Catholic Junior College

JC1 Promotional Examinations

Higher 2

CANDIDATE NAME	
CLASS	**1T**

CHEMISTRY **9729/02**

Paper 2 Structured Questions **Wednesday 2 October 2019**

Answers

Grade	

This document consists of **10** printed pages.

Paper 2

Answer **all** the questions.

Write your answers in the spaces provided. You are advised to spend **not** more than one hour on this section.

1 Ethanedioic acid, is a dibasic, organic acid with the formula HO_2CCO_2H. It is commonly found in many leafy vegetables, fruits, nuts and seeds. It is able to react with a base such as sodium hydroxide, NaOH.

(a) **FA 1** is a solution containing 5.00 g dm^{-3} of a similar dibasic, organic acid, $HO_2C(CH_2)_nCO_2H$. When 25.0 cm^3 of **FA 1** is titrated against NaOH of concentration 0.125 mol dm^{-3}, 17.00 cm^3 of NaOH is required.

The equation for this reaction is given as follows.

$$HO_2C(CH_2)_nCO_2H(aq) + 2NaOH(aq) \rightarrow Na_2(O_2C(CH_2)_nCO_2)(aq) + 2H_2O(l)$$

(i) Calculate the amount in moles of NaOH required to react with 25.0 cm^3 of the acid solution in **FA 1**.

Amount of NaOH = $(\frac{17.00}{1000} \times 0.125) = 0.00213$ mol

[1]

(ii) Calculate the amount in moles of the dibasic acid, $HO_2C(CH_2)_nCO_2H$ in 25.0 cm^3 of **FA 1** that has reacted.

Amount of acid = (½ x 0.00213) = 0.00106 mol

[1]

(iii) Calculate the concentration of the acid, $HO_2C(CH_2)_nCO_2H$ in mol dm^{-3} of solution in **FA 1**.

Concentration of acid = $(\frac{1000}{25.0} \times 0.00106) = 0.0425$ mol dm^{-3}

[1]

(iv) Hence, determine the value of ***n*** in the formula of the acid, $HO_2C(CH_2)_nCO_2H$.

$\frac{5.00}{M_r} = 0.0425$

M_r of acid, $HO_2C(CH_2)_nCO_2H = \frac{5.00}{0.0425} = 117.6$

$14n + 90.0 = 117.6$; n= 2 (whole number)

[1]

[Turn over

(b) Ethanedioic acid, HO_2CCO_2H (or $H_2C_2O_4$), is also a reducing agent and reacts with an oxidising agent such as acidified potassium manganate(VII), $KMnO_4$. It can be oxidised by acidified $KMnO_4$ to carbon dioxide, when heated to 60°C.
When a 25.0 cm^3 sample of ethanedioic acid is titrated against acidified $KMnO_4$ of concentration 0.0200 mol dm^{-3}, 23.00 cm^3 of $KMnO_4$ is required.

(i) Derive a balanced half-equation for the oxidation of ethanedioic acid to carbon dioxide in acidic conditions.

$H_2C_2O_4(aq) \rightarrow 2CO_2(g) + 2H^+(aq) + 2e^-$

…………………………………………………………………………………………[1]

(ii) By reference to the relevant half-equation from the *Data Booklet* for the reduction of acidified MnO_4^-, derive an overall balanced equation for the reaction between ethanedioic acid and acidified manganate(VII) ion, MnO_4^-.

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$
(1st equation x 5; 2nd equation x 2 and adding)

$5H_2C_2O_4(aq) + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$

[1]

(iii) Hence, calculate the amount in moles of the acid, HO_2CCO_2H (or $H_2C_2O_4$) reacted and subsequently its concentration in mol dm^{-3}.

Amount of MnO_4^- = $(\frac{23.00}{1000} \times 0.0200) = 0.000460$ mol

Amount of $H_2C_2O_4$ = $(\frac{5}{2} \times 0.000460) = 0.00115$ mol

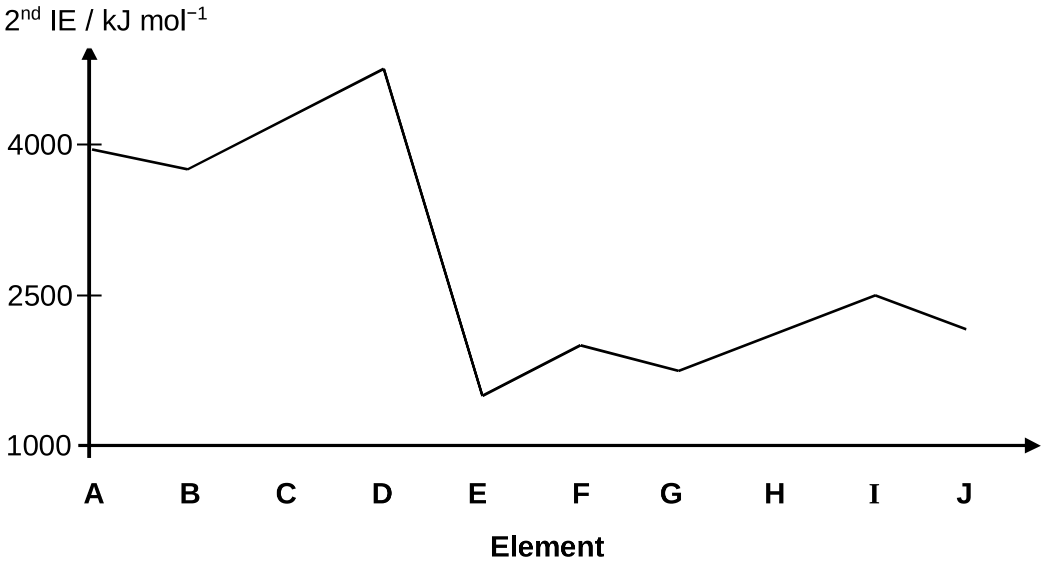
Concentration of $H_2C_2O_4$ = $(\frac{1000}{25.0} \times 0.00115) = 0.0460$ mol dm^{-3}

[2]

[Total: 8]

[Turn over

2 The graph below shows the second ionisation energies of unknown elements **A** – **J**, of consecutive proton numbers. The letters are not the atomic symbols of the elements. **J**, which has the largest A_r, has an atomic number below 20.



(a) Write the ground state electronic configuration of element **F**.

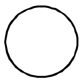
Electronic configuration of **F**: $1s^2 2s^2 2p^6 3s^2 3p^1$

[1]

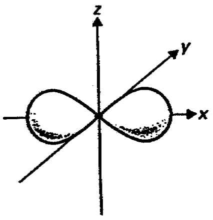
(b) Generally the second ionisation energy (2nd I.E.) increases across the period. Explain the decrease in 2nd I.E. between element **F** and **G**.

The second IE for **F** involves removing an electron from the 3s orbital while the second IE for **G** involves removing an electron from the 3p orbital. Electron in the 3p orbital is further from and less strongly attracted by the nucleus. [1]

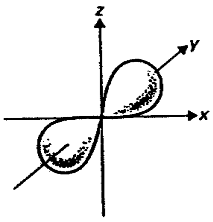
(c) Sketch and label all the valence orbitals of **F**, clearly showing the labelled axes.



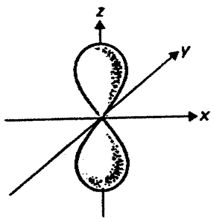
3s



$3p_x$



$3p_y$



$3p_z$

[2]

[Total: 4]

3 Canisters of flammable gas are used as portable fuel, and may contain a few types of short chain hydrocarbons, which are liquefied under high pressure.

A canister was connected to a gas syringe and the valve opened to allow some of the gas into the syringe. It was found that 0.300 g of gas took up 144.0 cm^3 at temperature of 24°C and pressure of 1.02×10^5 Pa.

[Turn over

Calculate the average M_r of the gas mixture assuming it behaves ideally.

$pV = nRT$

$$pV = \frac{mRT}{M_r}$$

$$\therefore M_r = \frac{mRT}{pV} = \frac{0.300 \times 8.31 \times (273 + 24)}{1.02 \times 10^5 \times 144 \times 10^{-6}} = 50.4 \text{ (1 d.p.)}$$

[Total: 3]

4 Nitroglycerin, $C_3H_5(NO_3)_3$, is a flammable liquid commonly used to manufacture dynamite. Upon ignition, nitroglycerin decomposes to produce nitrogen, oxygen, carbon dioxide and steam.

Given:

Standard enthalpy change of formation of nitroglycerin(l) / kJ mol^{-1}	–364
Standard enthalpy change of formation of H_2O(g) / kJ mol^{-1}	–242
Standard enthalpy change of formation of CO_2(g) / kJ mol^{-1}	–394

(a) Write a balanced equation, with state symbols, for the decomposition of 1 mol of liquid nitroglycerin. [1]

$$C_3H_5(NO_3)_3(l) \rightarrow 3/2N_2(g) + 1/4O_2(g) + 3CO_2(g) + 5/2\,H_2O(g)$$

(b) With reference to the above data, calculate the standard enthalpy change of decomposition of 1 mol of nitroglycerin. [1]

$$\Delta H_{decomposition} = \Sigma(\Delta H_{formation}\text{ products}) - \Sigma(\Delta H_{formation}\text{ reactants})$$
$$= 3(-394) + 5/2(-242) - (-364)$$
$$= -1423 \text{ kJ mol}^{-1}$$

(c) By using your answer in **(b)**, calculate ΔG^θ at 298 K for this decomposition given that $\Delta S^\theta = +208$ J K^{-1} mol^{-1}.

Hence, predict the spontaneity of the reaction at 298 K. [2]

$$\Delta G^\theta_{decomposition} = \Delta H_{decomposition} - T\Delta S^\theta$$

[Turn over

$= –1423 – [298 \times (+208/1000)]$

$= –1485 \text{ kJ mol}^{–1}$

Since ΔG^{θ} is negative, the reaction is spontaneous at 298 K.

(d) Is the reaction spontaneous at all temperatures? Explain. [1]

The spontaneity is **not** affected by changes in temperature because

$\Delta H_{decomposition}$ is negative, T is always positive and ΔS^{θ} is positive, (or, $–T\Delta S^{\theta}$ is always negative), i.e.

$\Delta G = \Delta H – T\Delta S$ = negative – [(+positive) x (+positive)] = negative

Yes. The decomposition reaction of nitroglycerin is spontaneous at all temperatures.

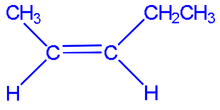
[Total: 5]

[Turn over

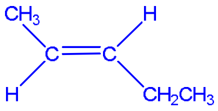
5 Pentenes are often produced as by-products of thermal cracking of petroleum. Pent-2-ene is one of the isomers of pentene and has the following formula:

$$CH_3CH{=}CHCH_2CH_3$$

(a) Draw and **label clearly** the two different structural formulae of pent-2-ene that show *cis-trans* isomerism.



cis-pent-2-ene

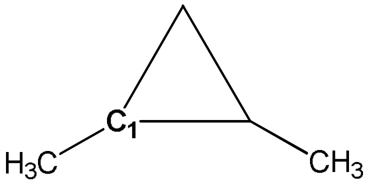


trans-pent-2-ene

[2]

One constitutional isomer of pent-2-ene is 1,2-dimethylcyclopropane, which consists of a cyclopropane ring substituted with two methyl groups attached to adjacent carbon atoms. Due to restricted ring rotation, *cis-trans* isomerism also exists in 1,2-dimethylcyclopropane.

The structure of 1,2-dimethylcyclopropane is shown below (the hydrogen atoms on the ring structure **are not displayed**):



1,2-dimethylcyclopropane

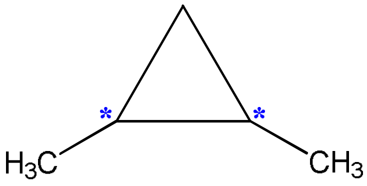
(b) State the hybridisation present at **C**$_1$.

sp^3

.... [1]

(c) Label with an asterisk (*), any chiral carbon atom(s) present in 1,2-dimethylcyclopropane.

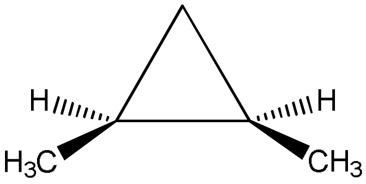
[1]



1,2-dimethylcyclopropane

(d) The effect of plane-polarised light on 1,2-dimethylcyclopropane was investigated and three stereoisomers of 1,2-dimethylcyclopropane were identified.

(i) The following isomer was found to have no effect on plane-polarised light.



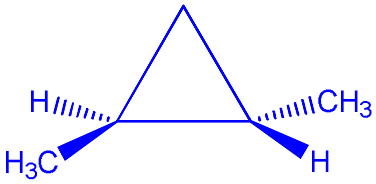
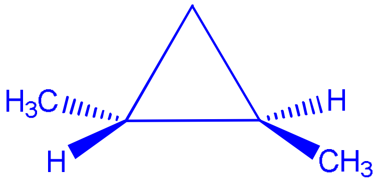
1,2-dimethylcyclopropane

Suggest a reason for this observation.

Although there are two chiral carbon atoms present in 1,2-dimethylcyclopropane, there is an internal plane of symmetry present and hence there is no optical activity.

…………………………………………………………………………………………[1]

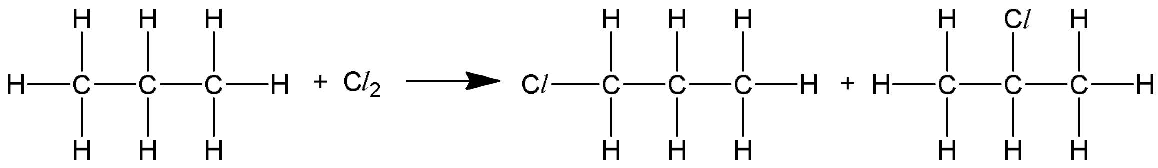
(ii) On the other hand, the remaining two isomers are optically active. Draw the 3-D structures for these isomers using wedged and dashed bonds.

Structure of isomers	
(1) 	**(2)** 

[1]
[Total: 6]

[Turn over

6 Propane, C_3H_8, reacts with excess chlorine gas, Cl_2, in the presence of *uv* light to form two monochloroalkanes.



$$CH_3CH_2CH_3 + Cl_2 \longrightarrow ClCH_2CH_2CH_3 + CH_3CHClCH_3$$

propane 1-chloropropane 2-chloropropane

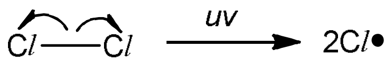
(a) State the name of the reaction mechanism of the monochlorination of propane.

Free-radical substitution ....[1]

(b) The reaction between propane and chlorine gas proceeds via a three-stage reaction mechanism. The mechanism to form 2-chloropropane is illustrated below.

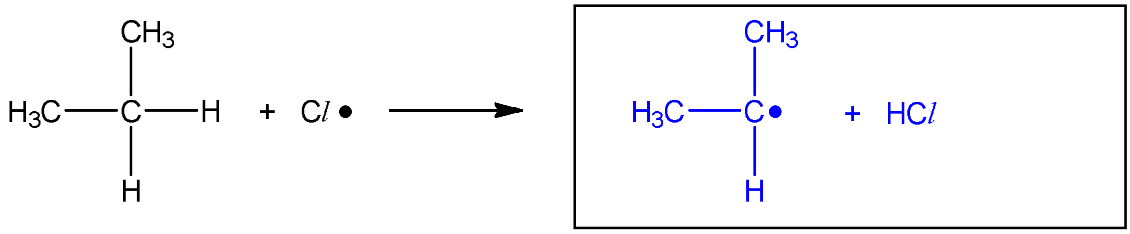
In the boxes provided below, fill in the blanks with the balanced equations for the propagation and termination steps.

Initiation

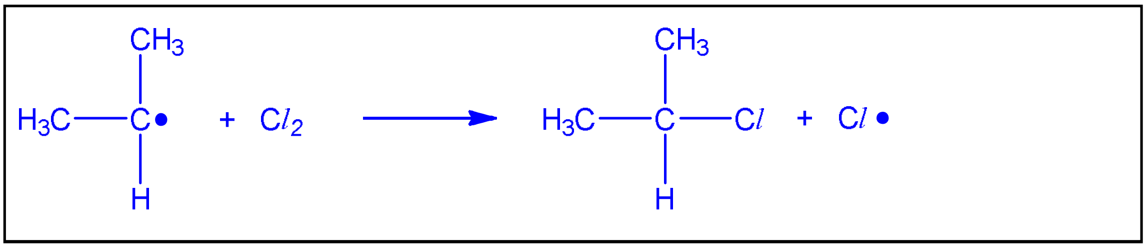


$$Cl\text{—}Cl \xrightarrow{uv} 2Cl\bullet$$

Propagation



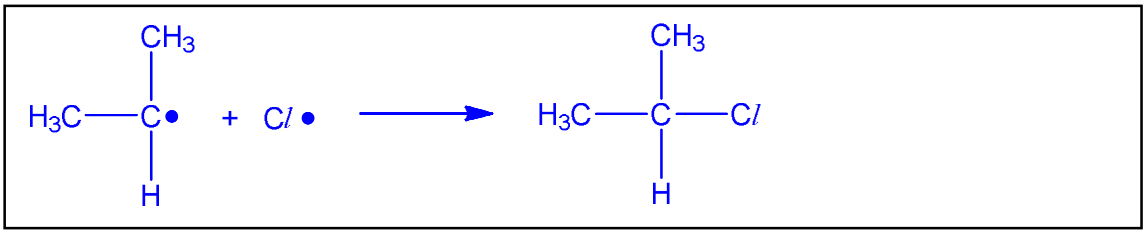
$$(CH_3)_2CH\text{—}H + Cl\bullet \longrightarrow (CH_3)_2C\bullet H + HCl$$



$$(CH_3)_2C\bullet H + Cl_2 \longrightarrow (CH_3)_2CHCl + Cl\bullet$$

Termination

$$Cl\bullet + Cl\bullet \longrightarrow Cl_2$$



$$(CH_3)_2C\bullet H + Cl\bullet \longrightarrow (CH_3)_2CHCl$$

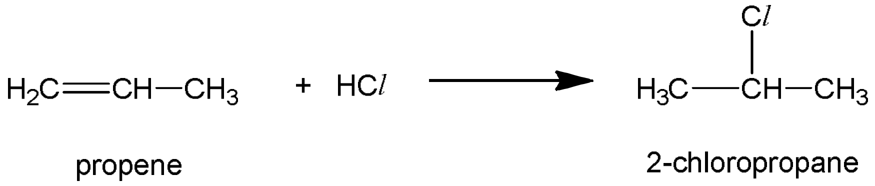
[2]

(c) Based on the different types of environment surrounding the hydrogen atoms, predict the relative proportions of 1-chloropropane and 2-chloropropane that are likely to be formed in the reaction.

6 : 2 = 3 : 1

1-chloropropane : 2-chloropropane = ……….. : ………… [1]

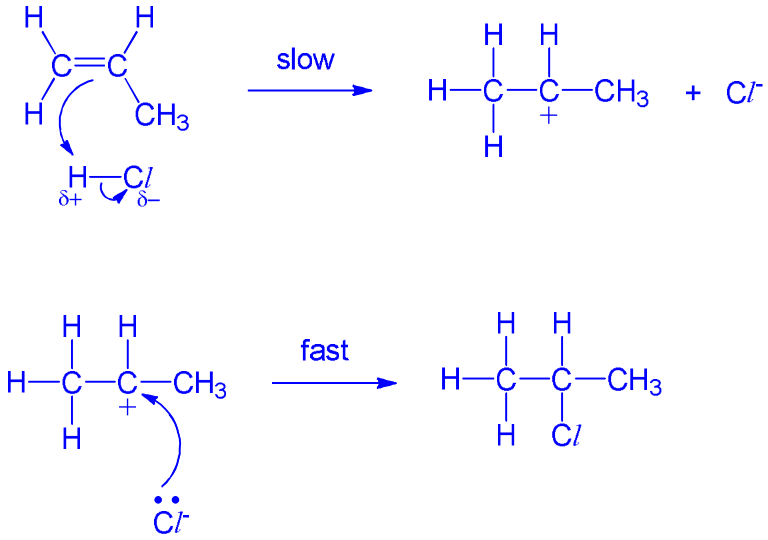
(d) 2-chloropropane can also be formed when propene, C_3H_6, is reacted with HC*l* gas.



$$H_2C{=}CH{-}CH_3 + HCl \longrightarrow H_3C{-}\overset{\displaystyle Cl}{\overset{|}{C}}H{-}CH_3$$

Name and describe the mechanism for the reaction between propene and hydrogen chloride, showing curly arrows, charges, dipoles and any relevant lone pairs.

Mechanism: Electrophilic Addition



[3]

(e) Suggest a simple chemical test to distinguish between propane and propene, clearly stating all observations for both compounds.

To separate test-tubes containing each sample, add Br_2 in hexane. The orange-red bromine will decolorise when added to propene but there is no decolourisation for propane.

OR

To separate test-tubes containing each sample, add aqueous Br_2. The orange bromine water will decolourise for propene but there is no decolourisation for propane.

OR

To separate test-tube containing each sample, add cold dilute $KMnO_4$ with aqueous NaOH. Purple $KMnO_4$ is decolourised when added to propene and a brown precipitate of MnO_2 is formed. Purple $KMnO_4$ remained for propane and no brown precipitate is formed.

OR

To separate test-tube containing each sample, add hot $KMnO_4$ with dilute H_2SO_4. Purple $KMnO_4$ is decolourised when added to propene, with effervescence of CO_2. Purple $KMnO_4$ remained for propane.

[Total: 9]