellow precipitate on warming with alkaline aqueous iodine.

Which of the following could be **not** be **Q**?

A   ethanal

B   ethanol

C   butan–2–ol

D   methyl ethanoate

25 Halogenoalkanes are very useful in making organic acids.

$$Br\diagdown\diagup\diagdown \longrightarrow CH_3COOH$$
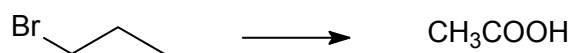
Which set of reagents, used in sequential order, would be the most suitable for this synthesis?

A   aqueous KOH, acidified $KMnO_4$

B   aqueous KOH, acidified $Na_2Cr_2O_7$

C   ethanolic KOH, acidified $KMnO_4$

D   ethanolic KCN, dilute H_2SO_4

Section B

For each of the question in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct.)

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Orange dichromate(VI) ions, $Cr_2O_7^{2-}$ and yellow chromate(VI) ions, CrO_4^{2-}, exist in equilibrium in aqueous solution.

$$Cr_2O_7^{2-}(aq) + H_2O(l) \rightleftharpoons 2CrO_4^{2-}(aq) + 2H^+(aq)$$
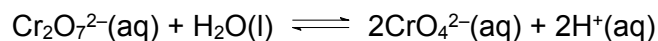
Which of the following statement(s) about the equilibrium is correct?

1 Addition of strong alkali will shift the position of equilibrium to the right.

2 Addition of K^+ (aq) will shift the position of equilibrium to the right.

3 This is a redox reaction.

27 The rate kinetics of decomposition of N_2O_5 is investigated by plotting the concentration of N_2O_5 with respect to time.

$$2N_2O_5(g) \longrightarrow 4NO_2(g) + O_2(g)$$
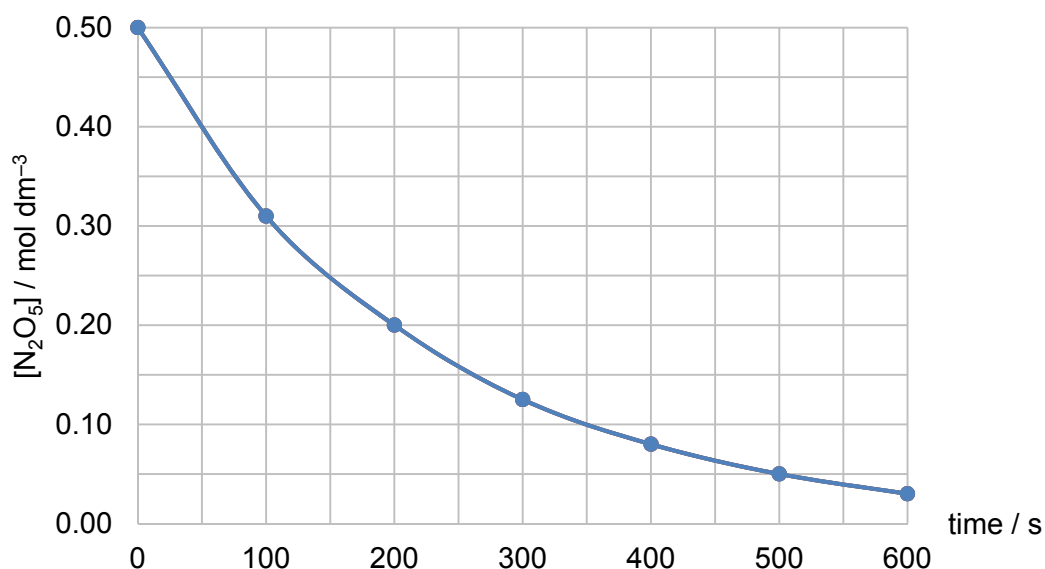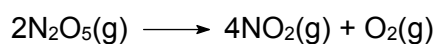
Which conclusions can be drawn from this result?

1 $[NO_2]$ is 0.60 mol dm^{-3} after 200 s.

2 The rate equation is rate = k $[N_2O_5]$.

3 The initial rate of production of O_2 is approximately 1×10^{-3} mol dm^{-3} s^{-1}.

28 Which of the following statement(s) about the chlorides of Period 3 elements is correct?

1 The pH of the solutions of chlorides generally decreases across the period.

2 When limited amount of water is added to the covalent chlorides, they give acidic white fumes.

3 Adding NaOH (aq) to a solution of $AlCl_3$ produces a white precipitate which is soluble in an excess of NaOH.

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

29 In a beehive, the queen bee secretes the substance below to cause worker bees to begin constructing royal colony cells.

$$CH_3CO(CH_2)_5CH=CHCO_2H$$
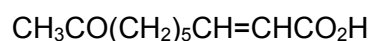
From the structure shown, which of the following statements are true?

1 It gives a brick red precipitate with alkaline Cu^{2+} solution.

2 It gives an orange precipitate with 2,4–dinitrophenylhydrazine solution.

3 It decolourises aqueous bromine solution.

30 An ester with a fruity odour has the following structural formula.
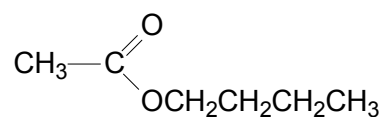
From the structure shown, which of the following statements are true?

1 The name of the ester is butyl ethanoate.

2 It has the same empirical formula as propanone.

3 The ester reacts with OH^- in 1 : 2 ratio in a complete reaction.

H1 Chemistry 8872   **AJC 2017 JC2 Prelim**   <u>**Paper 1 – 30 marks**</u>

Question Number	Key		Question Number	Key
1	A		16	C
2	C		17	B
3	A		18	A
4	D		19	B
5	D		20	A
6	A		21	B
7	C		22	A
8	B		23	D
9	B		24	D
10	C		25	C
11	D		26	D
12	C		27	A
13	B		28	A
14	D		29	C
15	D		30	B

A	**8**
B	**7**
C	**7**
D	**8**

1   Under room conditions of 25°C and 1 atm, 1 mole of gas occupies 24 dm^3 of space.   **A**

Moles of O_2 gas molecules = $\dfrac{1}{24000}$ mol

Moles of O atoms = $\dfrac{2}{24000}$ mol

No of O atoms = $\dfrac{2 \times 6.02 \times 10^{23}}{24000}$ atoms

2

	C	N
Mole ratio	46.2 / 12 = 3.85	53.8 / 14 = 3.84
Simplest ratio	1	1

C

Empirical formula = CN

n(cyanogen) = $\dfrac{0.500}{22.4} = 0.0223$ mol

M_r of cyanogen = $\dfrac{1}{0.0223}$ x 1.16 = 52

n(14+12) = 52
n = 2
Hence, molecular formula = $\underline{C_2N_2}$

3   CO + 1/2O$_2$ ⟶ **CO$_2$**   **A**
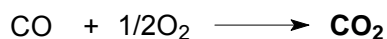
1 mol of CO produces   **1 mol CO$_2$**

H$_2$S + 3/2O$_2$ ⟶ H$_2$O + **SO$_2$**
3 mol H$_2$S produces   **3 mol SO$_2$**
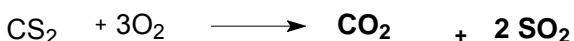
CS$_2$ + 3O$_2$ ⟶ **CO$_2$**   + **2 SO$_2$**
1 mol of CS$_2$ produces **1 mol CO$_2$ 2 mol of SO$_2$**

Total moles of SO$_2$ = 3 + 2 = 5 mol
Total moles of CO$_2$ = 1+1 = 2 mol
Therefore ratio of SO$_2$: CO$_2$ = $\underline{5 : 2}$

4   angle of deflection α $\dfrac{\text{charge size}}{\text{mass}}$ **D**

for ^{1}H$^+$, $\dfrac{z}{m} = +\dfrac{1}{1}$

for ^{2}X^{2-}, $\dfrac{z}{m} = -\dfrac{2}{2}$

Hence, angle of deflection for ^{2}X^{2-} = $\underline{-4^o}$ (i.e. in the opposite direction)

5 Hexagonal boron nitride resembles graphite, while cubic boron nitride resembles diamond. **D**

- Hence, both of them have <u>giant molecular structures</u>.
- Hexagonal boron nitride has <u>strong</u> covalent bonds between its atoms <u>within the layer</u>, but it has <u>weak</u> instantaneous dipole–induced dipole forces of attractions <u>between its layers</u>. Therefore, o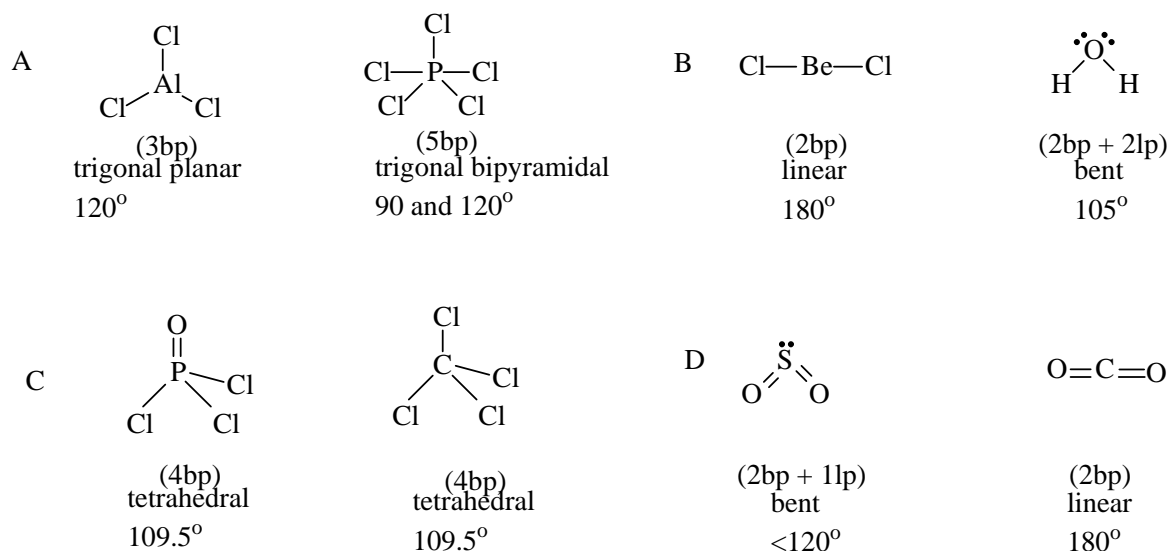nly hexagonal boron nitride is soft and slippery while cubic boron nitride is hard and rigid due to the strong, extensive covalent bonds between the B and N atoms.
- Hexagonal boron nitride resembles the structure of graphite as it also has a delocalized pi electron cloud system, which thus allows it to conduct electricity. Cubic boron nitride has no delocalised electrons to conduct electricity.

6 All molecules in the options have the <u>same</u> M_r and hence there is no difference in the **A** number of electrons and the <u>size of the electron cloud</u>.
Since $CH_3CH_2CH_2CH_2CH_2CH_3$ has an elongated shape as compared to other branched isomers, it has the greatest <u>surface area of contact</u> which allow for stronger id–id attractions between the molecules.

7 Considering that the shape and bond angle are dependent on the number of electron pairs **C** around the central atom,

A

Cl
|
Al (with Cl, Cl)
(3bp)
trigonal planar
120°

Cl—P—Cl (with Cl, Cl)
(5bp)
trigonal bipyramidal
90 and 120°

B   Cl—Be—Cl
(2bp)
linear
180°

O (with H, H)
(2bp + 2lp)
bent
105°

C

O
‖
P—Cl (with Cl, Cl)
(4bp)
tetrahedral
109.5^o

Cl
|
C—Cl (with Cl, Cl)
(4bp)
tetrahedral
109.5^o

D   S (with O, O)
(2bp + 1lp)
bent
$<120^o$

O=C=O
(2bp)
linear
180°

8 A represents E_a for forward reaction **B**
B represents enthalpy change of reaction for reverse reaction
C represents E_a for the reverse reaction
D has no significance

9 $\Delta H_r = [2\Delta H_f (H_2O) + \Delta H_f (O_2)] - 2\Delta H_f (H_2O_2)$ **B**
$= [2(-285.8) + 0] - 2(-187.8)$
$= \underline{-196 \text{ kJ mol}^{-1}}$

10 $\Delta H_{neut} = - Q / n_{H2O} = Vc\Delta T / n_{H2O}$ **C**
Volume of resultant solution of NaOH and HC*l* = 40 cm^3
n_{H2O} formed = n_{HCl} = 0.04 mol

Please note that the options given refer to the value of the ΔH_{neut}.

11 A. At t_1, catalyst increases the rate of the forward and backward reaction to the same extent such that there is no change to the concentration of the reactants and products.
B. At t_1, addition of CO_2 would have caused an immediate increase in $[CO_2]$ followed by a decrease in $[CO_2]$ since POE shift left. This however is not shown in the diagram.
C. At t_1, when temperature decreases for an forward exothermic reaction, POE shifts to the right increasing the conc. of CO_2 but diagram shows a decrease in concentration of CO_2.
D. At t_1, an increase in temperature will cause POE to shift left, decreasing the $[CO]$ and increasing the $[CO_2]$. When volume of the system is decreased at t_2, $[CO]$ and $[CO_2]$ will increases. By LCP, POE will shift right hence decreasing $[CO]$ and $[CO_2]$. All of these were reflected in the diagram.

D

12 $$K_c = \frac{[CO]^2}{[CO_2]}$$

C

	$CO_2(g)$	+	$C(s)$	$\rightleftharpoons$	$2CO(g)$
Initial (mol)	0.10		0.20		0
Change (mol)	–0.062		–(0.20 x 0.31) = –0.062		+0.062 x 2 = +0.124
Equilibrium (mol)	0.038		0.20 x 0.69 = 0.138		0.124
Equilibrium conc. (mol dm^{-3})	0.038 / 0.10 = 0.38		–		0.124 / 0.10 = 1.24

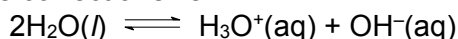*'ICE' table is not required*

Equilibrium no. of moles of CO_2 = 0.10 – (0.20 x 0.31) = <u>0.038 mol</u>
Equilibrium no. of moles of CO = 0.062 x 2 = <u>0.124 mol</u>

$$K_c = \frac{[CO]^2}{[CO_2]} = \frac{(1.24)^2}{(0.38)} = \underline{4.0 \text{ mol dm}^{-3}}$$

13 **B** is the correct answer.
$$2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$
When temperature increases, the forward endothermic reaction is favoured. Thus, the position of equilibrium shifts to the right to absorb the excess heat.

For **A**,
$K_w = [H^+][OH^-]$
$[H^+] = [OH^-] = \sqrt{10^{-13}} = 3.16 \times 10^{-7}$ mol dm^{-3}. Water is still a neutral liquid as the $[H^+] = [OH^-]$.

For **C**,
For T=25°C, $[H^+]$ = 1.00 x 10^{-7} mol dm^{-3}
For T=62°C, $[H^+]$ = 3.16 x 10^{-7} mol dm^{-3}
The ionic dissociation of water increases by a factor of <u>3.16</u> between 25 ^{O}C and 62 ^{O}C.

For **D**,
The association of water molecules by hydrogen bonding <u>decreases</u> as temperature rises. Molecules are moving at higher speeds, making it harder to form hydrogen bonds.

B

14   A. HNO_3 acts as a base here as H_2SO_4, being the stronger acid, has donated a proton to   **D**
      HNO_3, forming HSO_4^- and $H_2NO_3^+$, which will break down to H_2O and NO_2^+.
      B. The oxidation no. of N atom remained as +5.
      C. Water is not eliminated in this reaction.
      D. $H_2NO_3^+$ and HNO_3 forms a conjugate acid-base pair (differ by a H^+).

15   Area under the graph represents total number of molecules in sample.   **D**
      A is incorrect because when more gas is added to sample, no. of molecules at all energies
      will increase.
      B is incorrect because when temperature decreases, curve shifts to the left and has a higher
      peak. i.e. n_a will increase. (check graph below)
      C is incorrect because when temperature increases, curve shifts to the right and has a lower
      peak. i.e. n_a and n_b will decrease (check graph below)
      D is correct because the presence of a catalyst does not shift the curve at all. It only provides
      an alternative pathway with a lowered E_a (E_a'). Hence there is no effect on n_a, n_b and n_c.
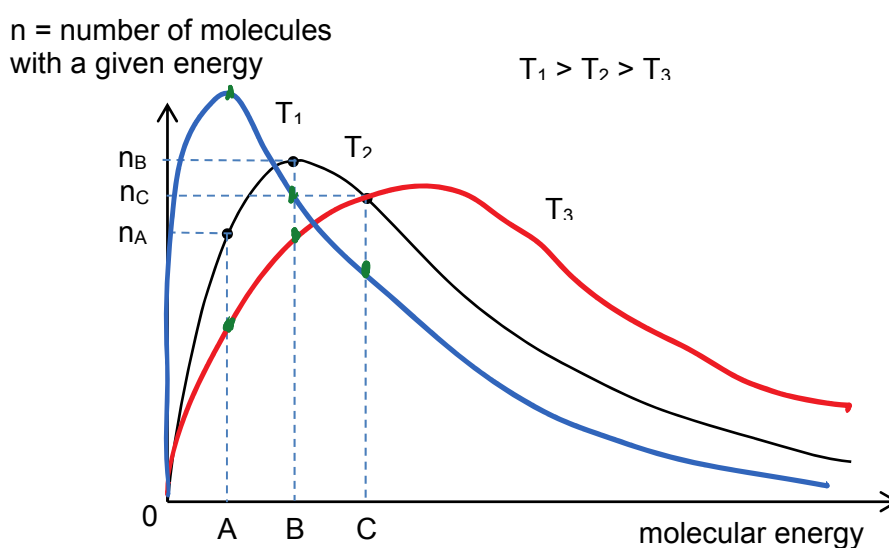
16   The easiest approach to answering this question is to start from the equimolar quantities of   **C**
      F and **G** after 9 min and work backwards.
      Since **F** has undergone 3 half–lives, its initial concentrations will be 8**F**.
      Initial concentration of **G** will be 2**G** as it has undergone 1 half–lives.

        8**F**   ⟶   4**F**   ⟶   2**F**   ⟶   **F**
        2**G**   **G**
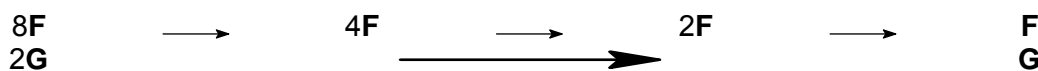
      ∴ value of h = <u>4</u>

17   The big dip in IE shows that element C is in the next period since valence electron is further   **B**
      from the nucleus, resulting in lower IE. Since A to H has atomic number 3 to 20, B is Ne
      (period 2), C is Na (period 3).

      A. D is Mg and $MgCl_2$ being an ionic solid will conduct electricity in the molten state.
      B. A which is F_2 which will react with C which is Na forms an ionic compound (NaF).
      C. Ne exits as a gas and Na is a solid. Hence, trend of melting point is not in the trend
      above.
      D. The oxide of H which is sulfur will give an acidic pH when dissolved in water.

18 MgO, Al_2O_3 are soluble in acid as they undergo acid–base reaction. Oxides of P are soluble in aq. acid. (Recall: Oxides of phosphorus can hydrolyse in water). **A**
SiO_2 is insoluble in acid. Thus **Z** is Si.

Filtrate contains Mg^{2+} or Al^{3+}.
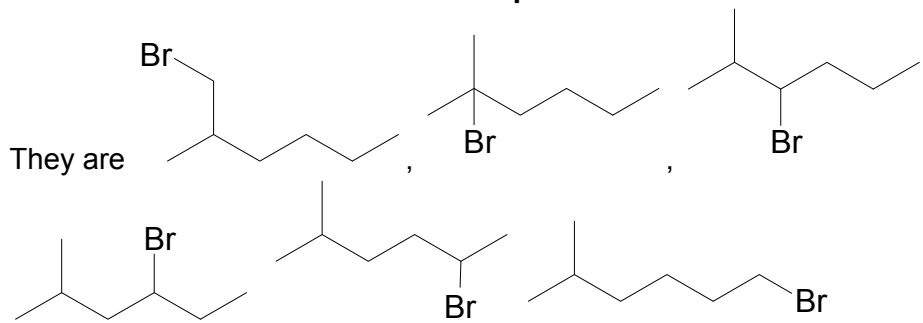When excess NaOH is added to the filtrate, $Mg(OH)_2$ is formed as white ppt.
$Al(OH)_3$ is amphoteric and reacts with excess NaOH to form salt and water.
$Al(OH)_3(s) + NaOH(aq) \rightarrow NaAl(OH)_4(aq)$
Hence, **X** is Al and **Y** is Mg.
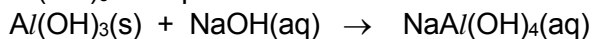
19 For structure B $(CH_3)_2CH(CH_2)_3CH_3$, there are **six different hydrogen environments** i.e. **6 different monobromo–substituted products** can be obtained. **B**

They are

, , ,

, .

The other options give less than 6 isomeric monobromo compounds with the formula $C_7H_{15}Br$.

20 Subjecting the molecule to heating with steam and concentrated phosphoric acid results in (electrophilic) addition of water to the alkene functional group and you get this product. **A**
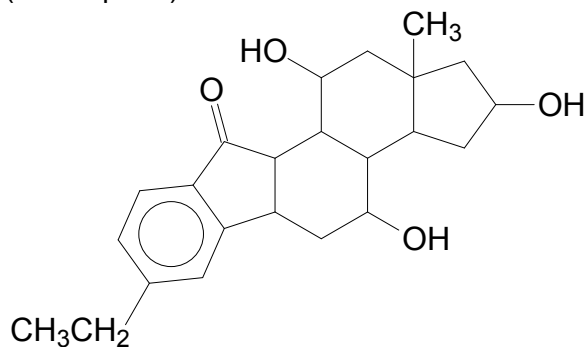
Upon heating with acidified potassium dichromate(VI), only the 3 secondary alcohols are oxidized to ketones. The ketone and the side–chain of the benzene ring does not undergo oxidation. As a result there are no carboxylic acid groups in the resultant product.

21 For **X**, acidified $KMnO_4$ is not suitable as it will cause oxidative cleavage of the double bond. **B**

For **Y**, $NaBH_4$ is unable to reduce the alkene double bond. $LiAlH_4$ will reduce the carboxylic acid to primary alcohol.

22   Making observations on the pattern in the given reaction,   **A**
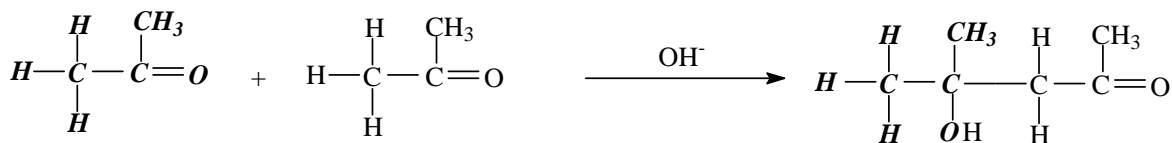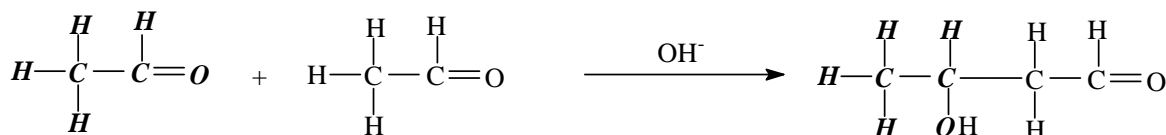
23   There are a few possible elimination products (Br eliminated together with a H atom on an adjacent carbon). Molecules in A – C are possible products upon elimination of 2 X H–Br.   **D**

Only the molecule in D has an additional carbon i.e.
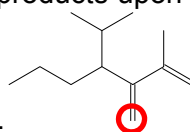
24   **D**

$CH_3 - \overset{H}{\underset{}{C}} = O$ gives yellow ppt in iodoform test

$CH_3 - \overset{H}{\underset{OH}{C}} - H$ gives yellow ppt in iodoform test

$CH_3 - \overset{H}{\underset{OH}{C}} - CH_2CH_3$ gives yellow ppt in iodoform test

$CH_3 - \overset{O}{\underset{}{C}} - O - CH_3$ does not give yellow ppt in iodoform test as the carbonyl carbon must be attached to only C or H

25   There is a loss of carbon atom in this reaction.   **C**
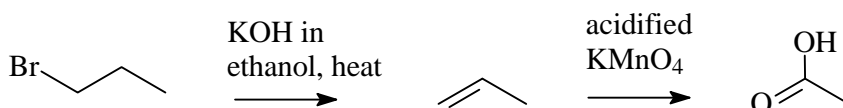
26   Option 1 is correct because addition of strong alkali reduces the concentration of H+, hence POE shifts to the right.   **D**

Option 2 is incorrect because K+ does not react with any of the species present. Hence there is no effect on the position of equilibrium.

Option 3 is incorrect because both $Cr_2O_7^{2-}$ and CrO_4^{2-} have the same oxidation no. of +6 despite having different colours ($Cr_2O_7^{2-}$ is orange in colour while CrO_4^{2-} is yellow). The equilibrium is known as an acid–base reaction instead of a redox reaction.

27 2. Graph shows half–life is constant at 150 s. Hence 1st order with respect to N_2O_5. **A**

3. Gradient of curve at t= 0 = $\dfrac{\Delta[NO_2]}{\Delta t}$ = *2.0 x 10⁻³ mol dm⁻³ s⁻¹* .

$\dfrac{\Delta[O_2]}{\Delta t} = \dfrac{\Delta[O_2]}{2\Delta t}$ = *1.0 x10⁻³ mol dm⁻³ s⁻¹*

1. After 200 s, the $[N_2O_5]$ is 0.20 mol dm⁻³. This means that 0.30 mol dm⁻³ of N_2O_5 has been reacted, implying that 0.6 mol dm⁻³ of NO_2 and 0.5 mol dm⁻³ of O_2 are formed.

28 All 3 statements are true. **A**

Statement 1: pH of NaC*l* (7)> MgC*l₂* (6.5) > A*l*C*l₃* (3) > SiC*l₄* and PC*l₃* or PC*l₅* (1 – 2)

Statement 2: A*l*C*l₃*(s) + 3H₂O(l) → A*l*(OH)₃ (s) + 3HC*l*(g)
Similarly for SiC*l₄* and PC*l₅*

Statement 3: A*l³⁺* ⇌ A*l*(OH)₃ ⇌ A*l*(OH)₄⁻

Upon adding NaOH, white ppt of A*l*(OH)₃ is formed. In excess NaOH, white ppt dissolves to form complex ion A*l*(OH)₄⁻ .

29 It <u>will not</u> give a brick red precipitate with alkaline Cu^{2+} solution since there is <u>no</u> aldehyde group. **C**

It gives an orange precipitate with 2,4–dinitrophenylhydrazine solution since there is a carbonyl group (ketone).

It decolourises aqueous bromine solution since there is a C=C bond.

30 Option 1 is correct, as ethanoic acid and butan–1–ol react to give butyl ethanoate. **B**

Since it has a molecular formula of $C_6H_{12}O_2$, it has an empirical formula of C_3H_6O, like propanone, CH_3COCH_3.

Option 3 is incorrect as the expected products of base hydrolysis of the ester is sodium ethanoate ($CH_3COO^-Na^+$) and butan–1–ol.

ANDERSON JUNIOR COLLEGE

2017 JC 2 H1 PRELIMINARY EXAMINATIONS

NAME:_____ **PDG:**_____ /16

CHEMISTRY **8872/02**

Paper 2 **13 September 2017**

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Data Booklet

                                        Writing paper

READ THESE INSTRUCTIONS FIRST

Write your name, PDG and register number on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate writing paper.
Start each question on a fresh sheet of paper.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

	For Examiner's Use						
Paper 1 (33%)	**Paper 2 (67%)**						
	Section A				**Section B**		**Total**
	Q1	**Q2**	**Q3**	**Q4**			
/30							**/ 80**
			Final marks				**/100**
			Grade				

This document consists of **19** printed pages.

Section A

Answer **all** the questions in this section in the spaces provided.

1 **(a)** *Use of the Data Booklet will be relevant to this question.*

Iron ore from different mines will contain different percentages by mass of iron. The percentage of iron in a sample of ore can be estimated by converting all of the iron present into Fe^{2+}(aq) ions and then using a redox titration.

The sample of ore is crushed, weighed and then dissolved in aqueous acid. The Fe^{3+}(aq) ions are then reduced to Fe^{2+}(aq) ions by reaction with an excess of aqueous tin(II) chloride, $SnCl_2$.

(i) Construct an ionic equation for the reduction of Fe^{3+}(aq) ions by Sn^{2+}(aq) ions.

………………………………………………………………………………………………...[1]

A sample of iron ore weighing 11.05 g was converted to Fe^{2+}(aq) ions using the method described above. The resultant solution was then made up to a volume of 250 cm^3 in a volumetric flask.

25.0 cm^3 portions of this solution were then titrated with 0.100 mol dm^{-3} of aqueous potassium dichromate(VI) using a suitable indicator. The results are shown below.

titration number	1	2	3
initial burette reading / cm^3	0.00	19.95	2.10
final burette reading / cm^3	19.95	39.95	22.15
titre / cm^3	19.95		

(ii) Complete the table above and use the results to determine the number of moles of potassium dichromate(VI) required to react with the Fe^{2+} ions in 25.0 cm^3 of the solution.

[2]

(iii) Write an ionic equation for the reaction of Fe^{2+} ions with acidified $Cr_2O_7^{2-}$ ions.

…………………………………………………………………………………………....[1]

(iv) Calculate the total number of moles of Fe^{2+} in the original solution made up from the iron ore, and hence calculate the percentage by mass of iron in the sample of iron ore.

[2]

[Total: 6]

2 The Pollutant Standards Index (PSI) is an air quality indicator. It is based on five pollutants: particulate matter (PM10), sulfur dioxide, carbon monoxide, ozone and nitrogen dioxide.

To calculate the overall PSI, the PSI value is first determined, using the following table, for **each** of the five pollutants.

i	PSI value, P_i	Concentration, C_i				
		PM10 ($\mu g \, m^{-3}$)	SO$_2$ ($\mu g \, m^{-3}$)	CO ($mg \, m^{-3}$)	Ozone ($\mu g \, m^{-3}$)	NO$_2$ ($\mu g \, m^{-3}$)
1	50	50	80	5.0	118	−
2	100	150	365	10.0	157	−
3	200	350	800	17.0	235	1130
4	300	420	1600	34.0	785	2260
5	400	500	2100	46.0	980	3000
6	500	600	2620	57.5	1180	3750

[1 $\mu g = 10^{-6}$ g; 1 mg = 10^{-3} g]

Given the concentration of a pollutant (with units as stated in the table above), where C_{i+1} > concentration of pollutant > C_i ,

$$\text{PSI of pollutant} = [(\frac{P_{i+1} - P_i}{C_{i+1} - C_i})(\text{concentration of pollutant} - C_i)] + P_i$$

The overall PSI is then based on the maximum value out of the five calculated PSI pollutant values.

In Singapore, the 24–hr PSI is used by the National Environment Agency (NEA) to provide health advisory.

24−hr PSI	Healthy Persons	Elderly, Pregnant women, Children	Persons with chronic lung disease, heart disease, stroke
< 100	Normal activities		
101–200	Minimise prolonged or strenuous outdoor physical exertion.	Minimise prolonged outdoor activity.	Avoid all outdoor activities. If outdoor activity is unavoidable, wear N95 mask.
201–300	Avoid prolonged or strenuous outdoor physical exertion. If outdoor activity is unavoidable, wear N95 mask.	Avoid all outdoor activities. If outdoor activity is unavoidable, wear N95 mask (for adults).	
>300	Minimise all outdoor exposure. If outdoor activity is unavoidable, wear N95 mask.		

(a) **(i)** In a 1 m^3 sample of air, the mass of PM10 and carbon monoxide were found to be 320 µg and 20 mg respectively. Calculate the PSI values for each of the above pollutants, leaving your answers to **3 significant figures**.

[2]

(ii) Given that the PSI value of sulfur dioxide, ozone and nitrogen dioxide are 150, 112 and 133 respectively for the same sample of gas, use these values and your answers to **(a)(i)** to determine the overall PSI.

[1]

(iii) Assuming that the current overall PSI level is your answer in **(a)(ii)**, what advice would you give to a Physical Education (PE) teacher in Anderson Junior College who will be conducting a PE lesson soon?

………………………………………………………………………………………………......

…………………………………………………………………………………………..[1]

(b) The amount of sulfur dioxide in a sample of air can be determined by first reacting it with sodium iodate, $NaIO_3$. Iodine is one of the products in this reaction.

(i) Write an ionic equation for the reaction between sulfur dioxide and sodium iodate.

…………………………………………………………………………………………………...[1]

(ii) When a 1 m^3 sample of air was bubbled through a solution of sodium iodate, the resulting solution was neutralised by 10.0 cm^3 of 0.005 mol dm^{-3} sodium hydroxide solution.

Calculate the concentration of sulfur dioxide, in $\mu g\ m^{-3}$, in the sample of air.

[2]

(c) Some countries have set limits for particulates in the air. For example, the European Union has a daily average (24–hour) limit of 180 μg m^{-3} for PM10. Cities that violate this daily limit face a hefty financial penalty that is calculated with consideration of many factors such as the severity the violation has on the ecosystem, duration of the non–compliance and country's GDP etc.

   (i) A collected sample of air from the German city of Leipzig contains 2 x 10^{-5} % by mass of PM10. Given that the density of air is 1 kg m^{-3}, calculate the concentration of PM10 in the sample collected.

[1]

   **(ii)** Hence, deduce whether the German city of Leipzig will be faced with any financial penalty.

………………………………………………………………………………………………………......

……………………………………………………………………………………………………..[1]

[Total: 9]

3 The *Oribatula tibialis* mite uses hydrogen cyanide, HCN, a **highly volatile and toxic substance**, to poison its predators.

The HCN is stored in the form of mandelonitrile hexanoate, $C_{14}H_{17}NO_2$, in the mite's oil glands, to avoid poisoning itself. When attacked by predators, the mite secretes mandelonitrile hexanoate, which then release HCN, when in contact with the moisture, for example, from the predators' saliva.

(a) One of the possible reaction pathways of how mandelonitrile hexanoate secreted by *Oribatula tibialis* mite can release HCN is shown below.

mandelonitrile hexanoate $C_6H_{12}O_2$ C_7H_6O
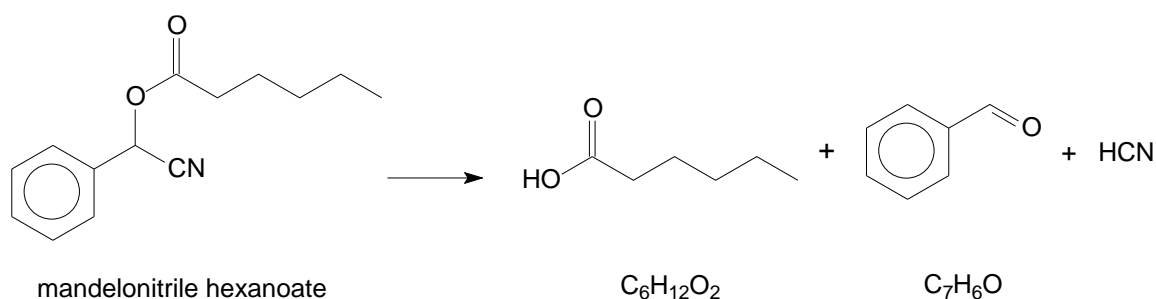
(i) Name the functional group present, in addition to the hydrocarbon groups, in each of these compounds.

…..…………………………………………………………………

……………………………………………………………………
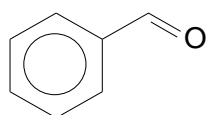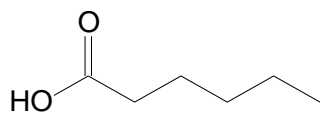
[1]

(ii) Describe a chemical test that would allow you to distinguish between the two organic products of the reaction. State what you would observe for each compound.

………

……………………………………………………………………………………………………[2]

(b) A sequence of reactions, starting from benzyl alcohol, is shown below.
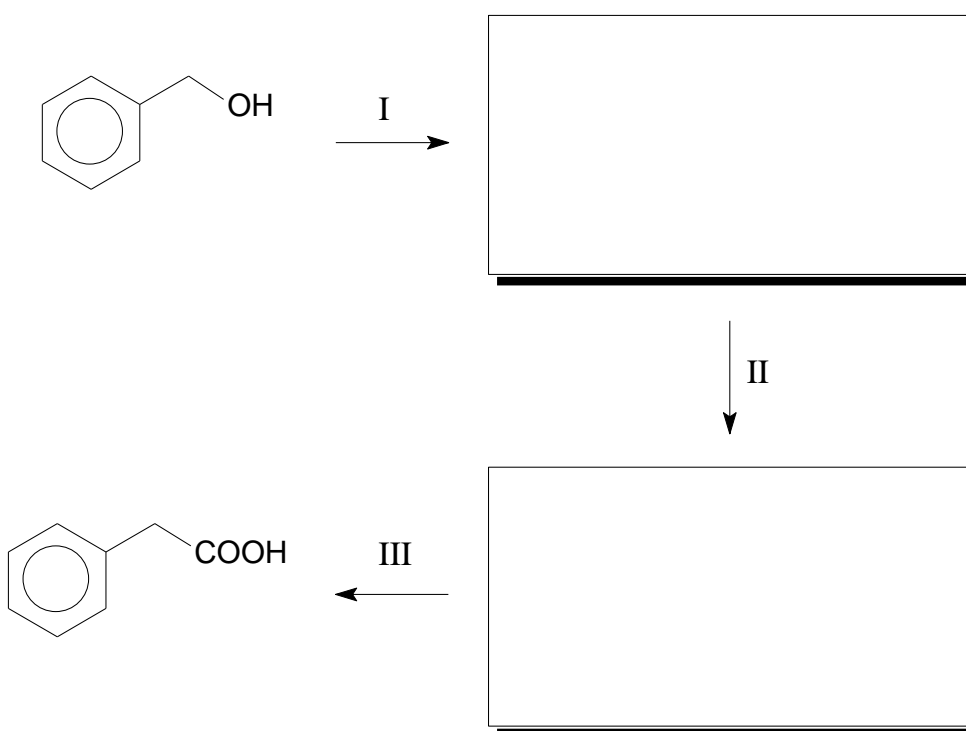
(i) In the appropriate boxes, draw the structure of the two intermediates. [2]

(ii) State the reagents and conditions required for

stage I   …………………………………………………………………………………..

stage II   …………………………………………………………………………………..

stage III …………………………………………………………………………………..

[3]

(c) Benzoic acid, $C_7H_6O_2$, can be produced by the following reaction.

Reaction 1: $C_7H_6O(l) + C_7H_6O_3(s) \longrightarrow 2C_7H_6O_2(s)$
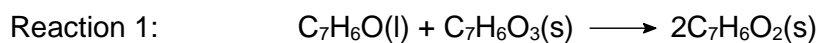
(i) Write an equation which represent the enthalpy change of combustion of benzoic acid.

……………………………………………………………………………………………………[1]

$$C_7H_6O(l) + C_7H_6O_3(s) + 15O_2(g) \longrightarrow 2C_7H_6O_2(s) + 15O_2(g)$$

$\Delta H_1^{\ominus}$ $\uparrow$ $\Delta H_3^{\ominus}$ $\downarrow$

$\Delta H_2^{\ominus}$

$$14C(s) + 6H_2(g) + 17O_2(g) \longrightarrow 14CO_2(s) + 6H_2O(l)$$
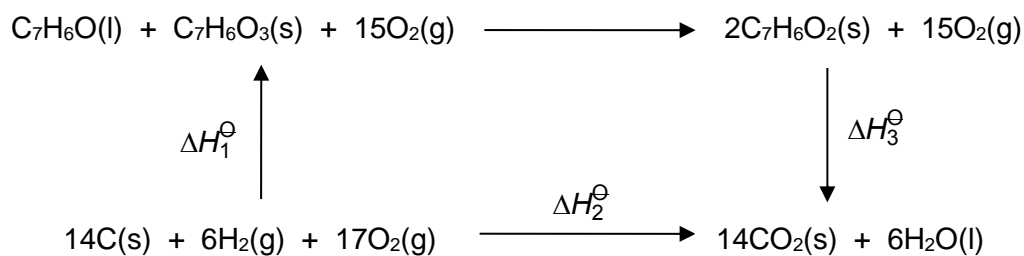
(ii) Use the above energy cycle and the following data to calculate the value for $\Delta H_1^{\ominus}$, $\Delta H_2^{\ominus}$ and $\Delta H_3^{\ominus}$.

$\Delta H_c^{\ominus}$ carbon $= -393.5$ kJ mol^{-1}

$\Delta H_c^{\ominus}$ hydrogen $= -285.8$ kJ mol^{-1}

$\Delta H_f^{\ominus}$ $C_7H_6O(l)$ $= -87.0$ kJ mol^{-1}

$\Delta H_f^{\ominus}$ $C_7H_6O_3(s)$ $= -367.0$ kJ mol^{-1}

$\Delta H_c^{\ominus}$ $C_7H_6O_2(s)$ $= -3228$ kJ mol^{-1}

[3]

(iii) Hence, calculate the standard enthalpy change of reaction for reaction 1.

[1]

[Total: 13]

4 Scientists in the United States of America have come up with a simple 3–stage process to convert ethanol into butan–1–ol, in what could be an important step forward for renewable energy.
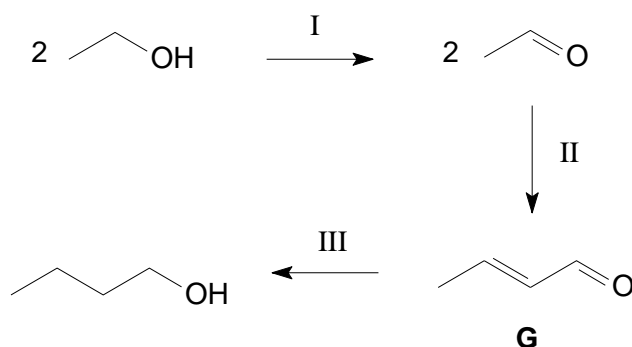

(a) **(i)** State the reagents and conditions required for stages I and III.

stage I ………………………………………………………………………………………......

stage III ……………………………………………………………………………………….....
[2]

(ii) By considering the change in molecular formula shown in stage II, suggest the type of reaction occurred.

………………………………………………………………………………………………[1]

(iii) Describe the type(s) of stereoisomerism shown by compound **G**.
Draw the displayed formula of the stereoisomers of **G**.

Type of isomerism …………………………………………………..

[2]

(iv) **G** reacts with a suitable reducing agent to give a compound **H**.

H effervesces with sodium metal and also decolourises aqueous bromine.

Suggest the structure of **H** and explain these observations.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………[2]

(b) Butan–1–ol has a number of structural isomers.

    (i) Explain what is meant by *structural isomers.*

    ………………………………………………………………………………………………………

    …………………………………………………………………………………………………[1]

    (ii) Draw the structural formula of the other three alcohols with the same molecular formula as butan–1–ol. Label your structures **J**, **K** and **L**. Classify these alcohols as primary, secondary or tertiary.

    [2]

    (iii) Identify which alcohol reacts with alkaline aqueous iodine and write a balanced equation for the reaction, showing the structural formula of the products.

    …………………………………………………………………………………………………[2]

[Total: 12]

Section B

Answer **two** questions from this section on separate writing paper.

5 **(a)** The melting points of four chlorides are given below.

compound	formula	m.p. / °C
sodium chloride	NaCl	801
aluminium chloride	AlCl₃	178
carbon tetrachloride	CCl₄	−23
silicon tetrachloride	SiCl₄	−70

    (i) Briefly relate these melting points to the structure of, and bonding in, each of these chlorides. [2]

    (ii) Describe the reaction, if any, of each of these four chlorides with water, stating the approximate pH of any solution formed, and writing a balanced equation for any reaction that takes place. Offer an explanation for any differences that occur in their reactivities. [6]

(b) Scientists in Germany have developed a liquid crystal elastomers (LCE)–based adhesive that uses UV light to switch and control its level of stickiness within seconds.

To control adhesion, the team used azobenzene, $C_{12}H_{10}N_2$ in the LCE as the light responsive molecule, which isomerises quickly from one state to another and changes size under UV light. This effect flexes the material enough to cause the microstructures to peel away from a surface and unstick, akin to how a gecko loses adhesion by moving its feet. When the light is removed, the material quickly recovers to its flat, sticky state.
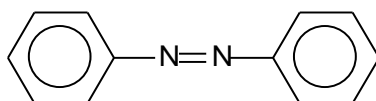
azobenzene

    (i) Outline the principles of Valence Shell Electron Pair Repulsion (VSEPR) theory and use it to suggest the bond angle around the nitrogen atom. [3]

    (ii) Azobenzene can react with bromine under certain conditions as shown in the equation below.
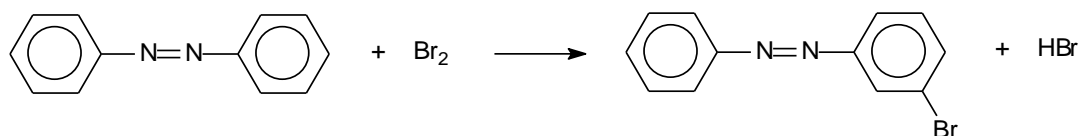
Name the type of reaction and state the conditions necessary for the reaction to occur. [2]

    (iii) Suggest the type of attraction that exists between the microstructures and the surface during adhesion. [1]

(c) *Use of the Data Booklet is relevant to this question.*

Compound **W** contains a primary amine functional group and has a molecular formula of $C_4H_7NO_3$. **W** gives an orange precipitate when treated with 2,4–dinitrophenylhydrazine but it has no reaction with Tollens' reagent. **W** gives a yellow precipitate when warmed with alkaline aqueous iodine.

W has a proton chemical shift value (δ) of 13.0 ppm.

When **W** is heated with excess CH_3Cl, it gives an organic compound $C_7H_{14}NO_3Cl$, as the major product.

Suggest the structure for **W** and show how you deduced the structure, write equations for all of the reactions described above and suggest the types of reactions that are occurring.   [6]

[Total: 20]

6 **(a)** In an experiment, 50.0 cm^3 of aqueous magnesium chloride were titrated with 1.00 mol dm^{-3} sodium hydroxide. The pH of the solution changed as in the diagram.
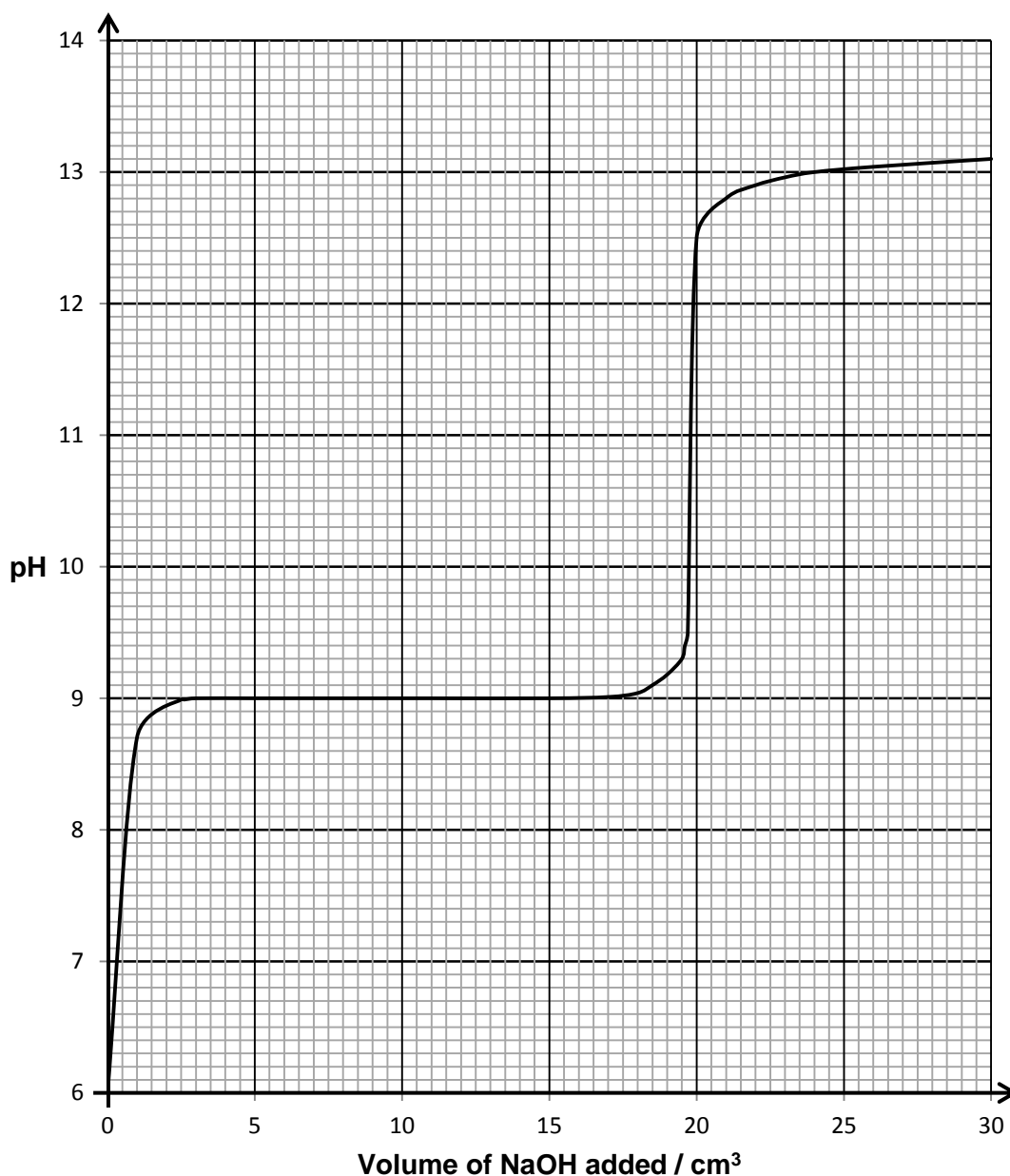
In this experiment, the hydrated magnesium ion, $Mg(H_2O)_6^{2+}$, acts as a weak acid.

(i) Write equation(s) to account for the initial pH of aqueous magnesium chloride. [1]

(ii) Hence, write an expression for the acid dissociation constant, K_a of $Mg(H_2O)_6^{2+}$ ion. [1]

(iii) Use the graph to determine the concentration of hydrogen ions, in mol dm^{-3}, present initially in the sample of aqueous magnesium chloride. [1]

(iv) The following table lists the information about two indicators.

indicator	colour in acid	colour in alkali	pH range over which the colour change occurs
alizarin yellow	yellow	orange	10.1 – 13.0
phenolphthalein	colourless	pink	8.2 – 10.0

Both indicators are added to aqueous magnesium chloride before the start of the titration.

State the colour of the solution at the following points of the titration.

(I) Before NaOH(aq) has been added.

(II) After 10 cm^3 of NaOH(aq) has been added.

(III) After 20 cm^3 of NaOH(aq) has been added.

[1]

(b) When hydrogen is reacted with iodine, the equilibrium is established.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9.6 \text{ kJ mol}^{-1}$$

The reaction below has an activation energy of +173.2 kJ mol^{-1}.

(i) Calculate the activation energy of the reverse reaction. [1]

(ii) Suggest the effect **each** of the following conditions has on the position of equilibrium and the rate of the reaction.

pressure   10 atm

temperature   2000 K

catalyst   platinum

[6]

(c) The Harcourt and Esson reaction is that between hydrogen peroxide and acidified potassium iodide.

$$H_2O_2 + 2I^- + 2H^+ \longrightarrow 2H_2O + I_2$$
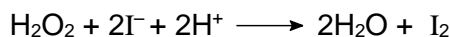
To determine the order of reaction of each reactant, two sets of reaction mixtures containing varying concentrations of I^- and H^+ were prepared. The concentration of hydrogen peroxide used for both experiments is 0.200 mol dm^{-3}. The results are as follows.

Set 1: $[I^-] = 0.175$ mol dm^{-3}

Set 2: $[I^-] = 0.350$ mol dm^{-3}
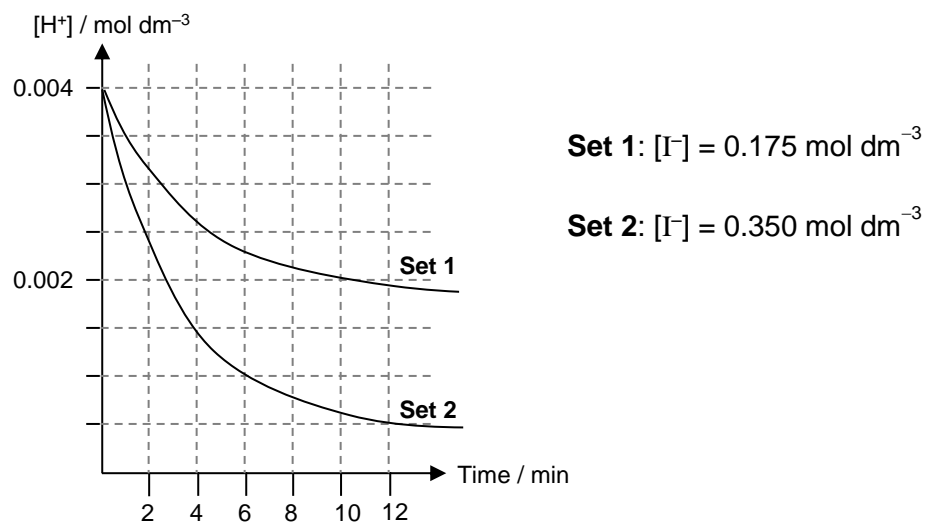
(i) Calculate the initial rate of reaction for **Set 1** and **2**. Show your working clearly. [1]

(ii) Use the information given above to determine the order of reaction with respect to I^- and H^+. Show your reasoning clearly. [2]

(iii) Using the information about **Set 1** and **2**, and your answers to **(c)(i)**, sketch a graph to show how the rate of reaction changes with concentration of iodine. Label your graph clearly. [2]

(iv) A student performed another experiment to determine the order of reaction with respect to H_2O_2, using the following concentrations.

	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
Set 3	0.3	0.10	0.004	

He made a random guess that the order of reaction with respect to hydrogen peroxide is two. Deduce an estimated value of the initial rate of reaction for **Set 3** if his guess is correct. [2]

(v) The actual order of reaction with respect to H_2O_2 is one.

The rate of the reaction was measured as 4.4×10^{-5} mol dm^{-3}s^{-1} when $[H_2O_2] = 0.002$ mol dm^{-3}, $[H^+] = 0.2$ mol dm^{-3} and $[I^-] = 0.2$ mol dm^{-3}

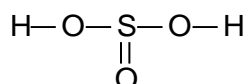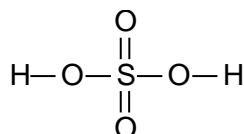Determine the rate constant for this reaction and state its units.

[2]

[Total: 20]

7 The oxygen family, also called the chalcogens, consists of the elements found in Group 16 of the Periodic Table and is considered among the main group elements. It consists of the elements oxygen, sulfur, selenium, tellurium and polonium.

(a) **(i)** State and explain the trend in the first ionisation energy of the Group 16 elements down the group. [2]

(ii) How would you expect the first ionisation energy of $_{34}$Se to compare with that of $_{35}$Br? Give your reasoning. [2]

(b) **(i)** Describe the structure of a ^{128}Te atom, in terms of number and type of sub–atomic particles and give the electronic configuration for a tellurium(II) ion, Te^{2+}. [3]

(ii) State the formula of the oxide of tellurium in its highest oxidation state. [1]

(iii) State one physical property that you would expect this oxide of tellurium to possess. Explain, in terms of the structure and bonding present, why it possesses this property. [2]

(iv) Write an equation to illustrate the behavior of this oxide of tellurium in water. [1]

(c) When SO_3 is distilled into ICl_3 at 10 °C, a single ionic product is formed.

$$ICl_3 + SO_3 \longrightarrow (ICl_2^+)(SO_3Cl^-)$$
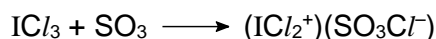
(i) Draw dot–and–cross diagrams to illustrate the bonding in **each** of the ions and predict their shapes. [4]

(ii) SO_3 dissolves in water to form sulfuric acid while the other oxide of sulfur, SO_2, gives H_2SO_3. The structures of the two acids are as shown below.

$$
\begin{array}{ccc}
& O & \\
& \| & \\
H-O-&S&-O-H \\
& \| & \\
& O &
\end{array}
\qquad\qquad
\begin{array}{ccc}
H-O-&S&-O-H \\
& \| & \\
& O &
\end{array}
$$

Explain why H_2SO_4 is a stronger acid than H_2SO_3. [2]

(d) $CH_3CH(OH)CH_2COCH_2CO_2H$ forms a cyclic 6–membered ring when heated with concentrated sulfuric acid.

(i) Suggest the role of concentrated sulfuric acid in this reaction. [1]

(ii) Write a balanced equation for the reaction and draw the organic compound formed. [2]

[Total: 20]

1   **(a)**   **(i)**   **$2Fe^{3+}(aq) + Sn^{2+}(aq) \longrightarrow 2Fe^{2+}(aq) + Sn^{4+}(aq)$**   [1]
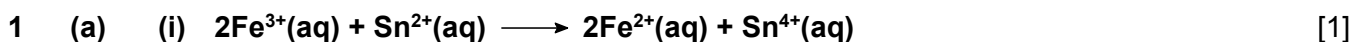
ignore state symbols

     (ii)

titration number	1	2	3
initial burette reading / cm³	0.00	19.95	2.10
final burette reading / cm³	19.95	39.05	22.15
titre / cm³	19.95	<u>20.00</u>	<u>20.05</u>

[2]

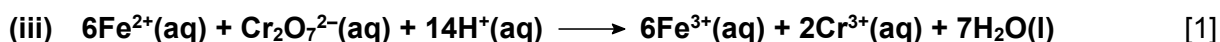average volume of KI used = $\frac{1}{3}$ (19.95 + 20.00 + 20.05)

                              = <u>20.00 cm³</u>

$n(K_2Cr_2O_7)$ required = $\frac{20.00}{1000}$ x 0.100

                            = <u>0.00200 mol</u>

[1]: correctly determine the titre for run 2 and 3 and used all 3 titres to find the average titre (accept if students used any 2 titres which are within 0.05 cm³)
[1]: $n(K_2Cr_2O_7)$

     (iii)   **$6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \longrightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$**   [1]

ignore state symbols

     (iv) $n(Fe^{2+})$ in 25.0 cm³ of solution = 6 x 0.00200   [2]
                                        = 0.0120 mol
         $n(Fe^{2+})$ in 250 cm³ of solution = 0.0120 x 10
                                         = <u>0.120 mol</u>

mass of Fe present = 0.120 x 55.8
                         = 6.696 g

% by mass of iron in the sample of iron ore = $\frac{6.696}{11.05}$ x 100%

                                                       = <u>60.6 %</u>

[1]: $n(Fe^{2+})$ originally present in 250 cm³ (scaling)
[1]: % by mass of iron in iron ore (ecf)

2 (a) (i) PSI of PM10 = $\dfrac{200-100}{350-150}(320-150)+100$ = <u>185</u> [2]

PSI of CO = $\dfrac{300-200}{34-17}(20-17)+200$ = <u>218</u>

[1] each

(ii) overall PSI is the maximum value out of 185, 218, 112, 133 and 150. Hence overall PSI is <u>218</u>. [1] ecf

(iii) I would advise the PE teacher to <u>avoid strenuous physical exertion</u> / <u>conduct the lesson indoor</u> (words to the effect based on valid reasoning). [1] ecf

(b) (i) $SO_2 + 2H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e^-$ (x 5) [1]
$2IO_3^- + 12H^+ + 10e^- \longrightarrow I_2 + 6H_2O$

overall: **$5SO_2 + 4H_2O + 2IO_3^- \longrightarrow 5SO_4^{2-} + 8H^+ + I_2$**

(ii) $H^+ + OH^- \longrightarrow H_2O$ [2]
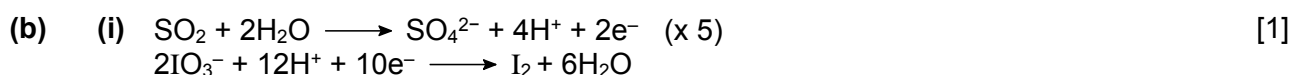
$n(NaOH)$ reacted = 0.01 x 0.005
$\qquad\qquad\qquad$ = 5×10^{-5} mol
$n(H^+)$ reacted with NaOH = 5×10^{-5}

$n(SO_2)$ in 1 m^3 sample of air = $5 \times 10^{-5} \times \dfrac{5}{8}$
$\qquad\qquad\qquad\qquad$ = <u>3.125×10^{-5} mol</u>
mass of SO_2 in 1 m^3 sample of air = $3.125 \times 10^{-5} \times 64.1$
$\qquad\qquad\qquad\qquad\qquad$ = 0.00200 g
$\qquad\qquad\qquad\qquad\qquad$ = 2000 μg
concentration of SO_2 = <u>2000</u> μg m^{-3}

[1]: $[SO_2]$ in mol m^{-3}
[1]: $[SO_2]$ in μg m^{-3}

(c) (i) In 1 m^3, [1]
$\qquad$ mass of air is 1 kg
$\qquad$ mass of PM10 is $\dfrac{2 \times 10^{-5}}{100} \times 1 = 2 \times 10^{-7}$ kg = 0.0002 g = 200 μg
Hence concentration of PM10 is <u>200</u> μg m^{-3}

(ii) Since concentration calculated in **(c)(i)** is <u>more than 180</u>, the sample of air has exceeded the limit. [1] ecf

The German city of Leipzig <u>will be fined</u>.

3   (a)   (i)   carboxylic acid   [1]
aldehyde

[1] both correct

(ii)   Add Tollens' reagent / 2,4–dinitrophenylhydrazine, warm (accept Fehling's)   [2]

For aldehyde, a silver mirror (or grey ppt) is formed / orange ppt formed.
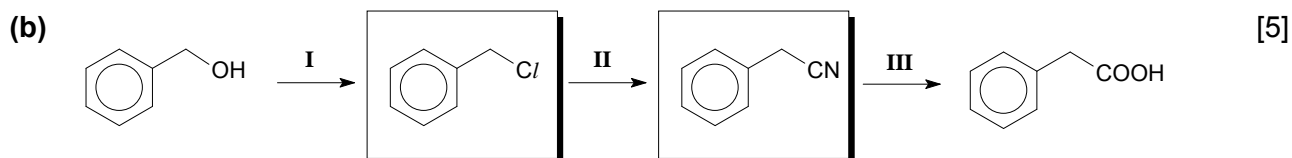No ppt formed for carboxylic acid.

Add Na or Mg metal.
For aldehyde, no gas evolved.
For carboxylic acid, effervescence observed, gas gives a 'pop' sound with lighted splint.

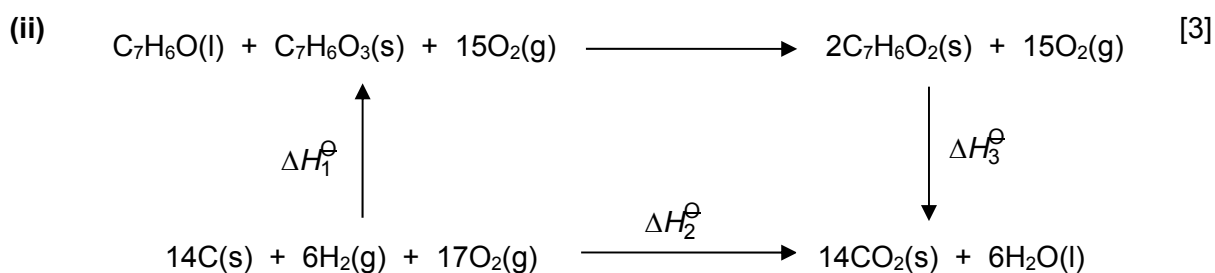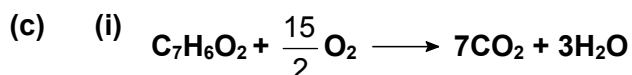[1]: reagent and condition
[1]: observation

(b)   [5]

stage I: anhydrous PCl_5, room temp (accept SOCl_2, PCl_3 (w heat) or Br analogous, NaBr in concentrated H$_2$SO$_4$ (w heat))
stage II: ethanolic KCN, heat under reflux
stage III: dilute H$_2$SO$_4$, heat (accept dil. HCl)

[1] each intermediate
[1] each set of reagent and condition

(c)   (i) $C_7H_6O_2 + \dfrac{15}{2} O_2 \longrightarrow 7CO_2 + 3H_2O$

(ii) $C_7H_6O(l) + C_7H_6O_3(s) + 15O_2(g) \longrightarrow 2C_7H_6O_2(s) + 15O_2(g)$ [3]

$14C(s) + 6H_2(g) + 17O_2(g) \xrightarrow{\Delta H_2^{\ominus}} 14CO_2(s) + 6H_2O(l)$

$\Delta H_1^{\ominus}$ $\Delta H_3^{\ominus}$

$\Delta H_1^{\ominus} = \Delta H_f^{\ominus} C_7H_6O(l) + \Delta H_f^{\ominus} C_7H_6O_3(s)$
$= (-87) + (-367)$
$= \underline{-454 \text{ kJ mol}^{-1}}$

$\Delta H_2^{\ominus} = 14\Delta H_c^{\ominus} \text{ carbon} + 6\Delta H_c^{\ominus} \text{ hydrogen}$
$= 14 (-393.5) + 6(-285.8)$
$= \underline{-7223.8 \text{ kJ mol}^{-1}}$

$\Delta H_3^{\ominus} = 2\Delta H_c^{\ominus} C_7H_6O_2(s)$
$= 2(-3228)$
$= \underline{-6456 \text{ kJ mol}^{-1}}$

(iii) By Hess' Law, [1]
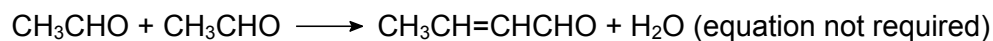
$\Delta H_r^{\ominus}$ for reaction 1 $= -\Delta H_1^{\ominus} + \Delta H_2^{\ominus} - \Delta H_3^{\ominus}$

$= -(-454) + (-7223.8) - (-6456)$

$= \underline{-314 \text{ kJ mol}^{-1}}$

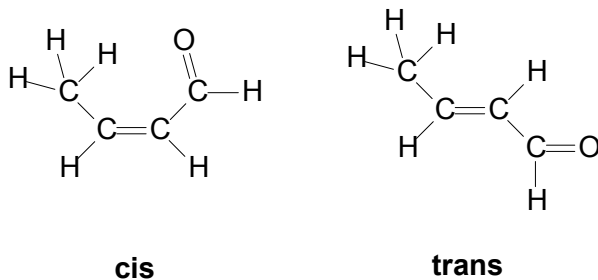**4** **(a)** **(i)** stage I: $K_2Cr_2O_7$, dilute H_2SO_4, <u>warm</u> with immediate <u>distillation</u> [2]

stage III: H_2, Pt / Pd, room temperature (accept Ni, with or w/o warm/heat)

[1] each

(ii) <u>condensation</u> [1]

$CH_3CHO + CH_3CHO \longrightarrow CH_3CH=CHCHO + H_2O$ (equation not required)

(iii) <u>cis–trans isomerism</u> [2]

cis   **trans**

[1]: type of isomerism with correct label
[1]: displayed structure

(iv) [2]

G is reduced to **H** (an <u>alcohol</u>) which reacts with <u>sodium metal</u> to give <u>effervescence of H_2</u>. **H** <u>reacts with aqueous Br_2</u> because of the <u>C=C bond present</u>.

[1]: structure of **H**
[1]: explanation

(b) **(i)** compounds with the <u>same molecular formula</u> [1]
but <u>different structural formula / structure</u>

(ii) [2]

$CH_3CH_2CHCH_3$ (OH) CH_3CHCH_2OH (CH_3) $(CH_3)_3COH$

J   **K**   **L**

2° 1° 3°

[1]: all 3 structural isomers correctly identified and labelled (in any order)
[1]: corresponding classification of 3 alcohols

(iii) **J** reacts with alkaline aqueous iodine [2]

$CH_3CH_2CH(OH)CH_3 + 4I_2 + 6OH^- \longrightarrow CH_3CH_2CO_2^- + CHI_3 + 5I^- + 5H_2O$
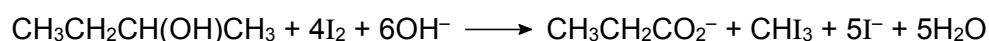
[1]: correctly identified the alcohol with positive reaction with I_2/OH^-
[1]: balanced equation

**5** **(a)** **(i)** NaCl exists as a <u>giant ionic lattice</u> with <u>strong electrostatic forces of attraction</u> between Na$^+$ and Cl^- ions. A lot of energy is required to break these strong ionic bonds in order to melt NaCl. Hence, it has a very high melting point. [1]

AlCl_3, CCl_4 and SiCl_4 are <u>simple molecular molecules</u> with <u>weak instantaneous dipole–induced dipole attraction</u> between the molecules. Hence, they have low melting points. [1]

(ii) NaCl <u>dissolves</u> in water without further reaction to give a neutral solution (<u>pH 7</u>). Hydrolysis does not occur for Na$^+$ and Cl^-. [6] max

$$NaCl(s) \longrightarrow Na^+(aq) + Cl^-(aq)$$

AlCl_3 <u>dissolves</u> in water with <u>some hydrolysis</u> (due to the large polarising power of Al^{3+} ions) to give an acidic solution (<u>pH 3</u>)

$$[Al(H_2O)_6]^{3+} (aq) + H_2O (l) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} (aq) + H_3O^+ (aq)$$
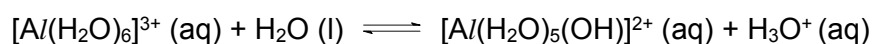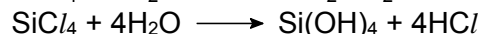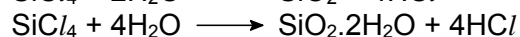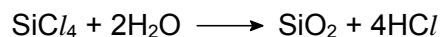
CCl_4 will <u>not undergo hydrolysis</u>. (<u>pH 7</u>)
This is because CCl_4 has <u>no vacant low−lying</u> (energetically accessible) d−orbitals to accept the lone pair of electrons from the water molecules.
or
<u>(steric hindrance)</u> it is difficult for the water molecule to attack the carbon atoms due to the large chlorine atoms present.

SiCl_4 undergo <u>complete hydrolysis</u> in water to give a strongly acidic solution due to the presence of empty low–lying 3d orbitals to accommodate the lone pair of electrons from water molecules. (<u>pH 1</u>)

$$SiCl_4 + 2H_2O \longrightarrow SiO_2 + 4HCl$$
$$SiCl_4 + 4H_2O \longrightarrow SiO_2.2H_2O + 4HCl$$
$$SiCl_4 + 4H_2O \longrightarrow Si(OH)_4 + 4HCl$$

[1] each description with correct pH
[1] each balanced equation

(b) **(i)** Valence <u>electron pairs</u> (bond pairs and lone pairs) around an atom of a molecule arrange themselves as <u>far apart</u> as possible to <u>minimise inter–electronic repulsion</u>. [1]

The strength of repulsion between electron pairs decreases in the order: lp–lp > lp–bp > bp–bp. [1]
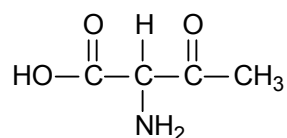
Since there are 2 bond pairs and 1 lone pair around N atom, bond angle will be <u>117°</u>. (accept 110° < angle < 120°) [1]

(ii) Type: substitution [1]
Conditions: Br$_2$, AlBr$_3$ or FeBr$_3$ catalyst [1]

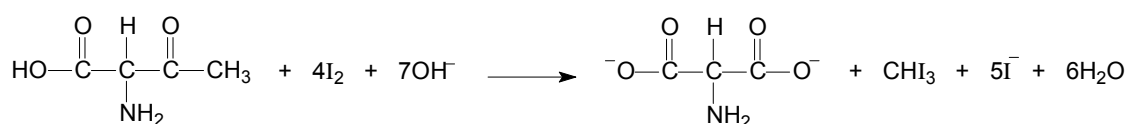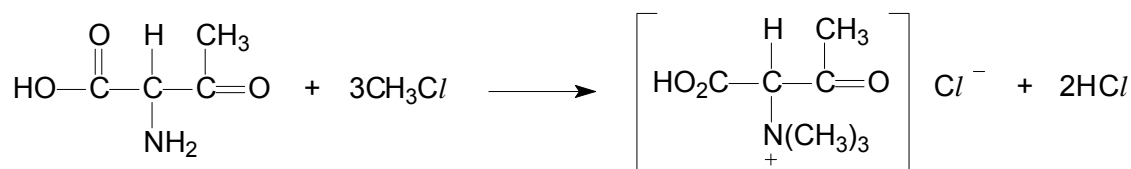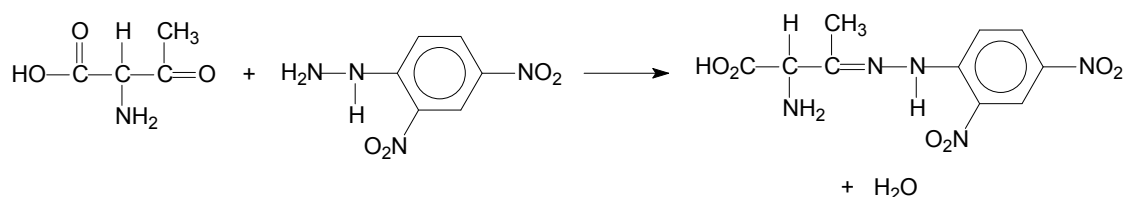**(iii)** instantaneous dipole–induced dipole / permanent dipole–permanent dipole / van der Waals [1]

(c)

$$HO-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle NH_2}{|}}{C}}-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$$

W

[6]

Observations	Type of reaction	Deduction
Compound **W** contains a primary amine functional group.		**W** contains R–NH$_2$.
W gives an orange precipitate when treated with 2,4–DNPH but it has no reaction with Tollens' reagent.	condensation	**W** is a ketone not an aldehyde.
W gives a yellow precipitate when warmed with alkaline aqueous iodine.	(mild) oxidation	**W** contains the structure RCOCH$_3$ or RCH(OH)CH$_3$.
W has a proton chemical shift (δ) of 13.0 ppm.		from page 34 of the *Data Booklet*, **W** contains –COOH.
W is heated with excess CH$_3$Cl, it gives C$_7$H$_{14}$NO$_3$Cl, as the major product.	substitution	further / multi–substitution occurs / product is a substituted amine

[2]: 5–8 points
[1]: 2–4 points

$$HO-\overset{O}{\overset{\|}{C}}-\overset{H}{\underset{NH_2}{\overset{|}{C}}}-\overset{O}{\overset{\|}{C}}-CH_3 \;+\; 4I_2 \;+\; 7OH^- \;\longrightarrow\; {}^-O-\overset{O}{\overset{\|}{C}}-\overset{H}{\underset{NH_2}{\overset{|}{C}}}-\overset{O}{\overset{\|}{C}}-O^- \;+\; CHI_3 \;+\; 5\bar{I} \;+\; 6H_2O$$

(accept if –CO$_2$H is not neutralised, i.e. 6OH$^-$/5H$_2$O)

$$HO-\overset{O}{\overset{\|}{C}}-\overset{H}{\underset{NH_2}{\overset{|}{C}}}-\overset{CH_3}{\overset{|}{C}}=O \;+\; H_2N-\underset{H}{\overset{|}{N}}-\!\!\bigcirc\!\!-NO_2 \;\longrightarrow\; HO_2C-\overset{H}{\underset{NH_2}{\overset{|}{C}}}-\overset{CH_3}{\overset{|}{C}}=N-\underset{H}{\overset{|}{N}}-\!\!\bigcirc\!\!-NO_2 \;+\; H_2O$$

(with O$_2$N substituents on the rings)

$$HO-\overset{O}{\overset{\|}{C}}-\overset{H}{\underset{NH_2}{\overset{|}{C}}}-\overset{CH_3}{\overset{|}{C}}=O \;+\; 3CH_3Cl \;\longrightarrow\; \left[HO_2C-\overset{H}{\underset{\underset{+}{N(CH_3)_3}}{\overset{|}{C}}}-\overset{CH_3}{\overset{|}{C}}=O \right] Cl^- \;+\; 2HCl$$

[1]: structure of **W**
[2]: deductions and types of reactions
[1] each balanced equation

6 **(a)** **(i)** $MgCl_2(s) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq)$ [1]
$Mg(H_2O)_6{}^{2+}(aq) + H_2O(l) \rightleftharpoons Mg(H_2O)_5(OH)^+(aq) + H_3O^+(aq)$
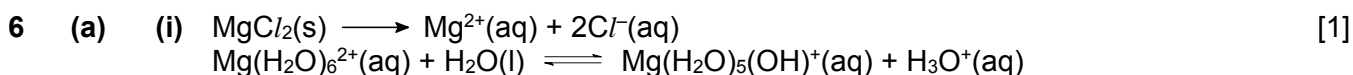
(ignore state symbol and if 1st equation is not given)

(ii) $K_a = \dfrac{[Mg(H_2O)_5(OH)^+][H_3O^+]}{[Mg(H_2O)_6{}^{2+}]}$ [1]

(iii) from the graph, pH = 6 [1]
$[H^+] = 10^{-6}$
$= \underline{1 \times 10^{-6} \text{ mol dm}^{-3}}$

(iv) **(I)** yellow [1]
(II) yellowish pink / pinkish yellow
(III) orange pink

(b) **(i)** Activation energy of reverse reaction = 9.6 + 173.2 [1]
$= \underline{182.8 \text{ kJ mol}^{-1}}$

(ii) <u>High pressure</u> [6]
Position of equilibrium (P.O.E.) remains <u>unchanged</u> since there are <u>equal number of moles of gaseous reactants and products particles</u>.
Rate will <u>increase</u> since there are <u>more gaseous particles per unit volume</u> thus <u>increases the frequency of effective collisions</u>.

<u>High temperature</u>
P.O.E. shifts <u>left</u>, since <u>backward endothermic</u> reaction is favoured to remove the excess heat.
Rate will <u>increase</u> as the <u>average kinetic energy</u> of particles is increased, leading to <u>greater frequency of effective collisions</u>.

<u>Presence of catalyst</u>
P.O.E. remains <u>unchanged</u>, as the rate of the forward and reverse reaction increase by the same extent.
Rate of reaction will <u>increase</u> since the presence of catalyst <u>provides an alternative pathway of lowered activation energy</u>. More reactant molecules will possess energy greater than or equal to the activation energy, leading to <u>greater frequency of effective collisions</u>.

[1] each effect on P.O.E.
[1] each effect on rate of reaction

(d) **(i)** Taking gradient at t = 0, [1]
set 1 $= \dfrac{0.004}{8}$
$= \underline{5 \times 10^{-4} \text{ mol dm}^{-3} \text{ min}^{-1}}$

set 2 $= \dfrac{0.004}{4}$
$= \underline{1 \times 10^{-3} \text{ mol dm}^{-3} \text{ min}^{-1}}$

[1] both correct (accept 6–8 min for set 1, 3–4min for set 2)

(ii) When $[H^+]$ decreases from 0.004 mol dm^{-3} to 0.002 mol dm^{-3}, time taken is 3 min [2]
When $[H^+]$ decreases from 0.002 mol dm^{-3} to 0.001 mol dm^{-3}, time taken is 3 min
Since $t_{1/2}$ is constant at 3 min, order of reaction wrt H^+ is <u>1</u>.

	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
Set 1	0.200	0.175	0.004	0.0005
Set 2	0.200	0.350	0.004	0.001

Comparing **Set 1** and **Set 2**, when concentration of $[I^-]$ is doubled, the rate is also <u>doubled</u>. Since rate is directly proportional to $[I^-]$, order of reaction wrt $[I^-]$ is <u>1</u>.

[1] each order of reaction

(iii) [2]
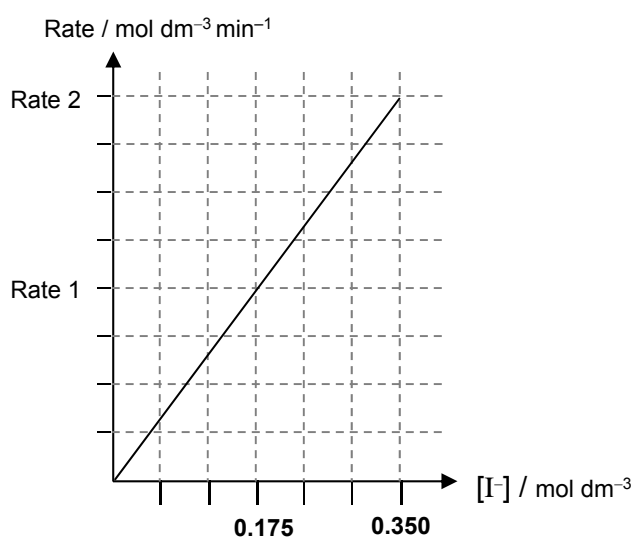
[1]: straight line passing thru the origin
[1]: labels using both sets of data

(iv) Based on student's guess, rate $= k[H_2O_2]^2[H^+][I^-]$ [2]

$$\frac{\text{rate}_3}{\text{rate}_1} = \frac{(0.3)^2(0.004)(0.10)}{(0.2)^2(0.004)(0.175)}$$
$\text{rate}_3 = 1.28 \times 0.0005$
$\quad = \underline{6.43 \times 10^{-4} \text{ mol dm}^{-3} \text{ min}^{-1}}$

Alternative

	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
Set 1	0.2	0.175	0.004	0.0005
Set 1a	0.2	0.10	0.004	0.000286
Set 3	0.3	0.10	0.004	0.000644

When $[I^-]$ is decreased from 0.175 to 0.10 mol dm^{-3},
rate $= 0.0005 \times (\frac{0.10}{0.175}) = 0.000286$ mol dm^{-3}.

When [H_2O_2] is increased from 0.2 to 0.3 mol dm^{-3},

rate = 0.000286 x ($\frac{0.30}{0.20}$)^2 = <u>0.000644 mol dm^{-3}</u>

[1]: proportional decrease in rate when [I$^-$] decreases by 1.75.
[1]: rate increases by (1.5)^2 when [H_2O_2] increases by 1.5.

(v) Rate = k [H_2O_2] [I$^-$] [H$^+$]   [2]
4.4 x 10^{-5} = k(0.002)(0.2)(0.2)
k = <u>0.550 mol^{-2} dm^6 s^{-1}</u>

[1]: value of k
[1]: units

7 **(a)** **(i)** I.E. <u>decreases</u> down the group   [2]
Nuclear charge increases, the number of <u>electron shells</u> also <u>increases</u> and valence electrons are <u>further away</u> from the nucleus.
<u>nuclear charge attraction</u> experienced by the valence electron <u>decreases</u>.

[1]: trend
[1]: explanation in terms of weaker attraction due to valence electron being further from nucleus / at a higher energy level

(ii) I.E. of Se is <u>lower</u>   [2]
Se has one proton less (<u>smaller nuclear charge</u>) but <u>relatively constant shielding effect</u> and <u>effective nuclear charge</u> is <u>smaller</u> in Se
<u>nuclear charge attraction</u> experienced by the valence electron is <u>weaker</u>.

[1]: I.E. of Se is lower
[1]: explanation in terms of ENC

(b) **(i)** no. of protons = <u>52</u>   [3]
= no. of electrons
no. of neutrons = 128 – 52
= <u>76</u>

electronic configuration of Te: $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^{10}\,4s^2\,4p^6\,4d^{10}\,5s^2\,5p^4$
electronic configuration of Te: $\underline{1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^{10}\,4s^2\,4p^6\,4d^{10}\,5s^2\,5p^2}$
(accept abbreviated electronic configuration: $[Kr]\,4d^{10}\,5s^2\,5p^2$)

[1]: no. of protons and electrons
[1]: no. of neutrons
[1]: electronic configuration

(ii) <u>TeO_3</u>   [1]

(iii) TeO_3 has a <u>simple molecular structure</u> with <u>weak intermolecular forces</u> (id–id / vdW)   [2]
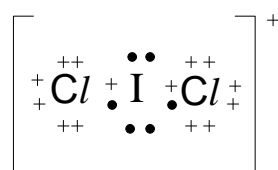
hence likely to be a volatile liquid or solid with <u>low bp / m.p.</u> that <u>does not conduct electricity in all states</u>

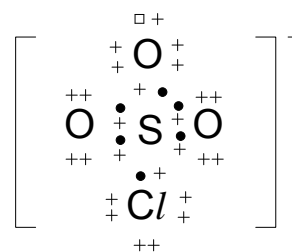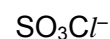[1]: either physical property
[1]: structure and bonding

(iv) Hydrolysis   [1]
$TeO_3 + H_2O \longrightarrow H_2TeO_4$

(c) **(i)** ICl_2^+ SO_3Cl^- [4]

shape: <u>bent</u>

shape: <u>tetrahedral</u>

(ii) $H_2SO_4 + H_2O \rightleftharpoons HSO_4^- + H_3O^+$ [2]
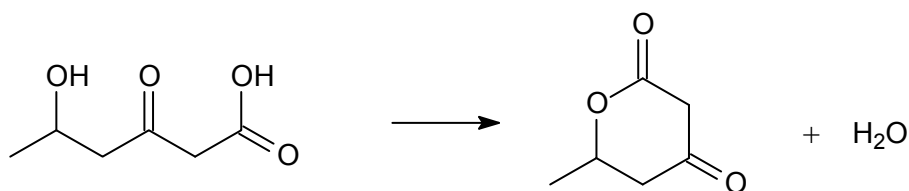$H_2SO_3 + H_2O \rightleftharpoons HSO_3^- + H_3O^+$

The HSO_4^- conjugate base has an <u>additional electronegative O atom</u>. This results in a <u>greater electron–withdrawing effect</u> which allows the <u>negative charge on the anion is to be dispersed</u> to a larger extent, <u>stabilizing the anion</u>.
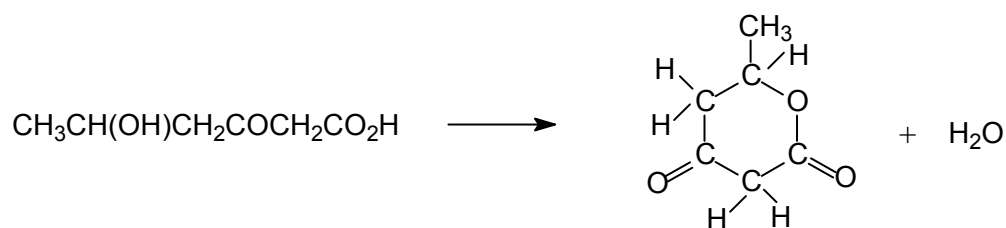The dissociation of H_2SO_4 is more favoured, POE will be shifted more to the right.

[1]: identify presence of an additional O atom in HSO_4^-
[1]: greater dispersal of charge

(d)   **(i)** catalyst / dehydrating agent (do not accept drying agent)   [1]

     (ii)   [2]

OR

$CH_3CH(OH)CH_2COCH_2CO_2H \longrightarrow$

$+ \ H_2O$

[1]: structural formula of organic product
[1]: balanced equation