JURONG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME		CLASS	

CHEMISTRY

8872/02

Paper 2 Structured

28 August 2009

2 hours

Candidates answer Section A on the Question Paper

Additional Materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

A Data Booklet is provided. Do not write anything on the *Data Booklet*.

Section A
Answer **all** questions.

Section B
Answer **two** questions on separate answer 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	
Section A	
B5	
B6	
B7	
Total	

This document consists of **11** printed pages and **1** blank page.

[Turn over

Section A

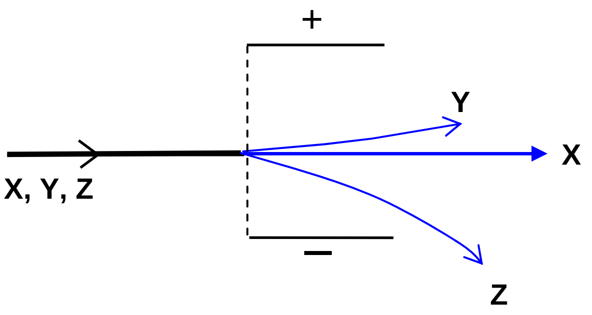
Answer **all** questions in this section in the spaces provided.

1. **(a)** Complete the table below.

Particle	Electric charge	Mass number	Number of		
			Protons	Electrons	Neutrons
X	0	**32**	16	**16**	16
Y	1-	81	**35**	36	**46**
Z	**3-**	70	31	28	**39**

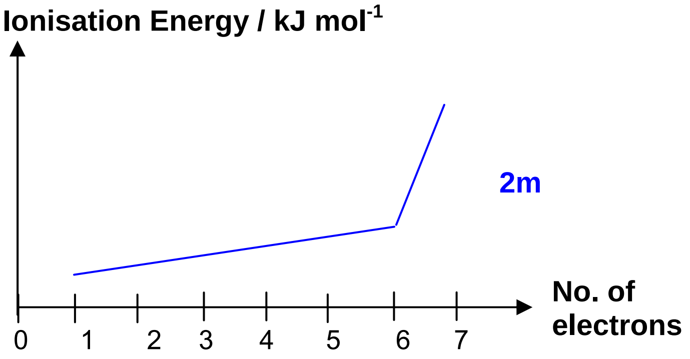
[2]

(b) Beams consisting of particles **X**, **Y** and **Z** are subjected to an electric field as shown in the diagram below. Sketch, and label, on the diagram below to show how beams of each of the three particles are affected by the electric field.



[3]

(c) Using the grid provided below, sketch a graph of the seven successive ionisation energies for element **X**.



[2]

[Total:7]

2. **(a)** On heating, sodium nitrate, ($NaNO_3$) decomposes giving the sodium nitrite, ($NaNO_2$) and oxygen while magnesium nitrate, ($Mg(NO_3)_2$), decomposes giving magnesium oxide, nitrogen dioxide and oxygen.

(i) Write balanced equations for the decomposition of sodium nitrate and magnesium nitrate respectively.

$NaNO_3 \rightarrow NaNO_2 + \frac{1}{2} O_2$ **1m**

$Mg(NO_3)_2 \rightarrow MgO + 2NO_2 + \frac{1}{2} O_2$ **1m**

[2]

(b) **(i)** 5.35 g of a mixture of sodium nitrate, ($NaNO_3$) and magnesium nitrate, ($Mg(NO_3)_2$), was heated in a fume cupboard until no more gases were evolved. The sodium nitrite, ($NaNO_2$), formed was dissolved in water to form a 250 cm^3 solution of nitrite ions, NO_2^-. The nitrite ions in the solution reacted with 40.00 cm^3 of acidified potassium manganate(VII) solution.

The nirite ion half equation is given by:

$$NO_2^- + H_2O \longrightarrow NO_3^- + 2H^+ + 2e^-$$

Write a balanced equation for the reaction between nitrite ions and manganate(VII) ions.

$5NO_2^- + 2MnO_4^- + 6H^+ \longrightarrow 5NO_3^- + 2Mn^{2+} + 3H_2O$ **2m**

[2]

(ii) Given that the concentration of the acidified potassium manganate(VII) solution was 0.200 mol dm^{-3}, calculate the number of moles of potassium manganate(VII) that reacted.

No. of moles of MnO_4^- = $0.200 \times 40/1000 = 8.00 \times 10^{-3}$ **1m**

[1]

(iii) Calculate the number of moles of sodium nitrite, ($NaNO_2$), in 250 cm^3 of the solution.

No. of moles of $NaNO_2$ = $8.00 \times 10^{-3} \times 5/2 = 2.00 \times 10^{-2}$ **1m**

[1]

2. **(b)** **(iv)** Calculate the number of moles of sodium nitrate, ($NaNO_3$), in 5.35 g of the mixture.

No. of moles of $NaNO_3 = 2.00 \times 10^{-2}$ **1m**

[1]

(iv) Hence calculate the respective mass of sodium nitrate, ($NaNO_3$) and magnesium nitrate, ($Mg(NO_3)_2$), in the mixture.

Mass of $NaNO_3 = 2.00 \times 10^{-2}$ X M_r = 1.70 g **1m**

Mass of $Mg(NO_3)_2$ = 5.35 – 1.70 = 3.65 g **1m**

[2]

[Total: 9]

3. Propane, C_3H_8, is isolated from bottled gas used for cooking and heating.

(a) Write an equation for the complete combustion of propane.

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4\ H_2O$ **1m**

[1]

(b) The density of propane is 1.83 g dm^{-3}.

(i) Calculate the number of moles of propane present in 50 cm^3.

No. of moles of propane = (50/1000 X 1.83) / 44 = 2.08×10^{-3} **1m**

3. **(b)** **(ii)** Calculate the volume of oxygen (measured at room temperature and pressure) that would be required to completely burn 50 cm^3 of propane.

Volume of propane = 5 x 50 = 250 cm^3 / 0.250 dm^3 **2m**

[4]

(c) **(i)** Write an equation which represents the standard enthalpy change of formation of gaseous propane.

$3C(graphite) + 4H_2(g) \rightarrow C_3H_8(g)$ **1m**

(ii) Use the following standard enthalpy changes of combustion, $\Delta H_c^{\ominus}$, to calculate the standard enthalpy change of formation of propane.

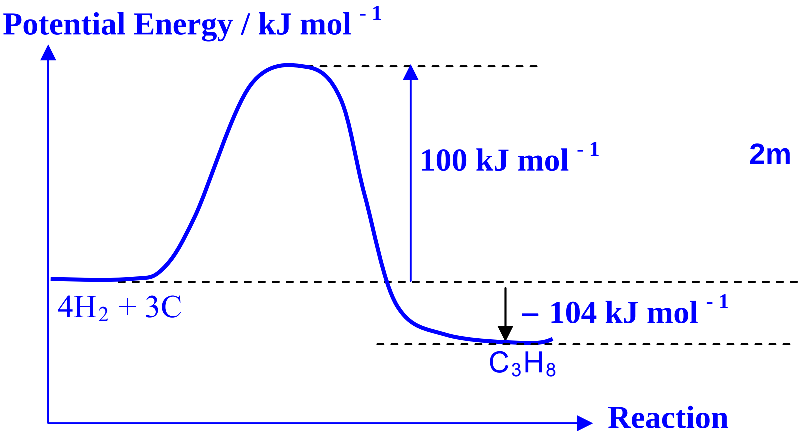
substance	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
carbon	–393
hydrogen	–286
propane	–2219

ΔH_f = 3(–393) + 4(–286) –(–2219) = – 104 kJ mol^{-1} **1m substitution**

1m ans + units

[3]

(d) Given that the activation energy for the standard enthalpy change of formation of propane is 100 kJ mol^{-1}, draw a labelled energy profile diagram for the reaction.



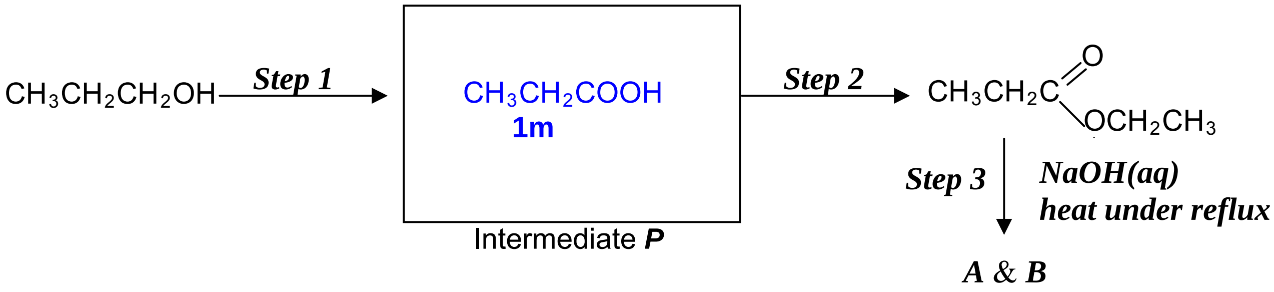
2m

[2]

[Total: 10]

4. **(a)** For the following two conversions, state clearly the reagents and conditions required in each step. Draw the structure of intermediate ***P*** formed in the box provided.

(i)



Reagents and conditions:

Step1: _____hot acidified $KMnO_4$_ **1m**

Step 2: __CH_3CH_2OH, concentrated H_2SO_4, heat **1m**

(ii) Draw the structures of products ***A*** and ***B*.** State the type of reaction for ***Step 3***.

$CH_3CH_2COO^-Na^+$ **1m**	CH_3CH_2OH **1m**
A	***B***

Type of reaction:_hydrolysis___ **1m**

Intermediate ***P*** can be synthesized from ethanol in 3 steps as shown beolw:

(iii) $CH_3CH_2OH \longrightarrow \boldsymbol{X} \longrightarrow \boldsymbol{Y} \longrightarrow$ Intermediate ***P***

Draw structures of ***X*** and ***Y*** in the boxes below.

CH_3CH_2Cl or CH_3CH_2Br **1m**	CH_3CH_2CN **1m**
X	***Y***

[8]

4. **(b)** Draw the structures of the organic products formed when butan-2-ol reacts with the following reagents:

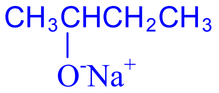
(i) Hot acidified potassium dichromate(VI).

$CH_3COCH_2CH_3$ **1m**

(ii) Alkaline aqueous iodine

$CH_3CH_2COO^-$ + CHI_3 **1m**

(iii) Na



$CH_3\underset{\underset{O^-Na^+}{|}}{C}HCH_2CH_3$ **1m**

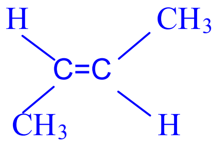
[3]

(c) Butan-2-ol reacts with hot concentrated sulphuric acid to form two isomers ***M*** and ***N***. ***M*** exhibits stereoisomerism while ***N*** does not.

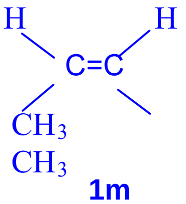
(i) Draw the structure of ***N***.

$CH=CHCH_2CH_3$ **1m**

(ii) With the aid of diagrams, show how ***M*** exhibits stereoisomerism.



1m



1m

[3]

[Total: 14]

Section B

Answer **two** of the three questions in this section on separate paper.

5. This question is about ethanoic acid and methanol.

(a) Vinegar is a dilute solution of ethanoic acid, CH_3COOH.

(i) Write an expression for the acid dissociation constant, K_a, for ethanoic acid.

$K_a = [CH_3COO^-][H^+]/[CH_3COOH]$ **1m**

(ii) When 0.15 g of pure ethanoic acid is dissolved in water and made up to 100 cm^3, the resulting pH is 3.18. Use this information to calculate the value of K_a for ethanoic acid. Include a unit in your answer.

Concentration of ethanoic acid = (0.15/60.0)/(100/1000) **1m**

= 0.0250 mol dm^{-3}

$[H^+] = 10^{-3.18} = 6.61 \times 10^{-4}$ mol dm^{-3} **1m**

$K_a = [CH_3COO^-][H^+]/[CH_3COOH]$

$= (6.61 \times 10^{-4})^2/0.0250$

$= 1.75 \times 10^{-5}$ **1m**

mol dm^{-3} **1m**

OR

$K_a = [CH_3COO^-][H^+]/[CH_3COOH]$

$= (6.61 \times 10^{-4})^2/(0.0250 - 6.61 \times 10^{-4})$

$= 1.80 \times 10^{-5}$ **1m**

mol dm^{-3} **1m**

(iii) State an assumption made in your calculation.

1m for any of the following:

1. $[H^+] = [CH_3COO^-]$ because H^+ from water is insignificant or all H^+ is from the acid
2. $6.61 \times 10^{-4} << 0.0250$, so can be ignored in calculation OR degree of ionisation of the acid is very small or negligible, hence $[CH_3COOH] = 0.0250$ mol dm^{-3}

5. **(a)** **(iv)** Calculate the volume of 0.050 mol dm^{-3} aqueous barium hydroxide needed to neutralise the 100 cm^3 of ethanoic acid solution in **(ii)**.

Amount of ethanoic acid = 100/1000 × 0.0250 = 2.50×10^{-3} mol

$Ba(OH)_2 = 2OH^-$

Amount of $Ba(OH)_2$ required = ½(2.50×10^{-3}) = 1.25×10^{-3} mol **1m**

Volume of $Ba(OH)_2$ required = 1.25×10^{-3}/ 0.050 = 0.0250 dm^3

= 25.0 cm^3 **1m**

(v) Suggest a suitable indicator for the titration and state the colour change at the end-point for the indicator you have suggested.

Phenolphthalein **1m**

Colourless to pale pink **1m** [10]

(b) One of the steps involved in the synthesis of methanol involves the water-gas shift reaction. In this reaction, a mixture of steam and carbon monoxide will form an equilibrium mixture as shown by the equation.

$$H_2O(g) + CO(g) = H_2(g) + CO_2(g)$$

The reaction is an example of a *dynamic equilibrium*.

(i) Explain the meaning of the term *dynamic equilibrium*.

Dynamic equilibrium refers to a reversible reaction in which the rate of the forward reaction equals to the rate of backward reaction. **1m**

(ii) 1.0 mol of steam and 1.0 mol of carbon monoxide are allowed to react at 230°C. At equilibrium, there was 0.67 mol of hydrogen gas present. Calculate the equilibrium constant, K_c, at this temperature and state its units.

	$H_2O(g)$ +	$CO(g)$ =	$H_2(g)$ +	$CO_2(g)$
Initial amount/mol	1.0	1.0	0	0
Equil. amount/mol	0.33	0.33	0.67	0.67 **1m**

$$K_c = \frac{(0.67)^2}{(0.33)^2}$$

= 4.12 **1m**

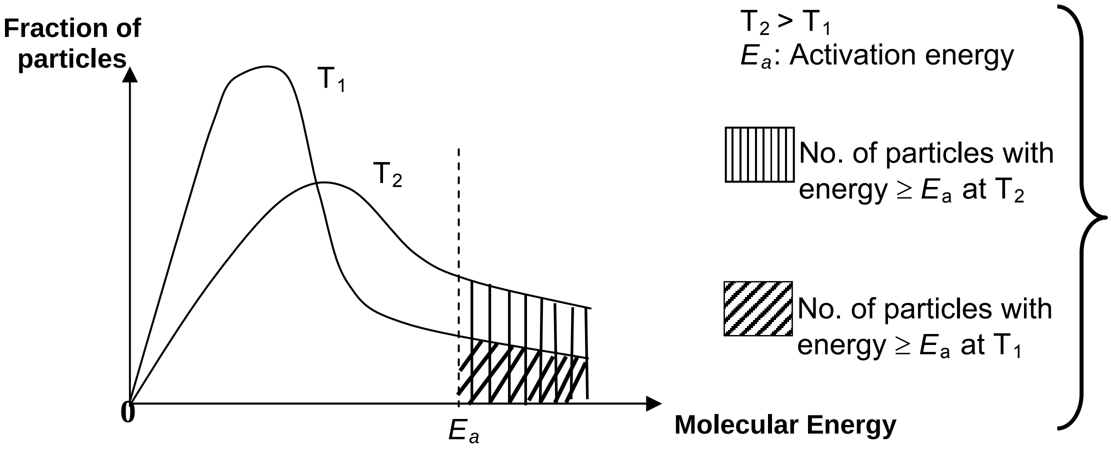
No units **1m**

(iii) State and explain what would happen to the equilibrium position if the initial concentration of steam was increased.

When the initial concentration steam was increased, the equilibrium position will shift to the right to remove some of the steam. **2m**

5. **(b)** **(iv)** Explain, with the aid of an appropriate diagram, the effect, if any, on the rate of attainment of the equilibrium when the temperature of the system is increased.

When the temperature increases from T_1 to T_2, the number of molecules with energy ≥ activation energy increases. **1m**



1m

Therefore, frequency of effective collisions increases and hence, the rate of attainment of equilibrium is increases. **1m**

[10]

[Total: 20]

6. This question is about alcohols.

(a) Alcohols can be classified as primary, secondary or tertiary. Describe how you would classify alcohols in these groups by heating them with acidified potassium dichromate(VI) and, where necessary, carrying out a further test on the product. You should include any reagents and give the expected observations. **Equations are not required**.

Add acidified potassium dichromate(VI) to each sample separately and heat under reflux or distill. If the sample turned orange potassium dichromate(VI) green, it is either primary or secondary alchohol.

If the sample does not change the colour of potassium dichromate(VI), it is a tertiary alcohol. **2m**

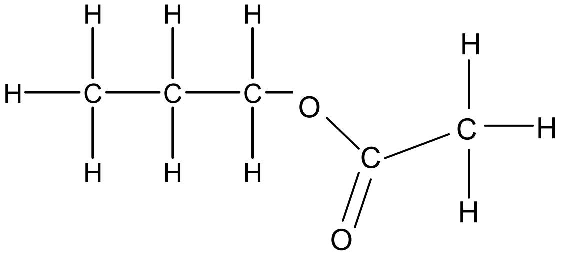
If 1st step involves heating under reflux:	If first step involves distillation:
(Test for ketone) Add Brady's reagent/ 2,4-dinitrophenyhydrazine to each of the products from the oxidation of the primary and secondary alcohols. If an orange ppt is obtained, a carbonyl compound/ketone is present and the alcohol is secondary. If no orange ppt is obtained, a carboxylic acid is present and the alcohol is primary.	–
(Test for carboxylic acid) Add Na_2CO_3(aq) to each of the products from oxidation of the primary and secondary alcohols and pass any gas evolved into limewater. If gas evolved forms a white ppt with limewater, a carboxylic acid is present and the alcohol is primary. If no white ppt was formed with limewater, no carboxylic acid is present and the alcohol is secondary.	Add Tollen's reagent to each of the products from the oxidation of the primary and secondary alcohols and heat. If a silver mirror is observed, aldehyde is present and the alcohol is primary. If no silver mirror is observed, no aldehyde is present and the alcohol is secondary. Use of Fehling's solution is also acceptable.

[4]

3m

6. **(b)** The ester formed between propan-1-ol and ethanoic acid contributes to the flavour of ripe pears.

(i) Draw the **displayed** formula of the ester.



2m

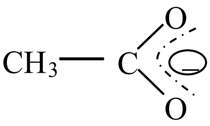
(ii) State whether ethanoic acid or propan-1-ol is the stronger acid. Explain your answer.

Ethanoic acid is the stronger acid. **1m**

CH_3COO^- is stabilised as the negative charge on the O atom is dispersed by the delocalisation of negative charge over the two O atoms. **1m**

OR

CH_3COO^- is stabilised as the negative charge on the O atom is dispersed by the delocalisation as shown in the diagram below:



1m

[4]

(c) Propan-1-ol can be converted to 1-bromopropane in one step.

(i) Suggest the reagents and conditions necessary for this conversion.

PBr_3 , room temperature or HBr, heat **1m**

(ii) Describe a chemical test that can distinguish 1-bromopropane from bromobenzene.

Test: Add NaOH(aq) to each compound separately and heat. Add excess HNO_3(aq), followed by $AgNO_3$(aq). **1m**

Observations: 1-bromopropane will give a cream ppt while bromobenzene will not. **1m**

[3]

(d) **(i)** Define the term *standard enthalpy change of combustion*.

It is the enthalpy change/ heat released which occurs one mole of substance is burnt in excess oxygen/ is completely burnt in oxygen under standard conditions. **1m**

6. **(d)** **(ii)** Use the following standard enthalpies of formation to calculate the standard enthalpy change of combustion of propan-1-ol.

Compound	$CO_2(g)$	$CH_3CH_2CH_2OH(l)$	$H_2O(l)$
$\Delta H_f^{\ominus}$/ kJ mol^{-1}	–394	–304	–286

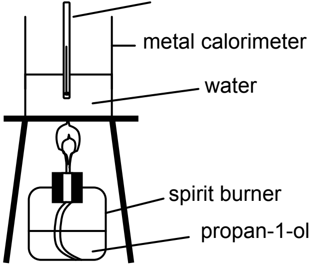
$CH_3CH_2CH_2OH(l) + 9/2O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

$\Delta H_c^{\ominus} = 4(–286) + 3(–394) – (–304)$

$= –2022$ kJ mol^{-1} **2m**

(iii) Experimentally, a value for the standard enthalpy change of combustion of propan-1-ol can be determined in the laboratory using the apparatus shown below.

The following results were obtained.
mass of water in the calorimeter = 100g
initial temperature of water = 25°C
final temperature of water = 32.5°C
original mass of burner + propan-1-ol = 53.35 g
final mass of burner + propan-1-ol = 53.25 g
specific heat capacity of water = 4.18 J g^{-1} K^{-1}



Use these results to calculate the experimental enthalpy change of combustion for propan-1-ol.

Heat evolved = 100 × 4.18 × 7.5 = 3135J = 3.135 kJ **1m**

Mass of propan-1-ol used = 53.35 – 53.25 = 0.10 g

Amount of propan-1-ol used = 0.10/60.0 = 1.67×10^{-3} mol **1m**

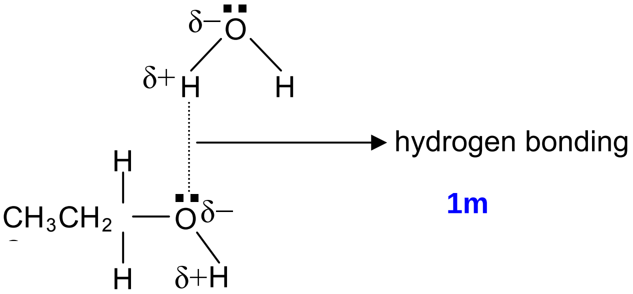
$\Delta H_c^{\ominus} = –3.135/1.67 \times 10^{-3} = –1877$ kJ mol^{-1} **1m**

(iv) Give one reason why you would expect your answer to **(iii)** to differ from that in **(ii)**. [7]

There was heat loss to the surroundings in the experiment. **1m**

(e) Explain why propan-1-ol is miscible with water. Include a diagram in your answer. [2]

Propan-1-ol molecules can form hydrogen bonding with water molecules. **1m**



1m

[Total: 20]

7. This question is about phosphorus and its compounds.

(a) **(i)** State the full electronic configuration of phosphorus.

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

(ii) Suggest how the first ionisation energy of phosphorus would compare to that of sulphur and explain your reasoning. [3]

Phosphorus has higher first ionisation energy than sulphur. **1m**

Mutual repulsion between the paired 3p electrons in sulphur makes it easier to remove the one of the paired 3p electrons from sulphur than to remove the unpaired 3p electron from phosphorus which does not experience such repulsion. **1m**

(b) One of the products from the reaction of phosphorus and sulphur is phosphorus sulphide, P_4S_3, which is used in small amounts in the tip of a match. On striking a match, this compound burns to give phosphorus(V) oxide, P_4O_{10} and sulphur dioxide, SO_2.

(i) Construct a balanced equation for this reaction.

$P_4S_3 + 8O_2 \rightarrow P_4O_{10} + 3SO_2$ **1m**

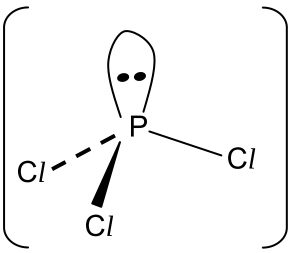
(ii) Both oxides formed in **(i)** dissolve in water. Construct an equation for the reaction of each oxide with water.

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ **1m**

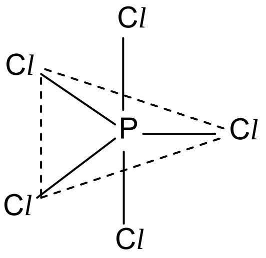
$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$ **1m** [3]

(c) Phosphorus reacts with limited amount of chlorine to give PCl_3 and excess chlorine to form phosphorus pentachloride, PCl_5.

(i) Draw the name the shapes of PCl_3 and PCl_5.



trigonal pyramidal



trigonal bipyramidal

2m

(ii) Explain why PCl_5 sublimes at 160 °C while PCl_3 boils at 76.1 °C.

Both PCl_5 and PCl_3 have simple molecular structures.

Due to the larger number of electrons in the PCl_5 molecule/ larger electron cloud of PCl_5 molecule **1m**

more energy/ larger amount of energy is required to overcome/break the stronger induced dipole-induced dipole interaction/attraction between PCl_5 molecules than the weaker permanent dipole-permanent dipole interaction/attraction between PCl_3 molecules. **1m**

7. **(c)** **(iii)** Describe, with an equation, the reaction of PCl_5, with water. What would be the effect of adding universal indicator to the product?

$PCl_5(s)$ hydrolyse in water to give acidic solutions. **1m**
$PCl_5(s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(aq)$ **1m**
The universal indicator turned from green to red. **1m** [7]

(d) Phosphorus compounds are also used in the pharmaceutical industries. For example, solutions containing hydrogen phosphates are used as buffers found in the hydrophilic gel used in skin patches. Write equations to show how the solution containing $H_2PO_4^-$/ HPO_4^{2-} can act as a buffer when H^+ and OH^- ions are added respectively to the solution.

On addition of H^+: [2]

$$HPO_4^{2-} + H^+ \rightarrow H_2PO_4^- \quad \textbf{1m}$$

On addition of OH^-:

$$H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O \ \textbf{1m}$$

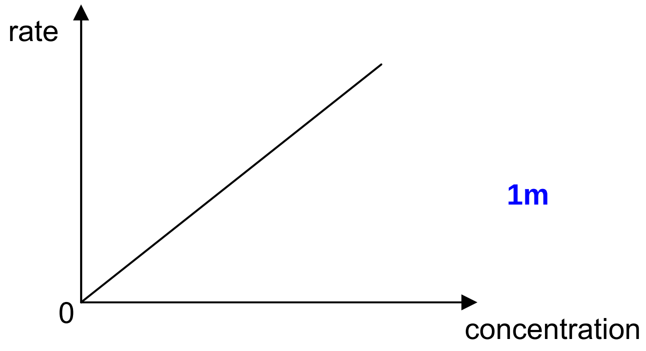
(e) Phosphine, PH_3, is a widely used fumigant. The thermal decomposition of phosphine into phosphorus and hydrogen is a *first-order reaction.*

$$4PH_3(g) \rightarrow P_4(g) + 6H_2(g)$$

(i) Explain the term in *italics*.

A first-order reaction refers to one in which the order of reaction with respect to the reactant is one in the rate equation. **1m**

(ii) Sketch a rate against concentration of phosphine graph for the decomposition reaction.



1m

The half-life of the reaction is 35.0 seconds at 680°C. Calculate

(iii) the rate constant for the reaction.

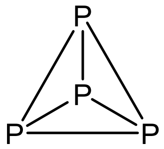
$k = \ln2/t_{1/2} = \ln2/35.0 = 0.0198\ s^{-1}$ **1m**

(iv) the time taken for 87.5% of the phosphine to decompose.

100% → 50% → 25% → 12.5%

Time taken = 3 × 35.0 = 105 s **1m**

7. **(e)** **(v)** Given that phosphorus has the structure shown below and the following bond energy values, calculate the enthalpy change for the decomposition reaction.



bond	bond energy / kJ mol^{-1}
P−H	326
P−P	209
H−H	435

[5]

ΔH_{r}’ = 12(326) – {6(209) + 6(435)}

= +48 kJ mol^{-1} **1m**

[Total: 20]