ANDERSON JUNIOR COLLEGE

2018 JC 2 PRELIMINARY EXAMINATION

CHEMISTRY **8873/01**

Paper 1 Multiple Choice **17 September 2018**

1 hour

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: 17/09/2018

This document consists of **11** printed pages.

1 An unknown gaseous hydrocarbon C_xH_y of volume V is mixed with oxygen and then completely combusted.

Which volume of oxygen reacts with the hydrocarbon?

A $(\frac{x}{2} + \frac{y}{4})V$ **B** xV **C** $(x + \frac{y}{2})V$ **D** $(x + \frac{y}{4})V$

2 A sample of silicon contains three naturally occurring isotopes, ^{28}Si, ^{29}Si and ^{30}Si.

The sample is made up of 92.23% ^{28}Si and the relative atomic mass of silicon in this sample is 28.10.

What is the percentage of the isotope ^{29}Si in the sample?

A 2.23% **B** 3.89% **C** 5.54% **D** 7.77%

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

How many hydrogen atoms are present in 15 g of ethanoic acid?

[L = Avogadro constant]

A $\frac{1}{L}$ **B** $\frac{L}{4}$ **C** L **D** $60L$

4 The space shuttle's upward thrust, on lift off, came from the reaction between aluminium and ammonium perchlorate.

$$10Al + 6NH_4ClO_4 \longrightarrow 4Al_2O_3 + 2AlCl_3 + 12H_2O + 3N_2$$

Which statement about the overall reaction is correct?

1 Aluminium is oxidised.

2 Chlorine is reduced.

3 Hydrogen is oxidised.

4 Nitrogen is reduced.

5 Oxygen is oxidised.

A 1 and 2 only

B 2 and 5 only

C 1, 2 and 3 only

D 3, 4 and 5 only

5 Which of the following statements about isotopes is correct?

A They have the same number of protons but different number of electrons.

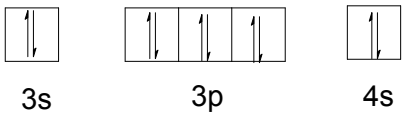
B They have the same number of protons but different number of neutrons.

C They have the same number of neutrons but different number of electrons.

D They have the same number of neutrons but different number of protons.

6 Which diagram represents the arrangement of electrons in the 3rd and 4th quantum shell of a Ca^{3+} ion?

A



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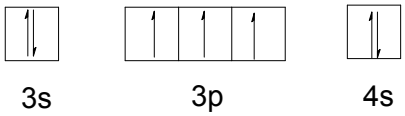

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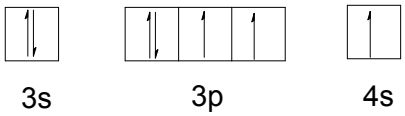
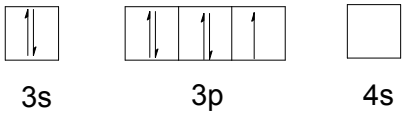


D



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

The successive ionisation energies, in kJ mol^{-1}, of an element **D** are given below.

900 1730 2570 3830 4860 6950 8210 12600

What is **D**?

A $_{52}Te$ **B** $_{53}I$ **C** $_{84}Po$ **D** $_{85}At$

8 Argon has the following electronic configuration:

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Which of the following ions does **not** have the same electronic configuration as argon?

A P^{3-} **B** Cl^- **C** Ca^+ **D** Ti^{4+}

9 Which of the following molecules has the greatest polarity?

A BF_3 **B** NCl_3 **C** $SiCl_4$ **D** SF_6

10 As a fixed mass of ice melts at 0 °C, which of the following statements are true?

1 The weak covalent bonds between H_2O molecules are broken.

2 There is a contraction in volume.

3 The temperature of the ice–water mixture increases.

4 The average number of hydrogen bonds per H_2O molecule remains unchanged.

A 1 and 2 only

B 3 and 4 only

C 2 and 3 only

D 2 and 4 only

11 In which pair of species are the values of the bond angles the most different?

A PF_3 and NH_3

B NH_4^+ and SO_4^{2-}

C NH_2^- and H_2S

D CH_3^- and CH_3^+

12 The Brønsted–Lowry theory describes acid and base character.

When concentrated sulfuric acid and concentrated nitric acid are mixed, the following reactions occur.

$$H_2SO_4 + HNO_3 \rightleftharpoons HSO_4^- + H_2NO_3^+$$

$$H_2NO_3^+ \rightleftharpoons H_2O + NO_2^+$$

$$H_2O + H_2SO_4 \rightleftharpoons HSO_4^- + H_3O^+$$

Which species are bases in these reactions?

1 HSO_4^-

2 HNO_3

3 NO_2^+

A 1 only

B 2 only

C 3 only

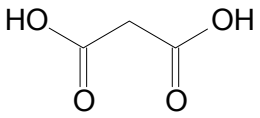
D 1 and 2 only

13 A solution was made by mixing equal volumes of two acids of pH 1 and pH 3.

What is the pH of the resulting solution?

A 1.0 **B** 1.3 **C** 2.0 **D** 2.5

14 Malonic acid is a weak dibasic acid and has the structure shown below.



The concentration of a solution of malonic acid was determined by titrating it against a standard solution of aqueous sodium hydroxide in a burette. The pH of the first and second equivalence points are found to be 4.5 and 9.1 respectively.

Which of the following is a suitable indicator for part of this titration?

	indicator	*pH range*
A	thymol blue	1.2 to 2.8
B	methyl orange	3.2 to 4.4
C	bromocresol green	3.8 to 5.5
D	phenol red	6.4 to 8.0

15 The main buffering agent to maintain the blood pH at 7.4 is the H_2CO_3/HCO_3^- system. The following two equations show the equilibria of H_2CO_3/HCO_3^- system in the body.

$$H_2O(l) + CO_2(g) \rightleftharpoons H_2CO_3(aq) \quad \ldots\ldots (1)$$

$$H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq) \quad \ldots\ldots (2)$$

During strenuous exercise, the blood pH may fall below 7.4.

Which of the following actions will help the body increase the blood pH?

1 Breathing into a paper bag.

2 Removing H^+ ions from the blood.

3 Secreting HCO_3^- ions into the blood.

A 1 and 2 only **B** 2 and 3 only **C** 1 and 3 only **D** 1, 2 and 3

16 Which series is correctly arranged in order of increasing values?

A atomic radius of P, S, C*l*

B ionic radius of Na^+, Mg^{2+}, Al^{3+}

C melting point of A*l*, Si, P

D second ionisation energy of Si, P, S

17 An element *X* in Period 3 is a semiconductor and has a chloride which reacts with water to form an acidic solution.

An element *Y* has an atomic number one less than element *X*.

What is a property of the oxide of element *Y*?

A It is a gas at room temperature.

B It is amphoteric.

C It is covalent.

D Its formula is YO_2.

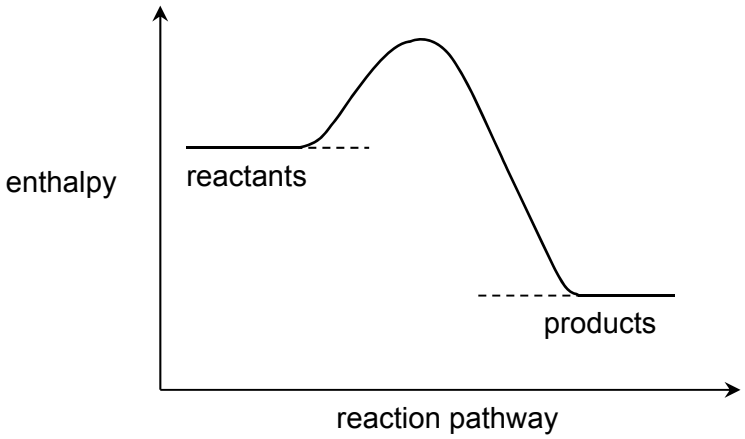
18 The information relates to element *Z*.

- *Z* is in Period 3 of the Periodic Table.
- *Z* has a lower electrical conductivity than Mg.
- A *Z* atom has a half–filled subshell in its ground state.
- *Z* forms an acidic oxide on exposure to air.

What is *Z*?

A Na **B** Si **C** P **D** C*l*

19 Which enthalpy change could **never** be correctly represented by the following enthalpy diagram?



A standard enthalpy change of combustion

B standard enthalpy change of formation

C standard enthalpy change of neutralisation

D standard enthalpy change of vapourisation

20 Which statement best defines the term bond energy for a diatomic gaseous molecule PQ?

A energy released when one mole of PQ is formed from its gaseous ions

B energy released when one molecule of PQ is formed from its gaseous atoms

C energy required when one molecule of PQ is broken into its gaseous atoms

D energy required when one mole of PQ is broken into its gaseous atoms

21 N_2O_5 decomposes according to the equation.

$$N_2O_5 \longrightarrow 2NO_2 + \frac{1}{2}O_2$$

The decomposition is first order and the half–life of N_2O_5 is 150 s.

When a sample containing 0.10 mol of N_2O_5 was placed in a 1 dm^3 vessel, what is the concentration of NO_2 after 5 minutes?

A 0.150 mol dm^{-3}

B 0.100 mol dm^{-3}

C 0.050 mol dm^{-3}

D 0.025 mol dm^{-3}

22 The following reaction is first order with respect to P and zero order with respect to Q.

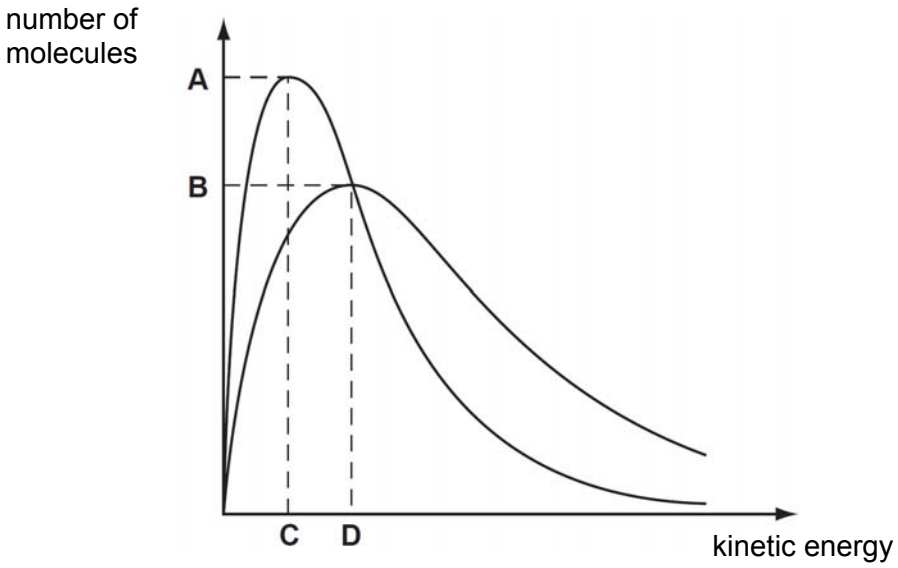
$$P + Q \longrightarrow \text{products}$$

If the rate constant doubles for each 10 ^{o}C rise in temperature, which of the following sets of conditions will give the greatest rate of reaction?

	[P] / mol dm^{-3}	[Q] / mol dm^{-3}	T / ^{o}C
A	0.1	0.2	40
B	0.1	0.3	30
C	0.2	0.2	30
D	0.3	0.1	20

23 The diagram shows the Maxwell–Boltzmann energy distribution curves for molecules of a sample of a gas at two different temperatures.

Which letter on the axes represents the proportion of molecules with the most probable energy at the lower temperature?



24 Metals such as rhodium (Rh), palladium (Pd) and platinum (Pt) are surface catalysts used in the catalytic converter to convert unburnt hydrocarbon, CO and oxides of nitrogen to less harmful gases such as CO_2, H_2O and N_2 to reduce air pollution.

Which of the following statements are correct?

1 The metals increase the rate of reaction by providing an alternative pathway of lower activation energy and make the reaction more exothermic.

2 The metals act as heterogeneous catalysts.

3 The metals in the catalytic convertor will be depleted with time and needs to be replaced.

4 Rh, Pd and Pt are inert metals with high melting points.

A 1 and 3 only

B 2 and 4 only

C 2 only

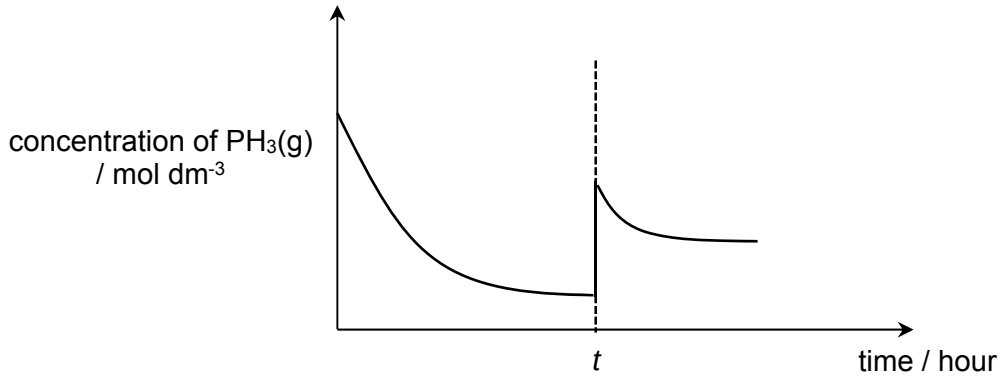
D 3 only

25 Phosphine, PH_3, decomposes to give phosphorus and hydrogen gas.

$$4PH_3(g) \rightleftharpoons P_4(g) + 6H_2(g) \qquad \Delta H > 0$$

The graph below shows the change in concentration of PH_3 over time until the reaction mixture reaches equilibrium at a constant temperature of 400 K.

Which of the following are **not** possible changes made at *t* hour?



1 Addition of PH_3 to the reaction mixture

2 Reduction in the volume of the vessel

3 Removal of P_4 from the reaction mixture

4 Addition of a catalyst

A 1 and 2 only **B** 3 and 4 only **C** 2 and 4 only **D** 2, 3 and 4 only

26 Which of the following statements about graphene is true?

A Each carbon atoms form σ bonds with 6 neighbouring carbon atoms.

B It is an extremely thin 3–dimensional layer of carbon atoms.

C It is a good thermal conductor.

D Weak instantaneous dipole–induced dipole forces of attraction exist between the layers of graphene.

27 "Clearfilm" is manufactured from a polymer made by copolymerizing CH_2=CH*Cl* with CH_2=CCl_2 in a regular "head to tail" linkage where CH_2 is taken as the "head" of the monomer.

Which of the following could represent part of the polymer chain in "clearfilm"?

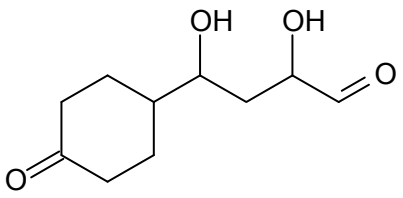
A –CH*Cl*–CH_2–CCl_2–

B –CCl_2–CCl_2–CH_2–CH*Cl*–

C –CH_2–CH*Cl*–CCl_2–

D –CH_2–CCl_2–CH*Cl*–CH_2–

28 Which of the following statements are true about the following compound?



1 Its molecular formula is $C_{10}H_{14}O_4$.

2 It reacts with sodium hydrogen carbonate to give carbon dioxide gas.

3 It reacts with hot acidified potassium dichromate to form a product with 5 O atoms.

4 It reacts with 2 mol of sodium metal to form 1 mol of hydrogen gas.

A 1 and 2 only

B 3 and 4 only

C 2 and 4 only

D 1 and 3 only

29 Part of the structure of a polyester is shown below:

$$–O–CH(CH_3)–CO_2–CH(CH_3)–CO–$$

Which of the following statements are true?

1 It is a thermoplastic.

2 The polymer chains are held together by hydrogen bonds.

3 The C–O–C angle in the polymer is 120°.

4 It undergoes acid hydrolysis to give $HOCH(CH_3)CO_2H$.

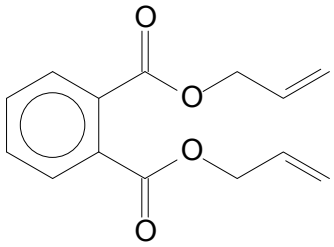
A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 3 and 4 only

30 Diallyl phthalate (DAP) has a structure shown below. As a monomer, it is used as a cross-linking agent in unsaturated polyesters. When it undergoes polymerisation to form poly(diallyl phthalate), one of the two >C=C< is first used to join up the DAP monomers into a pre-polymer. During the molding process, the second >C=C< polymerises leading to a highly cross-linked thermoset polymer.



DAP

Its polymer is used in the production of thermosetting molding powders.

Which of the following statements is **not** true?

A Cross–linkages with unsaturated polyesters are formed by the unsaturated >C=C< bonds of DAP monomers.

B Poly(diallyl phthalate) is soft and flexible.

C Poly(diallyl phthalate) is an electrical insulator.

D Poly(diallyl phthalate) is resistant to high temperature.

H1 Chemistry 8873 **AJC 2018 JC2 PRELIM** **Paper 1 – 30 marks**

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

A	**5**
B	**9**
C	**6**
D	**10**

1 (a) Standard enthalpy change of combustion is the heat evolved when one mole of substance, in its standard state, is burnt in excess oxygen under standard conditions of 298 K and 1 bar. [2]

[1]: "heat evolved", "one mole", "excess oxygen"
[1]: 298 K and 1 bar

(b) ($CH_3CH_2OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$)

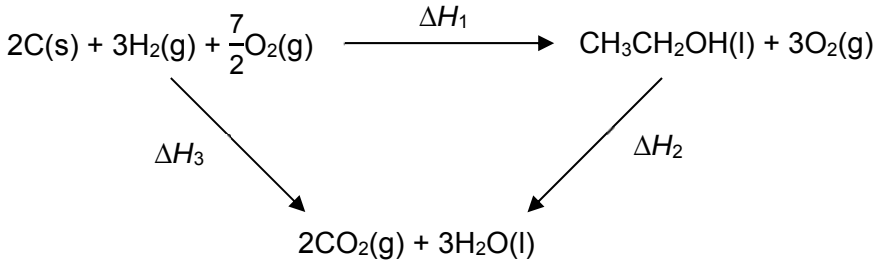
Heat absorbed by water (65% efficient) = $mc\Delta T$
= (100)(4.18)(65 – 20)
= 18810 J [1]

Heat evolved by combustion of ethanol (100%) = $\frac{18810}{0.65}$
= 28938 J
= 28.94 kJ [1]

Enthalpy change of combustion of ethanol = $-\frac{28.94}{\frac{1}{46}}$
= –1330 kJ mol^{-1} [1]

(c) (i) (standard) enthalpy change of formation of ethanol [1]

(ii) [3]



$\Delta H_1 = \Delta H_3 - \Delta H_2$
= [2(–393.5) + 3(–285.8)] – (–1330)
= –1644.4 + 1330
= –314 kJ mol^{-1}

[1]: application of Hess' Law
[1]: correct answer with sign (ecf)
[1]: correct units

(d) (i) 6 453 600 x 159 x 2.33 = 2.39 x 10^9 kg (3 s.f.) [1]

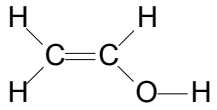
(ii) 1/100 x 2.33 = 0.0233 kg [1]

(iii) 0.1 x 0.0233 + 0.9 x 2.33 = 2.10 kg (3 s.f.) or 2.099 kg [1]

(iv) 6 453 600 x 159 x 2.10 / 1000 = 2.15 x 10^9 kg (3 s.f.) [1]

Reduction in CO_2 emission = 2.39 x 10^9 – 2.15 x 10^9 = 2.40 x 10^8 kg

Alternative
[(2.33 – 2.10) x 6 453 600 x 159] kg

(e) **(i)**  [1]

(ii) H_2 with Ni at high temperature and pressure [1]
or
H_2 with Pt / Pd, r.t.p

(iii) Hydrogen bonding [1]

(iv) [1]: Partial charges on O–H bond of PVA + O–H bond of water [2]
[1]: Show attraction between lone pair on O atom with H atom of O–H group

(v) The borate ion forms cross linkages via hydrogen bonds between PVA polymer molecules. [1]

(vi) dilute H_2SO_4, heat (accept NaOH(aq)) [1]

2 **(a)** A thermoplastic is a substance / polymer that softens on heated and hardens when cooled. [1]

(b) **(i)** LDPE has branched polymer chains; [1]
less close / less regular packing so weaker instantaneous dipole – induced dipole attraction [1]

HDPE has no / little branching in polymer chains; [1]
closer and regular packing so stronger instantaneous dipole – induced dipole attraction [1]

(ii) LDPE: plastic carrier bags or other similar low strength and flexible sheet materials [1]

HDPE: milk bottles and similar containers, washing up bowls, plastic pipes [1]

(c) **(i)** X: I_2 or iodine
Y: C*l*$_2$ or chlorine (accept F_2 or fluorine)
Z: Br_2 or bromine

[2]: all correct
[1]: 1 or 2 correct

(ii) Chlorine, C*l*$_2$ (accept Y_2) [1]

Chloride or Y^- not accepted

(iii) Although chlorine has the smallest nuclear charge, it has the least shielding effect / least number of electron shells. [1]

Valence shell of chlorine atom is closest to the nucleus hence the incoming electron that resides in it will be more strongly attracted / easily gained. [1]

(d) **(i)** Thermal stability: HC*l* > HBr > HI [1]

(ii) Down the group, H–X bond energy decreases from 431 to 299 kJ mol^{-1}. [1]

Reason:
- size of halogen atom increases
- bonding electrons are further from both nuclei
- and less strongly attracted to the two nuclei
- (H–X bond strength decreases)

} [1]

(e) **(i)** Similarity: both are electrical conductors [1]

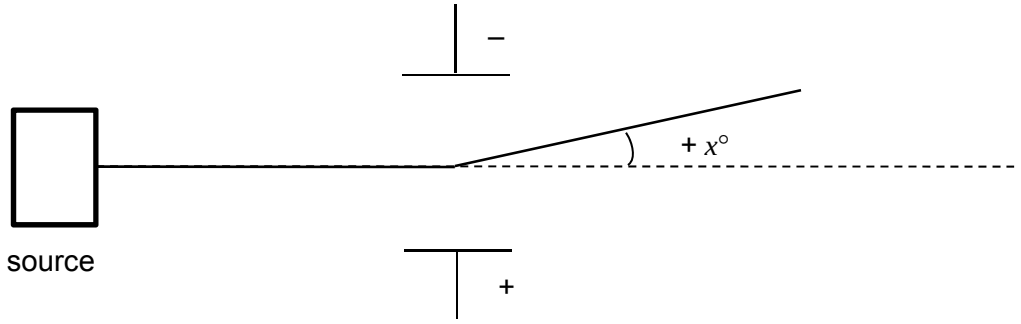
Difference: CNT is rigid but graphene is flexible. [1]

(ii) A dimension between 1 – 100 nm [1]

(iii) Via digestive tract / oral uptake [1]

Via the skin / dermal uptake [1]

3 (a) (i) [1]



The plate on top is negatively charged as the <u>positively charged proton is attracted to it.</u> [1]

(ii) **I**: $^{16}O^{2-}$ ions
q/m of proton = 1/1 [1]
q/m of $^{16}O^{2-}$ ions = 2/16 = 1/8 [1]
Hence, angle of deflection is 1/8 that of proton, and in the <u>opposite direction / (towards positive plate),</u>
<u>$-x/8°$.</u>

II: ^{4}He nuclei
q/m = 2/4 = ½ [1]
Hence, angle of deflection is 1/2 that of proton, <u>$+x/2°$ (towards negative plate)</u> [1]

III: ^{2}H atom
0°. The atom has no net charge and hence remains <u>undeflected</u>. [1]

(b) (i) **1s 2s 2p 3s 3p 4s 3d** [1]

(ii) **$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$** [1]

(iii) **4p** [1]

4 **(a)** n(acid) in 250 cm^3 = 2.29 / 104 = <u>0.0220 mol</u> [1]

n(acid) in 25 cm^3 = 0.0220 / 10 = <u>0.00220 mol</u> [1]

(b) Vol of NaOH needed for complete neutralisation = 22.00 cm^3 [1]

n(NaOH) = 22/1000 × 0.100 = <u>0.00220 mol</u>

(c) Since <u>n(acid) = n(NaOH)</u> [1]

It is a <u>monobasic</u> acid.

(d) $[H^+] = 10^{-2.2}$ = <u>6.31×10^{-3} mol dm^{-3}</u> [2]

[acid] = (2.29/104) / (250/1000) = <u>0.0881 mol dm^{-3}</u>

Since <u>$[H^+] < [acid]$</u>, It only partially ionises in water, thus it is a weak acid.

[1]: $[H^+]$ and [acid]
[1]: link $[H^+] < [acid]$ to strength

(e) $K_a = \dfrac{(6.31 \times 10^{-3})^2}{0.0881 - 6.31 \times 10^{-3}}$ (accept $\approx \dfrac{(6.31 \times 10^{-3})^2}{0.0881}$) [2]

= <u>4.5×10^{-4} mol dm^{-3}</u>

Read from graph, when 11 cm^3 of NaOH(aq) was added, pH = pK_a (MBC occurs)
pK_a = 4.0 (accept 3.8 – 4.0)
$K_a = 1.0 – 1.6 \times 10^{-4}$

[1]: use K_a expression in working / recognise pH = pK_a at MBC
[1]: correct answer

(f) Volume of excess NaOH added = 45 – 22 = 23 cm^3 [1]
Amount of excess NaOH = 23/1000 x 0.100 = 2.30×10^{-3} mol

Total volume of solution = 25 + 45 = 70 cm^3
$[OH^-]$ = 0.0023/(70/1000)
= <u>0.0329 mol dm^{-3}</u>

(g) $[H^+][OH^-] = 1 \times 10^{-14}$
$[H^+] = (1 \times 10^{-14}) / 0.0329 = 3.04 \times 10^{-13}$ mol dm^{-3}

pH = – log (3.04×10^{-13}) = <u>12.5</u> [1]

(alternatively, find pOH and then 14 – pOH to get the pH)

5 (a) (i) Na_2O, dissolves readily in water to give an alkaline solution of pH 13 [1]

P_4O_{10} dissolves readily in water to give an acidic solution of pH 2. [1]

$Na_2O + H_2O \longrightarrow 2NaOH$ [1]

$P_4O_{10} + 6H_2O \longrightarrow 4H_3PO_4$ [1]

(ii)

A	B	C
Al_2O_3	P_4O_{10}	Na_2O

[2]

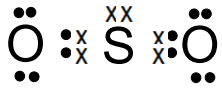
1 mark for 1 correct identity
2 mark for 3 correct identity

(iii) Both Na_2O and Al_2O_3 have giant ionic structures with strong electrostatic forces of attraction between the oppositely charged ions. [1]

Since Al^{3+} has a higher charge and a smaller ionic radius than Na^+, [1]

the electrostatic attraction between Al^{3+} and O^{2-} is stronger. Hence more energy is required to break the stronger ionic bond resulting in a higher melting point for Al_2O_3. [1]

(b)



[1]

(c) (i) It acts as a catalyst that speeds up the forward and backward reaction such that the equilibrium can be achieved faster. [1]

Is a drying agent and remove water and shift position of equilibrium to the right. Yield of ester increases. [1]

(ii) $K_c = \dfrac{[CH_3CO_2CH_2CH_3][H_2O]}{[CH_3CO_2H][CH_3CH_2OH]}$ [1]

(iii)

$CH_3COOH\ (l) + CH_3CH_2OH\ (l) \rightleftharpoons CH_3COOCH_2CH_3\ (l) + H_2O\ (l)$

I / mol	x	x	0	0
C / mol	–1	–1	+1	+1
E / mol	x – 1	x–1	1	1

Let the volume of the reaction mixture be V dm^3

$$4 = \frac{\frac{1}{V} \times \frac{1}{V}}{\frac{x-1}{V} \times \frac{x-1}{V}}$$ [1]

$4 = 1 / (x–1)(x–1)$

$(x–1)(x–1) = ¼$

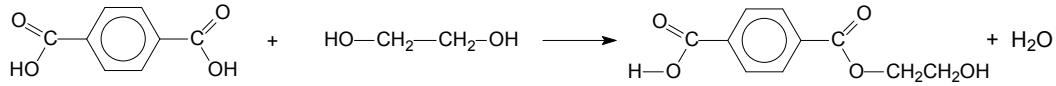
$x – 1 = ½$

$x = 1.5$ mol

n(ethanoic acid) = 1.5 mol [1]

(iv) Amount of ethyl ethanoate would <u>decrease</u>. [1]

When sodium hydroxide is added, an <u>acid–base reaction</u> would take place between sodium hydroxide and ethanoic acid. This decreases the concentration of ethanoic acid which will <u>shift the POE to the left</u> to increase the concentration of ethanoic acid. [1]

(d) **(i)**  [1]

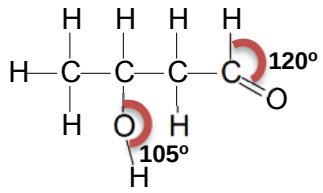
(ii) PET contains <u>ester bonds</u> which will be <u>hydrolysed</u> in the presence of alkaline solution. [1]

Poly(propene) contains <u>non polar C–C and C–H bonds</u> which are <u>inert</u> to alkaline solution. [1]

6 (a) (i) Addition [1]

Two molecules of ethanal react together to form one molecule of 2–hydroxybutanal. [1]

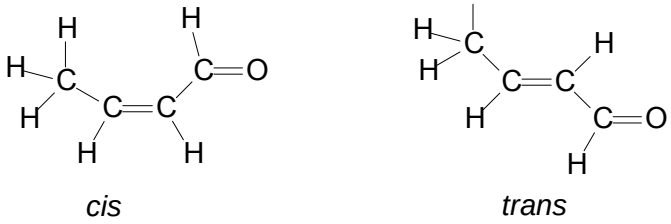
(ii)



Correct displayed formula [1]
Correct 120° bond angle [1]
Correct 105° bond angle [1]

(iii) Elimination of water [1]

(iv)



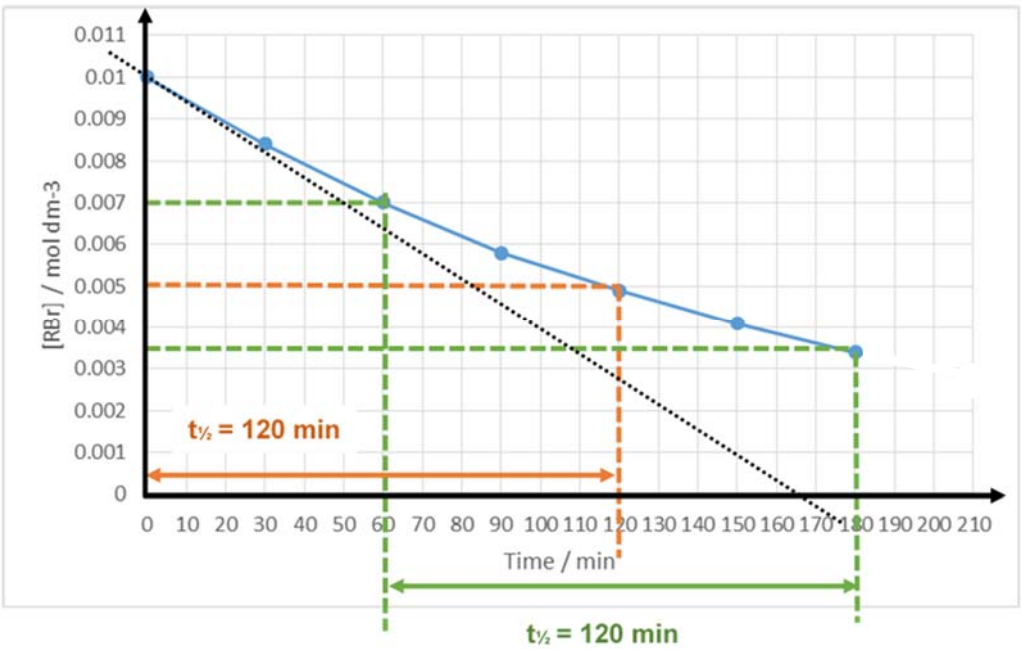
cis *trans*

Correct isomer and label [1] × 2 [2]

(v) **Y** is **$CH_3CH{=}CHCO_2H$** [1]

(b) (i) So that [NaOH] remains relatively constant and any change in rate of reaction is only due to change in [bromoalkane] [1]

(ii)



Correct axes with labels and units + smooth curve [1]
Construction lines to obtain of at least two $t_{½}$ + read $t_{½}$ correctly [1]
Explain that two or more $t_{1/2}$ are constant hence first order w.r.t. bromoethane [1]

(iii) **Rate = *k* [RBr] [NaOH]** [1]

(iv) From graph, initial rate = $\left(\frac{0.0100}{165}\right)$ [1]

$= \mathbf{6.06 \times 10^{-5}}$ (mol dm^{-3} min^{-1}) (ignore units)

- Draw gradient at t=0 min to determine initial rate and obtain value of 10^{-5}

(v) $k = \frac{6.06\times10^{-5}}{0.01\times0.10} \quad \frac{\text{mol dm}^{-3}\ \text{min}^{-1}}{\left(\text{mol dm}^{-3}\right)^2}$ [1]

$= \mathbf{0.0606\ mol^{-1}\ dm^3\ min^{-1}}$

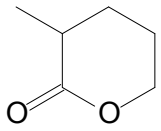
- Correct k and units (allow ecf)

(c) **(i)** C–O bond of alcohol: 970–1260 (cm^{-1}) [1]
O–H bond of alcohol: 3580–3650 (cm^{-1})
C–H bond of alky group: 2850 – 2950 (cm^{-1})

[1]: any 2

(ii) C–O bond of carboxylic acids: 1210–1440 (cm^{-1}) [1]
C=O bond of carboxylic acids: 1680–1730 (cm^{-1})
O–H bond of carboxylic acids: 2500–3000 (cm^{-1})

[1]: any 1

(iii) **M** is  [1]

Type of reaction: condensation / esterification

[1]

ANDERSON JUNIOR COLLEGE

2018 JC 2 PRELIMINARY EXAMINATION

NAME:_____ **PDG:**____ /17

CHEMISTRY **8873/02**

Paper 2 Structured Questions **12 September 2018**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

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.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

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	Q5*	Q6*	
/30							/ 80
			Final marks				/ 100
			Grade				

***** Circle the question you have attempted

This document consists of **21** printed pages.

Section A

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

1 Ethanol, CH_3CH_2OH, is a renewable biofuel which is made from the starch in corn grain or from the glucose in sugar cane.

(a) What is meant by the term *standard enthalpy change of combustion*?

……

……[2]

(b) When 1 g of ethanol was burned under a container of water, it was found that 100 g of water was heated from 20 °C to 65 °C. The process was known to be only 65 % efficient.

Use these data and values from the *Data Booklet* to calculate the enthalpy change of combustion of ethanol.

[3]

(c) Fig 1.1 shows an energy cycle involving ethanol.

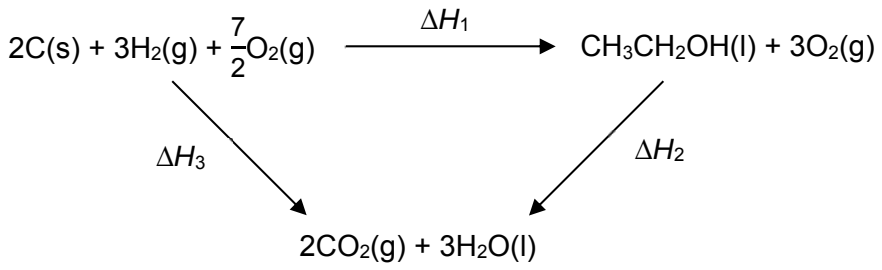


Fig 1.1

(i) Name the enthalpy change represented by ΔH_1.

……..[1]

(ii) Given that the enthalpy change of combustion of carbon and hydrogen are –393.5 kJ mol^{-1} and –285.8 kJ mol^{-1} respectively, use the energy cycle given above and your answer to **(b)** to calculate ΔH_1.

[3]

(d) In some countries, ethanol is blended with petrol for use in cars. Ethanol blended petrol can significantly reduce the greenhouse gas emissions. The carbon dioxide released by a vehicle when ethanol is burned is offset by the carbon dioxide captured when the feedstock crops are grown to produce ethanol.

Petrol which contains 10% ethanol by volume is named E10 and it is the most widely used around the world. On average, 2.33 kg of carbon dioxide is emitted for every one litre of petrol combusted in a car engine. In contrast, every one litre of ethanol combusted in the car engine reduces mass of carbon dioxide emitted by 99 % compared to petrol.

According to oil industry data, cars in Singapore consumed about 6,453,600 barrels of petrol in 2017. Each barrel is approximately 159 litres.

(i) Calculate the total mass of CO_2, in kg, emitted by cars in Singapore in 2017.

[1]

(ii) Calculate the mass of CO_2, in kg, emitted for every litre of ethanol combusted in the car engine.

[1]

(iii) Calculate the mass of CO_2, in kg, emitted for every litre of E10 petrol combusted in the car engine.

[1]

(iv) Hence, calculate the reduction in mass of CO_2, in kg, emitted if E10 was used by cars in Singapore in 2017 instead of regular petrol.

[1]

(e) Poly(vinyl alcohol) (PVA) is used to make film laundry bags which are used in hospitals to minimise the contact hospital workers have with contaminated clothing and bedding. The dirty items are put into these special bags, which are then placed directly into the washing machine. As the bags are water–soluble, they dissolve and are washed down the drain with the dirty water.

Fig 1.2 shows part of the PVA structure with three repeat units.

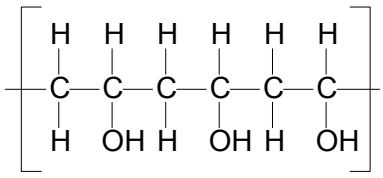


Fig 1.2

(i) Draw the full displayed formula of the monomer of PVA.

[1]

(ii) State the reagent and conditions required to convert the monomer of PVA to ethanol.

…… [1]

(iii) State the type of intermolecular forces that can be formed between PVA polymer and water molecules.

…… [1]

(iv) Copy the structure of PVA in the space below and use it to illustrate the type of attraction between PVA polymer and **one** water molecule.

[2]

(v) When borax, $Na_2B_4O_7.10H_2O$ was gradually added to PVA solution and stirred, the mixture thickens and eventually forms slime. When dissolved in solution, borax forms the borate ion, $B(OH)_4^-$, which has the structure given in Fig 1.4.

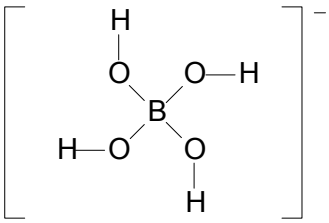


Fig 1.4

Suggest a reason why the presence of borate ions causes mixture to thicken and form slime.

……..

…… [1]

(vi) PVA cannot be synthesised directly from its monomer. Instead, it is formed from poly(vinyl acetate). Part of the structure of poly(vinyl acetate) is shown in Fig 1.3.

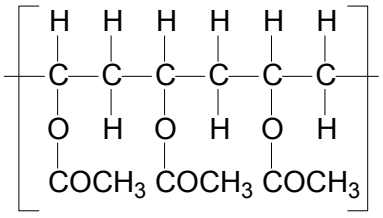


Fig 1.3

Suggest the reagent and condition required to form PVA from poly(vinyl acetate).

…… [1]

[Total: 20]

2 **(a)** Poly(ethene) is a *thermoplastic*.

Explain what you understand of the word in *italics*.

……

……[1]

(b) Ethene can be polymerised in slightly different ways to make low–density poly(ethene) (LDPE) and high–density poly(ethene) (HDPE). These polymers have different physical properties because of the structure of their molecules. LDPE is flexible whereas HDPE is relatively more rigid.

(i) Describe the structure and bonding in LDPE and HDPE and explain how they affect their physical properties.

……..

……..

……..

……..

……..

……..

……..

……..[4]

(ii) Suggest a use for each polymer in consideration of its physical properties.

HDPE: …….

LDPE: ……[2]

(c) An experiment was carried out to determine the relative oxidising power of three unknown halogens X_2, Y_2 and Z_2. Table 2.1 shows the results of experiments in which the halogens X_2, Y_2 and Z_2 were added to separate aqueous solutions containing X^-, Y^- and Z^- ions.

Table 2.1

	X^- (aq)	**Y^- (aq)**	**Z^- (aq)**
X_2		no reaction	no reaction
Y_2	brown solution formed		orange solution formed
Z_2	brown solution formed	no reaction	

(i) Using the results given in Table 2.1, suggest the identity of X_2, Y_2 and Z_2.

X_2: ……

Y_2: ……

Z_2: …… [2]

(ii) Hence, state the most powerful oxidising agent among the halogens.

…… [1]

(iii) Explain, in terms of ease of gain of electrons, why the element you have identified in **(c)(ii)** is the most powerful oxidising agent.

……..

……..

……..

……..

……..

……..[2]

(d) Three Group 17 hydrides were separately heated in an experiment. Their bond energy values and the observations of the experiment are given in Table 2.2.

Table 2.2

H–X	**bond energy / kJ mol^{-1}**	**observation**
H–C*l*	431	no visible change
H–Br	366	brown fumes of Br_2
H–I	299	dense purple fumes of I_2 on gentle heating

(i) Using the observations of the experiment, state the thermal stability of the Group 17 hydrides in decreasing order.

…… [1]

(ii) Explain, in terms of their bond energies, the trend in the thermal stability of Group 17 hydrides.

……..

……..

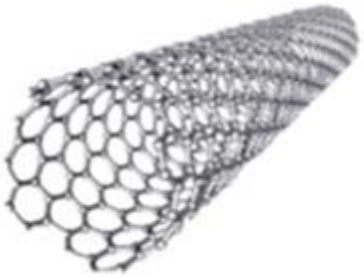
……..

……..

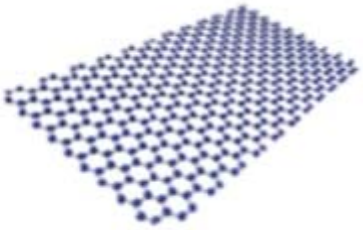
……..

……..[2]

(e) A carbon nanotube (CNT) resembles a sheet of graphene rolled up to form a tiny cylindrical tube, with a diameter in the nanometer scale. They are used to manufacture professional tennis rackets and hockey sticks to make them lighter and more durable under constant forceful impacts by the players.



Carbon nanotube (CNT)



Graphene

(i) Suggest one similarity and one difference in terms of physical property between CNT and graphene.

Similarity: ……..

……..

Difference: ……..

……..[2]

(ii) State what is meant by the term "*nanometer scale*".

……..[1]

(iii) As nanotechnology continues to expand into every industrial sector, workers will be at an increased risk of exposure to new nanomaterials. Consumers also face increased exposure to nanomaterials as they are found in hundreds of products, ranging from cosmetics, to clothing, to industrial and biomedical applications. A number of recent research studies with rodents have shown that CNTs may pose a respiratory hazard to human beings.

State two other ways in which nanomaterials may enter the human body, other than through inhalation.

……..

……..[2]

[Total: 20]

3 **(a)** Beams of particles travelling at the same speed from different sources are subjected to an electric field. Fig 3.1 shows the experimental set–up where protons are found to be deflected through an angle of $+x^{\circ}$.

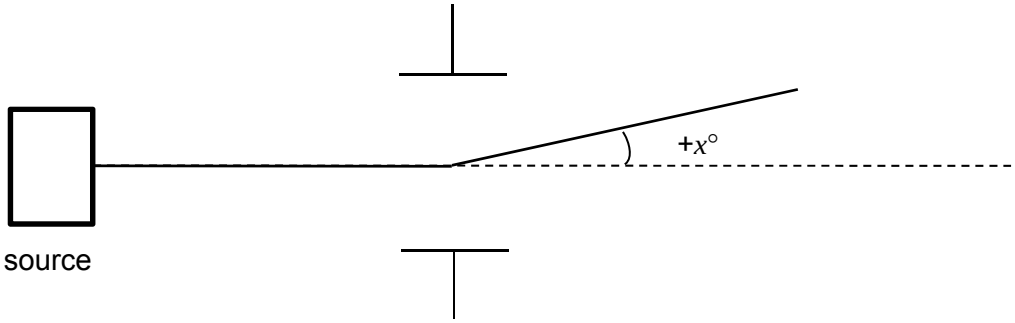


Fig 3.1

(i) Indicate, in Fig 3.1, the polarity of the plates and explain your answer.

……..

……. [2]

(ii) Assuming an identical set of experimental conditions, state and explain the **angle** and **direction** of deflection for the following particles.

I: $^{16}O^{2-}$ ion

……..

……..

……..

……..

II: ^{4}He nuclei

……..

……..

……..

……..

III: ^{2}H atom

……..

……..

……..

……..[5]

(b) Fig 3.2 shows a scheme of the 17 lowest energy subshells, which can be used to show the order in which the subshells are filled by electrons (the Aufbau principle).

1s	2s	3s	4s	5s	6s	7s
	2p	3p	4p	5p	6p	
		3d	4d	5d		
			4f	5f		

Fig 3.2

(i) List the order of filling subshells for an atom of a d–block element in the **fourth** period of the Periodic Table.

…….....[1]

(ii) Hence, write the electronic configuration of the copper atom.

…….....[1]

(iii) An electron of the copper atom undergoes excitation from the ground state. What is the lowest energy, empty orbital that the electron can be promoted to?

…….....[1]

[Total: 10]

4 A laboratory technician found a bottle in the school laboratory that contained a white crystalline solid. The label on the bottle was smudged such that he could only make out the words “acid” and “104 g mol^{-1}”. To investigate, he decided to conduct a titration using 0.100 mol dm^{-3} sodium hydroxide.

He dissolved 2.29 g of the unknown acid in 250 cm^3 of deionised water and pipetted 25.0 cm^3 of this solution into a conical flask. He gradually added 0.100 mol dm^{-3} NaOH(aq) solution from a burette and monitored the pH of the reaction mixture in the conical flask using a pH meter after each addition.

Fig 4.1 shows the pH–volume added curve he obtained.

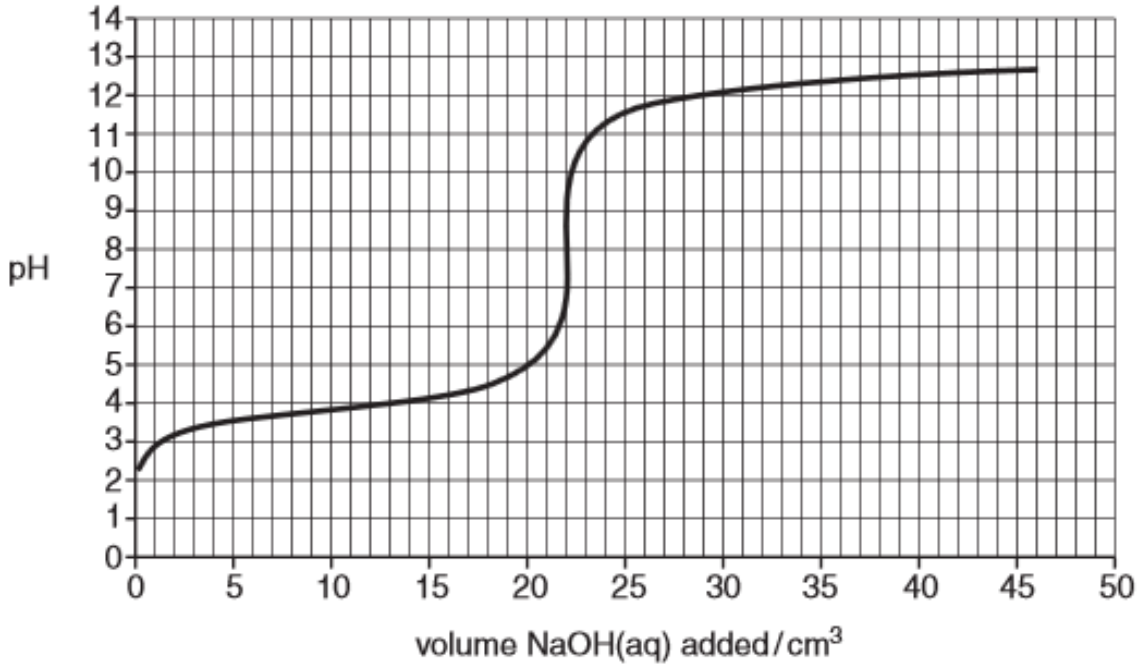


Fig 4.1

(a) Calculate the number of moles of the unknown acid transferred to the conical flask.

[2]

(b) Calculate the number of moles of sodium hydroxide that reacted with the unknown acid in the conical flask.

[1]

(c) Hence, using your answers to **(a)** and **(b)**, determine if the unknown acid is monobasic or dibasic.

[1]

(d) Given that the initial pH is 2.2, explain why the unknown acid is a weak acid.

……..

.....……[2]

(e) Hence, or otherwise, deduce the acid dissociation constant, K_a of the unknown acid.

[2]

(f) Show that the concentration of excess unreacted hydroxide ions when 45 cm^3 of sodium hydroxide was added to the conical flask is 0.0329 mol dm^{-3}.

[1]

(g) Hence, calculate the pH of the solution after 45 cm^3 of sodium hydroxide was added.

[1]

[Total: 10]

Section B

Answer **one** question from this section, in the spaces provided.

5 **(a)** The oxides of Period 3 elements Na_2O, Al_2O_3 and P_4O_{10} show different physical and chemical properties. Some information on these oxides is given in Table 5.1.

Table 5.1

oxide	melting point / ˚C	pH of the resulting solution from the reaction with H_2O
A	2040	7
B	24	2
C	1132	13

(i) Describe the reactions, if any, of the oxides Na_2O and P_4O_{10} with water. Include the approximate pH value of any resulting solutions, and write equations for any reactions that occur.

……

……

……

……

……

……

……[4]

(ii) Hence, suggest the identity of **A, B** and **C**.

A	**B**	**C**

[2]

(iii) Explain, in terms of structure and bonding, why **A** has a higher melting point than **C**.

……

……

……

……

……

……[3]

(b) SO_2 is another oxide of a Period 3 element.

Draw a dot–and–cross diagram to show the bonding in a molecule of SO_2.

[1]

(c) When ethanoic acid reacts with ethanol, in the presence of concentrated sulfuric acid, to form ethyl ethanoate and water, the following equilibrium is established.

$$CH_3CO_2H(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3CO_2CH_2CH_3(l) + H_2O(l)$$

(i) Explain the purposes of adding concentrated sulfuric acid.

……..……...

……..……...

……..…...[2]

(ii) Write an expression for the equilibrium constant, K_c, for the reaction between ethanoic acid and ethanol.

[1]

(iii) Equimolar amounts of ethanoic acid and ethanol were mixed and at equilibrium, 1.00 mol of ethyl ethanoate is present.

Given that the value of K_c is 4.0, determine the initial amount (in mole) of ethanoic acid.

[2]

(iv) Predict what would happen to the amount of ethyl ethanoate if sodium hydroxide was added to the reaction mixture at equilibrium. Explain your answer.

Prediction: ……..

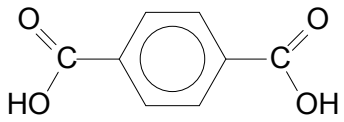
……

Explanation: ……..

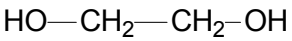
……[2]

(d) Polyesters are polymers formed from a dicarboxylic acid and a diol and they are mostly used in clothing, food packaging and plastic water and carbonated soft drinks bottles.

An example of a polyester is poly(ethylene terephthalate) (PET). Its monomer is synthesised from a condensation reaction between 1 mol of ethane–1,2–diol and 1 mol of benzene–1,4–dicarboxylic acid in the presence of a catalyst.



benzene–1,4–dicarboxylic acid



ethane–1,2–diol

(i) Write a balanced equation for the formation of the PET monomer.

……[1]

(ii) Bottles that are made of PET cannot be used to store alkaline cleaning solution. Bottles that are made of poly(propene) are used instead.

Explain, in terms of the bonds present in both polymers, why the above statements are true.

……

……

……

……....[2]

[Total: 20]

6 **(a)** The Russian composer Borodin was also a research chemist who discovered a reaction in which two ethanal molecules combine to form an aldol, 2–hydroxybutanal.

$$\underset{\text{ethanal}}{2CH_3CHO} \longrightarrow \underset{\text{2–hydroxybutanal}}{CH_3CH(OH)CH_2CHO}$$

(i) Suggest the type of reaction which takes place in the formation of 2–hydroxybutanal from ethanal. Explain your answer.

……

……

……[2]

(ii) Draw the displayed formula of 2–hydroxybutanal. Indicate clearly, in your answer, one bond angle which is 105° and one which is 120°.

[3]

On heating, 2–hydroxybutanal, $CH_3CH(OH)CH_2CHO$, forms compound **X**, C_4H_6O, which exists as a pair of isomers.

When compound **X** was heated with acidified $K_2Cr_2O_7$, compound **Y,** $C_4H_6O_2$ is formed. **Y** with reacts with sodium carbonate to produce carbon dioxide gas.

(iii) Suggest the type of reaction which occurs upon heating 2–hydroxybutanal.

……[1]

(iv) Draw the full structural formulae of the pair of isomers of **X**. Indicate clearly the type of isomerism by labelling the isomers.

[2]

(v) Suggest the structural formula of **Y**.

[1]

(b) An experiment was carried out to determine the order of reaction with respect to bromoethane in the following hydrolysis reaction with 0.10 mol dm^{-3} NaOH(aq).

$$CH_3CH_2Br + NaOH \longrightarrow CH_3CH_2OH + NaBr$$

Table 6.1 shows the data that was obtained from this experiment.

Table 6.1

time / min	$[CH_3CH_2Br]$ / mol dm^{-3}
0	0.0100
30	0.0084
60	0.0070
90	0.0058
120	0.0049
150	0.0041
180	0.0034

(i) The concentration of NaOH(aq) used in the experiment was in large excess relative to that of bromoethane. Suggest a reason why this is so.

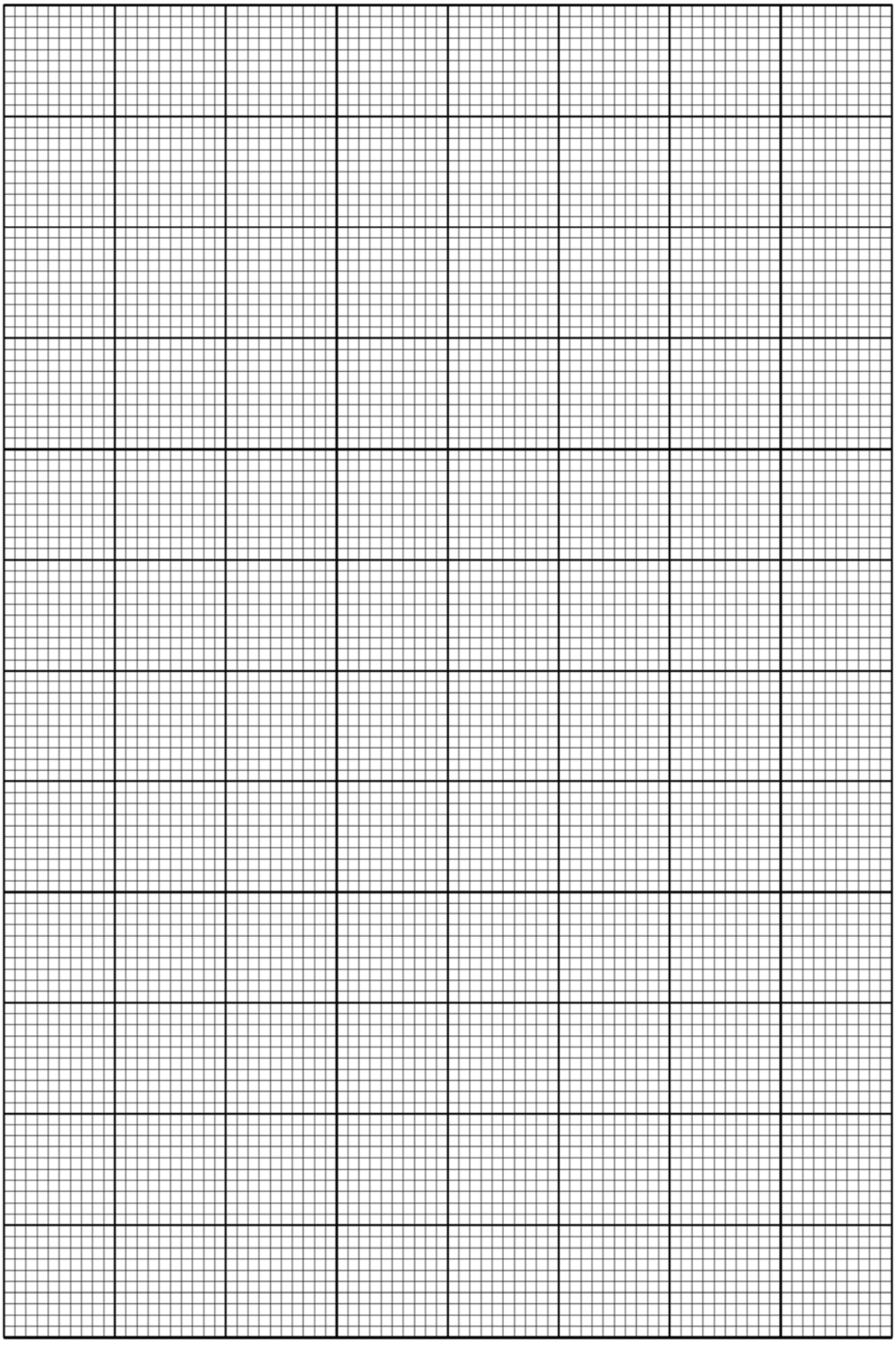
……

……[1]

(ii) Plot a suitable graph using the grid provided on page 19 to determine the order of reaction with respect to the bromoethane. Show your working clearly.

order with respect to bromoethane: ……[3]

6 (b) (ii)



(iii) The order of reaction with respect to sodium hydroxide is found to be first order. Hence, construct a rate equation for the hydrolysis reaction.

……[1]

(iv) Use your graph to determine the initial rate of reaction.

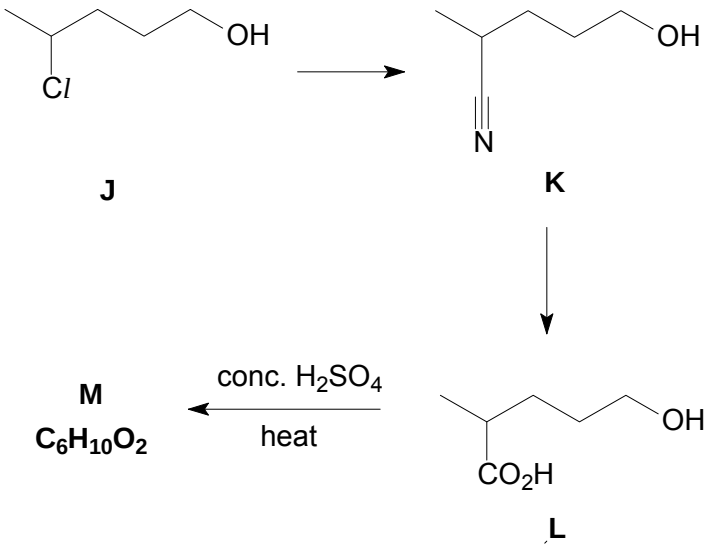
[1]

(v) Using your answer in **(b)(iv)** and other relevant experiment data given, calculate a value for the rate constant, stating its units.

[1]

(c) Use the table of characteristic values for infra–red absorption in the *Data Booklet* to answer this question.

Compound **J** undergoes a series of transformation as shown.



Infra–red absorptions can be used to identify functional groups in organic compounds. For example, compound **J** shows absorptions at 700 – 800 cm^{-1}, but not compounds **K** and **L**.

(i) Identify **two** infra–red absorption ranges that will be shown by **J**, **K** and **L**.

……[1]

(ii) Identify an infra–red absorption range that will be shown by **L** but not by **J** and **K**.

……[1]

(iii) The infra–red spectrum of **M** shows absorption in two ranges, 1050–1330 cm^{-1} and 1710–1750 cm^{-1}.

Suggest a structural formula for **M** and name the type of reaction which occurs in the last transformation step from **L** to **M**.

Type of reaction: …… [2]

[Total:20]