CATHOLIC JUNIOR COLLEGE
H1 CHEMISTRY PRELIM EXAM
PAPER 2 SOLUTIONS

SECTION A

1 The equation for the decomposition of gaseous **X** at 373 K is shown below.

$$2\mathbf{X}\ (g) \rightleftharpoons \mathbf{Y}\ (g) + \mathbf{Z}\ (g)$$

The values for the initial rates of decrease in concentration of **X** at various initial concentrations have been determined. These are shown in the table below.

Initial concentration / mol dm^{-3}	1.67	3.34	5.01	6.68
Initial rate / mol dm^{-3} s^{-1}	0.41	1.64	3.69	6.56

(a) (i) Determine order of reaction with respect to **X** and write down the rate equation for this reaction.

By inspection,

when initial concentration of **X** increases 2 times, from 1.67 to 3.34 mol dm^{-3}, the initial rate of reaction increases 4 times from 0.41 to 1.64 mol dm^{-3} s^{-1}.

$\therefore$ Order of reaction wrt **X** is 2nd order.

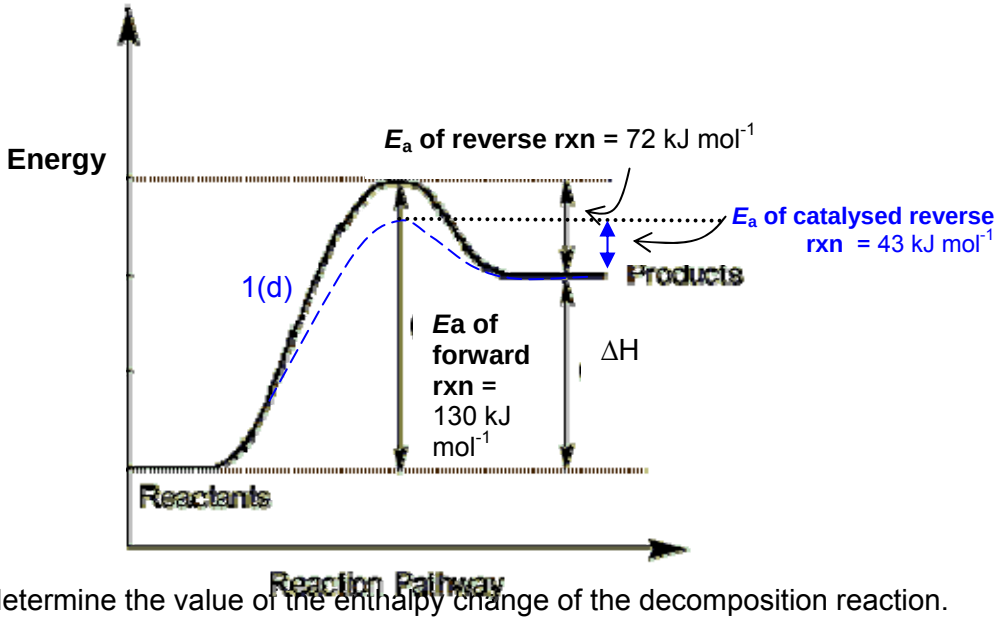
Rate equation: rate = k $[\mathbf{X}]^2$

(ii) Calculate the rate constant for this reaction, stating the units clearly.

Using data from 1st expt: $0.41 = k\ (1.67)^2$
$\therefore k = 0.41 / (1.67)^2 =$ 0.147 dm^3 mol^{-1} s^{-1}

[4]

(b) (i) At 373 K, the activation energy for the forward reaction is 130 kJ mol^{-1} and that for the reverse reaction is 72 kJ mol^{-1}. Sketch and label the energy profile diagram for this reaction.



(ii) Hence, determine the value of the enthalpy change of the decomposition reaction.

$\Delta H_r = 130 - 72 =$ +58 kJ mol^{-1}

[3]

(c) What will be the effects of increasing pressure on the decomposition of **X**?

By Le Chatelier's Principle, increasing pressure will favour will not shift the position of equilibrium in either direction as both forward and reverse reactions produce the same number of gaseous molecules. Hence the decomposition of X will not be favoured.

However, the rate of decomposition will still increase since pressure is increased.

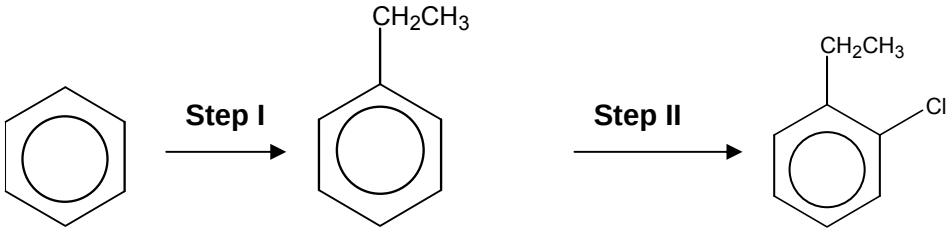
[2]

(d) In the presence of a catalyst, the activation energy of the reverse reaction is 43 kJ mol^{-1}. On the same axes in **(b)(i)**, draw the energy profile of the catalysed reaction and label it clearly.

[1]

[Total: 10]

2 2-chloroethylbenzene can be formed stepwise from benzene via the following reaction scheme.



(a) **Step I** shows how ethylbenzene is synthesised from benzene via a reaction known as Friedel-craft alkylation. The equation below represents the chemical reaction that occurs in **Step I**.

$$C_6H_6\ (l) + CH_3CH_2Cl\ (g) \rightarrow C_6H_5CH_2CH_3\ (l) + HCl\ (g)$$

(i) Use the following data to calculate the enthalpy change of the above Friedel-craft alkylation reaction.

$\Delta H^{\ominus}_f$ (C_6H_6)	= +49.0 kJ mol^{-1}
$\Delta H^{\ominus}_f$ (CH_3CH_2Cl)	= -109 kJ mol^{-1}
$\Delta H^{\ominus}_f$ ($C_6H_5CH_2CH_3$)	= -12.5 kJ mol^{-1}
$\Delta H^{\ominus}_f$ (HCl)	= -92.3 kJ mol^{-1}

$\Delta H_r = \sum \Delta H_f$ (products) - $\sum \Delta H_f$ (reactants) = (-92.3 -12.5) – (49 -109) = -44.8 kJ mol^{-1}

[1]

(ii) Write an equation to represent the standard enthalpy change of combustion, $\Delta H^{\ominus}_c$ of ethylbenzene.

$$C_6H_5CH_2CH_3\ (l) + \frac{21}{2} O_2\ (g) \rightarrow 8CO_2\ (g) + 5H_2O\ (l)$$

(iii) Calculate the standard enthalpy change of combustion, $\Delta H^{\ominus}_c$ of ethylbenzene given the following data:

$\Delta H^{\ominus}_c$ carbon	= -393 kJ mol^{-1}
$\Delta H^{\ominus}_c$ hydrogen	= -286 kJ mol^{-1}

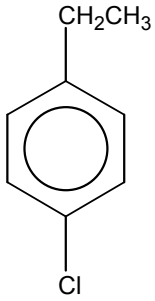
ΔH_c (ethylbenzene) = $\sum \Delta H_f$ (pdts) - $\sum \Delta H_f$(reactants)
= 8(-393) + 5(-286) – (-12.5) = -4561.5 = -4560 kJ mol^{-1} (3sf)

[3]

(b) **(i)** State the reagents and conditions used in **Step II**.

Reagent: Cl_2 in CCl_4 (or) Cl_2 (g) (or) Cl_2
Conditions: $FeCl_3$ / Fe / $AlCl_3$ catalyst, room temperature, in the dark / absence of light.

(ii) Draw the structure of another possible product that can be formed in **Step II** and briefly explain the formation of this product.

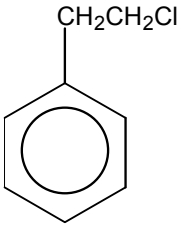


4-chloroethylbenzene can also be formed as the ethyl substituent on the benzene ring is 2, 4-directing.

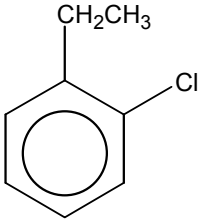
Hence the incoming Cl can substitute the H atom on the 2nd or 4th position of the benzene ring.

[3]

(c) Describe a simple chemical test that can be used to distinguish between 1-chloro-2-phenylethane and 2-chloroethylbenzene. State any observation made and write equation(s) where appropriate.



1-chloro-2-phenylethane



2-chloroethylbenzene

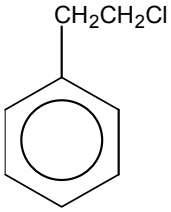
Chemical test:

1) Add excess NaOH(aq) to each compound separately and boil / heat.
2) Add HNO_3(aq), followed by addition of $AgNO_3$(aq)

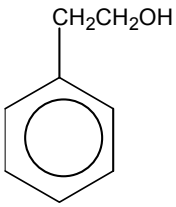
Observation:

1-chloro-2-phenylethane reacts to form a white ppt of AgCl.
But no ppt. observed to form for 2-chloroethylbenzene.

Equation:



+ OH^- (aq) →



+ Cl^- (aq)

Ag^+ (aq) + Cl^- (aq) → AgCl (s)

[3]

3 Physical properties of the oxides of some Period 3 elements **W, X, Y** and **Z** are given below.

Formula of oxide	Melting point /°C	Appearance at r.t.p.	Conductivity in molten state	Acidic/Basic nature of oxide
WO	1132	White solid	Good	Basic
$\mathbf{X}_2O_3$	2054	Solid (variable colour)	Good	Amphoteric

$\mathbf{Y}O_2$	1650	White solid	None	Acidic
$\mathbf{Z}O_2$	-72	Colourless gas	None	Acidic

(a) State the type(s) of particles present in the solid lattices of the four oxides above. In addition, identify **all** type(s) of bonds present in each oxide.

	WO	$\mathbf{X}_2O_3$	$\mathbf{Y}O_2$	$\mathbf{Z}O_2$
Type(s) of lattice particles	Oppositely charged ions	Oppositely charged ions	Atoms	Molecules
Type(s) of bonds	Ionic bonds	Ionic bonds with covalent character	Covalent bonds	Covalent bonds and intermolecular Van der Waals' forces

[4]

(b) Based on considerations of the properties of the respective oxides above,

(i) Draw and name the shape of the molecule of $\mathbf{Z}O_2$.

Shape: **V-shape or bent**

(NOT necessary to show bond angle in this case.)

Accept diagram in terms of Z.

(ii) Suggest, with reasons, whether **W**O is soluble in water.

WO is **soluble** in polar solvents like water.
It is a **basic oxide** implies it is a **metallic oxide (or ionic oxide)**, so it is expected to be able to hydrolyse water to form alkaline solution.
(Or) It is an **ionic oxide** and is able to form **favourable ion-dipole interactions** with H_2O molecules. The energy released is **enough to compensate the energy** to attract the ions from the ionic lattice.

(iii) State the possible identity of $\mathbf{X}_2O_3$ and hence write down balanced equations to show the amphoteric nature of $\mathbf{X}_2O_3$.

$\mathbf{X}_2O_3$ is $\mathbf{Al_2O_3}$.

$Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$

$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$

[6]
[Total: 10]

4 Every year, Singapore celebrates its independence on the 9th of August with a large-scale celebratory event – the National Day Parade. During the Parade, the most highly anticipated item is the fireworks display, which has never failed to captivate the hearts of the audience.

To create these spectacular visual effects, chemistry is actually involved. In fact, each firework that is launched into the sky comprises of chemicals and fuels that are precisely formulated so as to produce different special effects.

The power needed to lift each firework into the air is provided by the highly exothermic combustion of the 'black powder', a slow-burning combination of 75 % potassium nitrate, 15 % charcoal (carbon), and 10 % sulphur. For a typical 1-kg firework, it contains approximately 500 g of black powder. This composition of the black powder was first used in China about 1000 years ago, and has undergone little change since then. When the black powder burns in open air, the heat and gases generated dissipate quickly.
Hence, in order to successfully launch the firework high up into the atmosphere, the heat and gases generated during combustion need to be trapped at the bottom of the shell for enough pressure to build up prior to the launch.

When the black powder combusts, potassium nitrate in the powder will decompose according to the following equation:

$$2\,KNO_3(s) \rightarrow K_2O(s) + N_2(g) + \frac{5}{2}\,O_2(g)$$

The other two reagents in the black powder, sulphur and charcoal (carbon), will react with oxygen (from both air and potassium nitrate) to produce sulphur dioxide and carbon dioxide respectively:

$S(s) + O_2(g) \rightarrow SO_2(g)$ $\quad\quad$ ΔH_c = -296.83 kJ mol^{-1}
$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad\quad$ ΔH_c = ***x*** kJ mol^{-1}

The above combustions not only produce gases but also release a lot of heat energy. As such, the gases which are produced are simultaneously heated up and therefore rapidly expand. These rapidly expanding gases will become the explosive force of the reaction.

The colours of the fireworks are produced by heating the added metal salts, such as calcium chloride or sodium nitrate. Part of the heat energy which is produced from the combustions of sulphur and charcoal (carbon) will be absorbed by the atoms of the metal salts. As a result, the amount of unabsorbed energy released will be characteristic of the element.

The colours observed from the explosion of the fireworks are produced by the elements with the characteristic emissions listed in the table below:

Color	**Compound**	**Wavelength (nm)**	**Energy released/ kJ mol^{-1}**
red	strontium salts, lithium salts	652	183
orange	calcium salts	668	179
yellow	sodium salts	610-621	193
green	barium compounds + chlorine producer	589	203
blue	copper compounds + chlorine producer	505-535	224
purple	mixture of strontium (red) and copper (blue) compounds	420-460	260

(a) With reference to the oxidation states of nitrogen before and after the decomposition of potassium nitrate, describe its role in fireworks. [1]

N changes from **+5** (NO_3^-) to **0** (N_2).

KNO_3 acts as an **oxidising agent** as it is being **reduced** in the process.

(b) (i) Define the term *bond dissociation energy*.

Bond dissociation energy is the energy, ***per mole***, required to **break a particular covalent bond in gaseous molecules** of a substance thereby separating the two atoms originally joined by the bond.

(ii) Given that enthalpy change of converting C(s) to C(g) is +715 kJ mol^{-1}, together with the use of relevant values in the ***Data Booklet***, calculate the enthalpy change of combustion of C(s).

$C(s) \rightarrow C(g)$	$\Delta H_1 = +715$ kJ mol^{-1}
$C(g) + O_2(g) \rightarrow CO_2(g)$	$\Delta H_2 =$ **?** kJ mol^{-1}
$C(s) + O_2(g) \rightarrow CO_2(g)$	$\Delta H = (\Delta H_1 + \Delta H_2)$ kJ mol^{-1}

ΔH_c(C, g) = Sum of energy of bonds broken + Sum of energy of bonds formed
= (+496) + 2(-740) = **-984 kJ mol^{-1}**

ΔH_c(C, s) = +715 + (-984) = **-269 kJ mol^{-1}**

(iii) Hence, calculate the energy released from ignition of a typical 1-kg firework.

No. of mol of C in one firework = $\frac{(15/100)(500)}{A_r \text{ of C}} = \frac{(15/100)(500)}{12.0} = 6.25$ mol

No. of mol of S in one firework = $\frac{(10/100)(500)}{A_r \text{ of S}} = \frac{(10/100)(500)}{32.1} = 1.56$ mol

Energy released from ignition of one firework = [6.25 x (269) + 1.56 x (296.83)] kJ
= **2144 kJ**

[6]

(c) Predict what would be the colour observed when approximately 71.9 % of the heat energy released in part **(b)(iii)** is absorbed by 3 mol of metal salts present in the firework.

Energy released by 3 mol of metal atoms in firework
= (100 – 71.9)/100 x 2144
= **602.5 kJ**

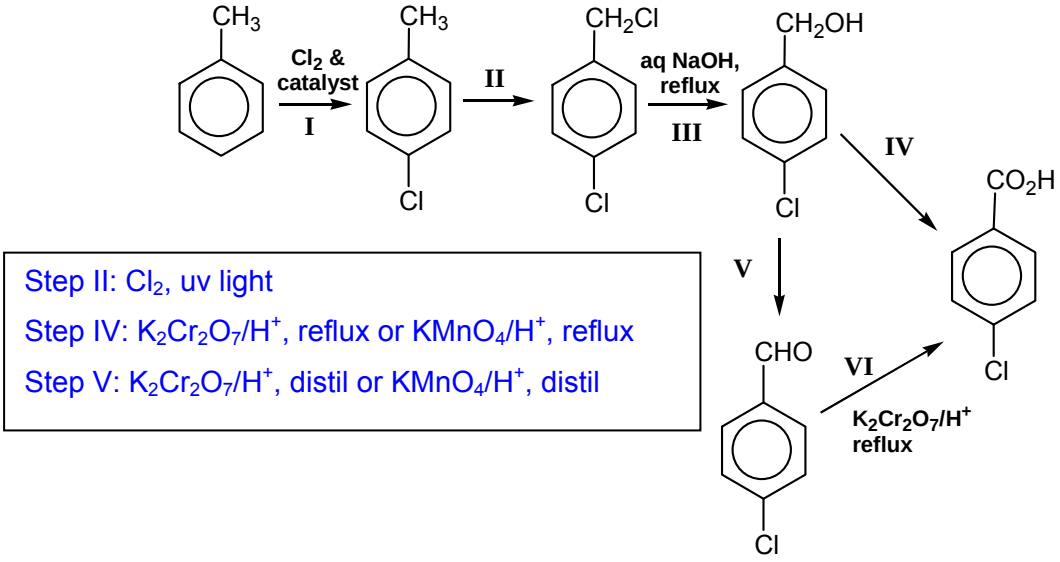
Energy released by 1 mol of metal atoms in firework
= 602.5 ÷ 3
= 200.8 kJ
= **201 kJ**

Observed colour should be **green**.

[3]
[Total: 10]

SECTION B

5



Step II: Cl_2, uv light

Step IV: $K_2Cr_2O_7/H^+$, reflux or $KMnO_4/H^+$, reflux

Step V: $K_2Cr_2O_7/H^+$, distil or $KMnO_4/H^+$, distil

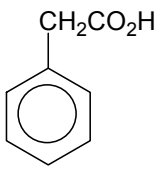
(a) (i) Suggest suitable reagents and conditions for steps **II, IV** and **V** of the reaction scheme above.

(ii) Explain briefly why the chloro- substituent group on the benzene ring does not get substituted during step **III** of the reaction.

[4]

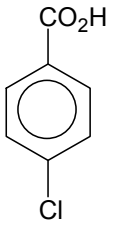
Chloro- group on the benzene ring does not get substituted as **C-X bond of benzene ring is stronger** than normal C-X bonds of halogenalkanes due to **partial double bond character**.

(b) 4-chlorobenzoic acid and phenylethanoic acid are two compounds containing benzene rings. Both compounds are not particularly soluble in water under room temperature conditions.



Phenylethanoic acid

and



4-Chloro-benzoic acid

State and explain which of these two acids are relatively more acidic. [3]

4-Chlorobenzoic acid is more acidic.

Strength of acid depends on the relative stability of its conjugate base.

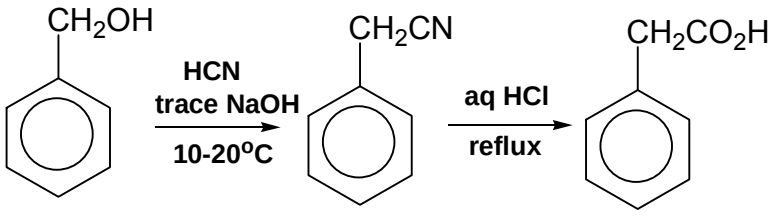
4-Chlorobenzoic acid forms the **more stable conjugate base** as there is an **extra electron-withdrawing** Cl on the benzene ring which helps to **further disperse the negative charge** on the conjugate base it forms, making it more stable.

(OR)

4-Chlorobenzoic acid contains an **extra Cl substituent group** attached to the 4th position of the benzene ring which is **electron-withdrawing**, it better **withdraws the electron cloud in the O- H bond** of the carboxyl group, making it **more polarized**.

As such, it undergoes **dissociation more readily** to form the **H^+ ions**, making it more acidic.

(c) The following shows the proposed reaction scheme to synthesise phenylethanoic acid from phenylmethanol.



Identify, with brief explanations, the two errors that appeared in the suggested method above. [4]

1st error: In step 1, **cannot use HCN for substitution** of hydroxyl group. That is **only used** for addition reaction **with carbonyl compounds**. Can use KCN(alc)

2nd error: There is a **missing step** for this reaction. **Cannot do a direct substitution of hydroxyl group to CN group**. Must first be converted to halogenoalkanes.

(d) One mole of phenylmethanol, $C_6H_5CH_2OH$ and 1 mole of phenylethanoic acid, $C_6H_5CH_2CO_2H$ were mixed and allowed to reach equilibrium at 25 °C.

$$C_6H_5CH_2CO_2H(l) + C_6H_5CH_2OH(l) \underset{\text{reflux}}{\overset{\text{c. } H_2SO_4}{\rightleftharpoons}} C_6H_5CH_2CO_2CH_2C_6H_5(l) + H_2O(l)$$

It was found that 60 % of $C_6H_5CH_2OH$ was converted at equilibrium.

(i) Write the equilibrium constant, K_c expression for the reaction.

$$K_c = \frac{[C_6H_5CH_2CO_2CH_2C_6H_5][H_2O]}{[C_6H_5CH_2CO_2H][C_6H_5CH_2OH]}$$

(ii) Calculate K_c at 25°C.

$$C_6H_5CH_2CO_2H(l) + C_6H_5CH_2OH(l) \underset{\text{reflux}}{\overset{\text{c. } H_2SO_4}{\rightleftharpoons}} C_6H_5CH_2CO_2CH_2C_6H_5(l) + H_2O(l)$$

Initial/mol:	1	1	0	0
Eqm/mol:	1-0.6 = 0.4	1-0.6 = 0.4	0.6	0.6

$$K_c = \frac{[C_6H_5CH_2CO_2CH_2C_6H_5][H_2O]}{[C_6H_5CH_2CO_2H][C_6H_5CH_2OH]} = \frac{[\frac{0.6}{V}][\frac{0.6}{V}]}{[\frac{0.4}{V}][\frac{0.4}{V}]} = \mathbf{2.25}\ \text{(No units)}$$

(iii) Suggest what would happen to the rate and equilibrium position of the reaction system when concentrated H_2SO_4 is added. [5]

Conc. H_2SO_4 acts as a catalyst and will **speed up the rate** of reaction.

Also, it acts as a **dehydrating agent** that will remove water from the reaction. By Le Chatelier's Principle, as the $[H_2O]$ falls, the eqm position will **shift to the right** to form more H_2O and at the same time forming more ester product.

(e) An excess of NaOH, 30.0 cm^3 of 1.00 mol dm^{-3} solutions, reacted with 5.70 g of an impure sample of ester, $C_6H_5CH_2CO_2CH_2C_6H_5$ formed from the earlier reaction in part **(d).**

(i) Write equation to show the reaction between NaOH and this ester, $C_6H_5CH_2CO_2CH_2C_6H_5$.

$C_6H_5CH_2CO_2CH_2C_6H_5$. + NaOH → $C_6H_5CH_2CO_2$**Na** + $C_6H_5CH_2OH$

(ii) The remaining NaOH required 25.0 cm^3 of 0.100 mol dm^{-3} H_2SO_4 for neutralisation. Calculate the percentage purity of the ester in the sample.

[4]

$2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2\ H_2O$

No. of mol of NaOH remained to react with H_2SO_4 = 2 x No of mol of H_2SO_4

$= 2 \times \left(\frac{25}{1000} \times 0.100\right)$

= 0.00500 mol

$C_6H_5CH_2CO_2CH_2C_6H_5$. ≡ NaOH

No. of mol of $C_6H_5CH_2CO_2CH_2C_6H_5$ in sample

= Actual no. of mol of NaOH used for hydrolysis = $\left(\frac{30}{1000} \times 1\right) - 0.00500$

= 0.0250 mol

Mass of $C_6H_5CH_2CO_2CH_2C_6H_5$ in sample = 0.0250 x Mr of $C_6H_5CH_2CO_2CH_2C_6H_5$

= 0.0250 x 226

= 5.65 g

Percentage purity of ester in sample = $\frac{5.65}{5.70} \times 100\%$

= **99.1%**

[Total: 20]

6 (a) Phenol is a monoprotic acid commonly used as an active ingredient in household disinfectants. A solution of phenol in water containing 2.50 mol dm^{-3} has a pH of 4.8

(i) Explain, with the aid of appropriate calculations, whether phenol is a strong or weak acid.

pH = 4.8; $\therefore [H^+] = 10^{-4.8}$ = 1.58 x 10^{-5} mol dm^{-3}

Phenol is a weak acid as $[H^+]$ is much lower than the concentration of the phenol solution (or) $[H^+] \neq$ [phenol].

(ii) Use the data given to calculate the value of K_a of phenol.

$K_a = [H^+]^2 / [HA]$ = $(1.58 \times 10^{-5})^2 / 2.50$ = 9.99 x 10^{-11} mol dm^{-3}

(ii) Suggest a suitable indicator for the titration of phenol with aqueous sodium hydroxide.

WA-SB titration: phenolphthalein

(iv) Phenol consists of 76.6% of C, 6.4% of H and 17.0% of O. Determine the empirical formula of phenol.

	C	**H**	**O**
% mass	76.6	6.4	17.0
No. of mol	6.38	6.4	1.06
Simplest ratio	6	6	1

Empirical formula is $\underline{C_6H_6O}$

(v) A sample of phenol of mass 1.04 g was dissolved in water and titrated with 0.500 mol dm^{-3} sodium hydroxide solution. It was found that 22.2 cm^3 of hydroxide was required for neutralisation. Calculate the M_r of phenol.

Amt of sodium hydroxide used = (22.2 / 1000) x 0.500 = 0.0111 mol.

Since phenol is monoprotic, phenol: NaOH = 1:1

∴Amt. of phenol = 0.0111 mol

M_r of phenol = 1.04/0.0111 = $\underline{93.7}$

(vi) Hence propose the structure of phenol.

M_r of $(C_6H_6O)_n$ = 93.7

n(72.0 + 6.0 + 16.0) = 93.7 ∴n = 1

Molecular formula = C_6H_6O

Since phenol consists of benzene ring, ∴phenol is $\underline{\mathbf{C_6H_5OH}}$

[10]

(b) A solution containing phenol and its salt, sodium phenoxide acts as a buffer solution.

(i) What do you understand by the term *buffer solution*?

A buffer is a solution capable of maintaining a $\underline{\text{fairly constant pH}}$ upon dilution or when $\underline{\text{small amount}}$ of acids or alkalis are added to it.

(ii) Write ionic equations to show how this solution reacts with

I added H^+ (aq) ions,

II added OH^- (aq) ions.

I: $H^+ + C_6H_5O^- \rightarrow C_6H_5OH$

II: $OH^- + C_6H_5OH \rightarrow C_6H_5O^- + H_2O$

[3]

(c) The melting points of four chlorides are given below.

compound	**formula**	**m.p. / °C**
Sodium chloride	NaCl	801
Aluminium chloride	$AlCl_3$	178

Carbon tetrachloride	CCl_4	-23
Silicon tetrachloride	$SiCl_4$	-70

(i) Briefly relate the melting points of NaCl, CCl_4 and $SiCl_4$ to the structure of, and bonding in, each of these chlorides.

NaCl consists of **giant ionic structure** with **strong electrostatic forces of attractions / ionic bonds** between Na^+ and Cl^- ions / (or) between oppositely charged ions. Since a lot of energy is required to break these strong ionic bonds to separate the ions, NaCl has a high melting point.

Both CCl_4 and $SiCl_4$ consist of **simple molecular** structure, with **weak Van der Waals' forces** of attractions between the molecules. Hence they have low melting point.

(ii) Describe the reaction, if any, of each of the 4 chlorides above with water, stating the approximate pH of any solution formed. Write balanced equation(s) for any reaction that takes place. Explain the differences in their reactivities.

- NaCl dissolves in water without hydrolysis. pH of resulting solution = 7.

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

- $AlCl_3$ undergoes substantial hydrolysis to form a solution of pH = 3.

  $AlCl_3(s) + 6H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$

  $[Al(H_2O)_6]^{3+}(aq) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H^+(aq)$

- CCl_4 is immiscible with water and is not hydrolysed by it.

- $SiCl_4$ is completely hydrolysed by water to give a solution of pH = 1 (or 2)

  $SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4H^+(aq) + 4Cl^-(aq)$

The degree of hydrolysis increases as the atom bonded to Cl gradually changes from metallic to non-metallic and the bond type gradually changes from ionic to covalent.

[7]
[Total: 20]

7 Nitrogen exhibits a range of oxidation number in its compounds.

(a) Copy and complete the table below which refers to possible reduction products of nitric acid.

Formula of product	Oxidation number of nitrogen
NO_2	+4
N_2O	+1
NH_2OH	-1
NH_4^+	-3

[2]

(b) Hydroxylamine, NH_2OH is oxidised by $Fe^{3+}(aq)$ which itself is reduced to $Fe^{2+}(aq)$.
In an experiment, 25.0 cm^3 of 0.100 mol dm^{-3} NH_2OH required 25.0 cm^3 of 0.200 mol dm^{-3} Fe^{3+} for complete reaction.

(i) Determine the number of moles of Fe^{3+} that react with one mole of NH_2OH.

No. of moles of Fe^{3+} = (25.0/1000) x 0.200 = 0.005 mol

(ii) What change in oxidation number does the nitrogen in NH_2OH undergo?

No. of moles of NH_2OH reacted = (25.0/1000) x 0.100 = 0.0025 mol

Since Fe^{3+}: NH_2OH: e^- = 2 : 1 : 2

no. of mol of e- given out by 1 mol of NH_2OH = 2

∴change in oxidation number of nitrogen = +2

(iii) Which formula from the table in **(a)** correspond to the nitrogen-containing product of this reaction?

New oxidation number of nitrogen = -1 + 2 = +1

∴the product is N_2O.

(iv) Write a half-equation to illustrate the oxidation of NH_2OH.

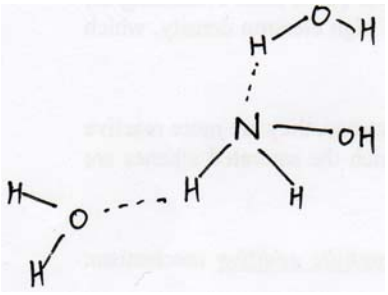
$2NH_2OH \rightarrow N_2O + H_2O + 4H^+ + 4e^-$

(v) Construct an equation for the reaction of NH_2OH with Fe^{3+}.

$2NH_2OH + 4Fe^{3+} \rightarrow N_2O + 4Fe^{2+} + H_2O + 4H^+$

[6]

(c) Hydroxylamine, NH_2OH, dissolves readily in water. Explain the solubility of hydroxylamine in water with the aid of a diagram to illustrate the intermolecular forces of attraction between hydroxylamine molecules and water molecules.



-------- H-bond

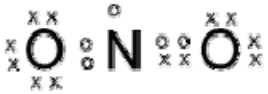
NH_2OH is soluble in water due to the formation of hydrogen bonding between NH_2OH and water molecules.

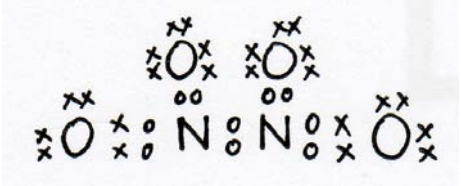
[2]

(d) The following equation shows the partial dissociation of brown nitrogen tetraoxide gas, N_2O_4 to colourless nitrogen dioxide gas, NO_2 at ***T*** K.

$$N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g)$$

(i) Draw the dot-and-cross diagrams of NO_2 and N_2O_4.





(ii) Identify the unique feature about the structure of NO_2.

NO_2 consists of an unpaired electron.

(iii) State and explain whether the decomposition of N_2O_4 is exothermic or endothermic.

Decomposition of N_2O_4 is endothermic since it involves the breaking of N-N bond in the N_2O_4 molecule to form two NO_2 molecules.

(iv) 0.5 mol of N_2O_4 is placed in a 1 dm^3 flask and allow to reach equilibrium. At equilibrium, 0.24 mol of N_2O_4 is left in the flask. Calculate the equilibrium constant, K_c at ***T*** K.

	N_2O_4 (g) $\rightleftharpoons$	$2NO_2$ (g)
Initial amt/mol:	0.5	0
Eqm amt/ mol:	0.24	2(0.5-0.24) = 0.52

$K_c = [NO_2]^2 / [N_2O_4] = (0.52)^2 / 0.24 =$ 1.13 mol dm^{-3}

(v) A flask containing the N_2O_4 / NO_2 gas mixture is immersed into hot water. State the observation and indicate how the rate of decomposition and K_c will be affected.

When temperature is increased, the brown gas mixture will become paler in colour as more NO_2 are formed.

K_c will thus increase as more NO_2 products are formed.

Rate of decomposition will also increase due to higher temperature.

[10]
[Total: 20]