



THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY (CH 110) TERM III, TEST TWO

DATE: **28 / 06 / 2023**

DURATION: **2 hours.**

INSTRUCTIONS: Answer Any three of the four questions.

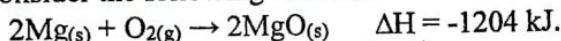
Each question carries **25 Marks**.

QUESTION ONE (THERMOCHEMISTRY) [25 marks]

a) State Hess's Law.

[2]

b) Consider the following reaction:



(i) Calculate the amount of heat transferred when 2.4 g of $\text{Mg}_{(\text{s})}$ reacts at constant pressure.

[3]

(ii) How many grams of $\text{MgO}_{(\text{s})}$ are produced during an enthalpy change of 96.0 kJ? [3]

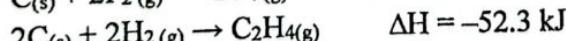
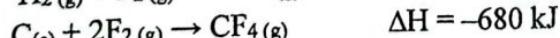
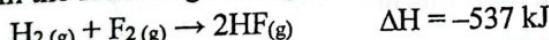
(iii) How many kilo joules of heat are absorbed when 7.50 g of $\text{MgO}_{(\text{s})}$ are decomposed into $\text{Mg}_{(\text{s})}$ and $\text{O}_{2(\text{g})}$ at constant pressure. [3]

c) Identify each process as endothermic or exothermic and indicate the sign of ΔH .

[3]

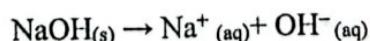
- Sweat evaporating from skin
- Water freezing in a freezer
- Wood burning in a fire

d) From the following enthalpies of reaction;



Calculate the ΔH for the reaction of $\text{C}_2\text{H}_{4(\text{g})}$ with $\text{F}_{2(\text{g})}$ to make $\text{CF}_{4(\text{g})}$ and $\text{HF}_{(\text{g})}$. [6]

e) When a 6.50 g sample of solid NaOH dissolves in 100.0 g of water in a coffee-cup calorimeter, the temperature rises from 21.6°C to 37.8°C . Calculate the ΔH (in kJ/mol NaOH) for the solution process. (Assume the specific heat of the solution formed is 4.18 J/g-K) [5]



QUESTION TWO (ATOMIC STRUCTURE AND PERIODICITY) [25 marks]

- a) Suppose you were de Broglie and you had just devised your formula. A friend points out that the world obviously isn't wavelike. Maybe you should check whether your formula has worrying consequences for everyday objects. Calculate the wavelength of a particle of mass 1 g traveling at 1 ms⁻¹. [2]
- b) Calculate the wavelength of a photon (in nanometers) emitted during a transition from the $n_i = 5$ state to the $n_f = 2$ state in the hydrogen atom and identify the spectral line series. [5]
- c) What is wrong with each of the following quantum number designation and/or sublevel names?

S. No.	n	l	m _l	Name
(i)	1	1	0	1p
(ii)	4	3	+1	4d
(iii)	3	1	-2	3p

$n=1$
 $l=0$
 $m_l=0$
nan (1S)
[6]

- d) Arrange each set of ions in order of decreasing size, and explain your answer

- (i) Ca²⁺, Sr²⁺, Mg²⁺
(ii) K⁺, S²⁻, Cl⁻
(iii) Au⁺, Au³⁺

[2]
[2]
[2]

- e) Write electron configuration of each transition metal ions, and predict whether it is paramagnetic or diamagnetic.

- (a) Mn²⁺ (b) Cr³⁺ (c) Hg²⁺

[6]

QUESTION THREE (ORGANIC CHEMISTRY) [25 Marks]

- a) Draw the structural formula for each of the following compounds: [3]
- i) Cis-3, 4-dimethyl-3-hexene ii) 6, 6-Dimethyl-2, 4-nonadiene iii) Methyl Ethanoate
- b) Draw any two possible structures for each of the following molecules: [4]

- i) C₅H₁₂ ii) C₅H₈

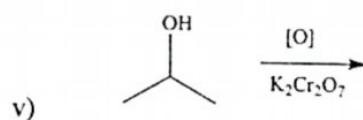
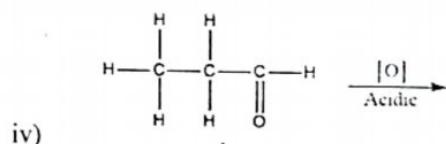
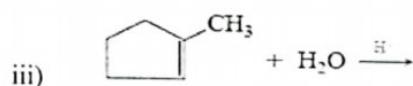
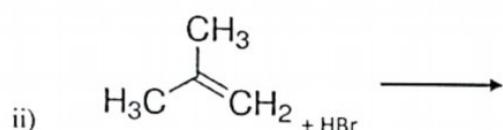
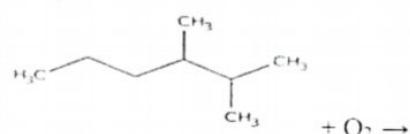
S P d f
O 1 2 3

C_nH_{2n-2}
C₅H₈

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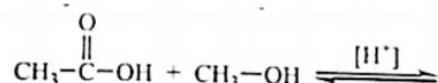
c) Predict and draw the major products of the following reactions:

(i)



d) Complete the following reaction:

[1]



a) What name is given to the type of reaction mentioned above? [1]

b) State the IUPAC name of the product formed [1]

c) State the IUPAC names of the reactants used [2]

e) Draw and name the structure of the compound with four carbon atoms that belongs to each of the following families of organic compounds: [8]

i) Aldehydes ii) Ketones iii) Carboxylic acids iv) Ester

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QUESTION FOUR (CHEMICAL BONDING) [25 Marks]

- a) Answer the following short answer questions:
- Which of the following elements, Be, B, C, and N has the lowest ionization energy? [1]
 - Which of these elements Li, O, Ne, & Na has the largest atomic radius? [1]
 - _____ is the energy change associated with the addition of an electron to a gaseous atom. [1]
 - The _____ is the change in energy that takes place when separated gaseous ions are packed together to form an ionic solid. [1]

- b) Complete the following table by indicating whether the given molecules are polar or non-polar. Further, indicate what intermolecular forces exist in each given substance.

Substance	Polarity	Intermolecular force
Carbon dioxide		
Ammonia		
Silicon tetrachloride		
Sulfur dioxide		

[4]

- c) Consider the cyanate ion, NCO^-
- Draw all the possible Lewis structures for the cyanate ion [6]
 - Among the possible Lewis structures you have drawn, identify the best structure. Justify your choice. [3]
 - What is the molecular geometry of the cyanate ion? [2]

- d) Answer the following question based on strontium chloride

- Draw the Born-Haber cycle for the formation of strontium chloride. [3]
- Use the following data to calculate the enthalpy of formation of strontium chloride. You must write all thermochemical equations for the steps of the cycle. [3]

The enthalpy of sublimation of strontium	+ 164 kJ/mol
First ionization energy for strontium	+ 549 kJ/mol
Second ionization energy for strontium	+ 1064 kJ/mol
The enthalpy of dissociation of chlorine, Cl_2	+ 243 kJ/mol
The electron affinity of chlorine, Cl	- 349 kJ/mol
Lattice energy of strontium chloride	- 2150 kJ/mol

====THE END=====

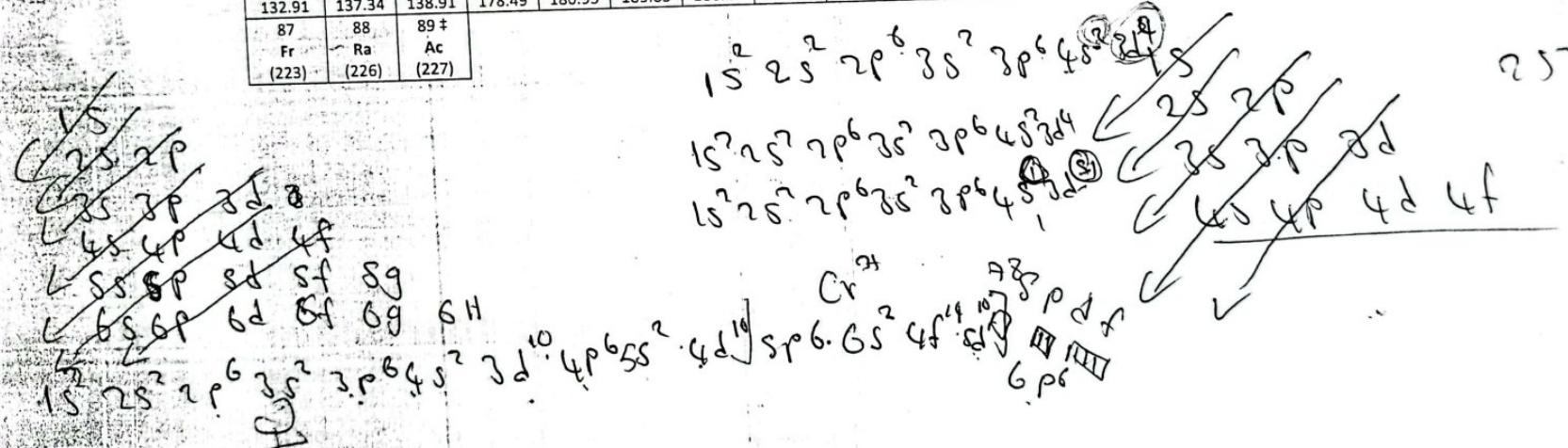
Physical Constants

Constant	Symbol	Value
Atomic mass unit	amu	$1.660554 \times 10^{-27} \text{ kg}$
Avogadro's number	N_A	$6.02214 \times 10^{23} \text{ mol}^{-1}$
Bohr radius	a_0	$5.292 \times 10^{-11} \text{ m}$
Boltzmann's constant	k	$1.38066 \times 10^{-23} \text{ J K}^{-1}$
Charge of an electron	e	$1.60218 \times 10^{-19} \text{ C}$
Faraday's constant	F	96,485 C mol ⁻¹
Gas constant	R	$8.31451 \text{ J K}^{-1} \text{ mol}^{-1}$
		$0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$
Mass of an electron	m_e	$9.10939 \times 10^{-31} \text{ kg}$
		$5.48580 \times 10^{-4} \text{ amu}$
Mass of a neutron	m_n	$1.67493 \times 10^{-27} \text{ kg}$
		1.00866 amu
Mass of a proton	m_p	$1.67262 \times 10^{-27} \text{ kg}$
		1.00728 amu
Rydberg constant	R_E (or A in Joules) or R_H	$2.18 \times 10^{-18} \text{ J}$ 109678 cm^{-1}
Planck's constant	h	$6.62608 \times 10^{-34} \text{ J s}$
Speed of light	c	$2.99792458 \times 10^8 \text{ m s}^{-1}$
$1 \text{ atm} = 760 \text{ mmHg} = 1.0132 \times 10^5 \text{ Nm}^{-2} = 1.0132 \times 10^5 \text{ Pa}$		

The Periodic Table

1	2	Atomic Number Element Atomic Mass	
1 H 1.01	4 Be 9.01		
3 Li 6.94	11 Na 22.99		
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90
37 Rb 85.47	38 Sr 87.62	23 V 50.94	24 Cr 52.00
55 Cs 132.91	56 Ba 137.34	25 Mn 54.94	26 Fe 55.85
87 Fr (223)	88 Ra (226)	27 Co 58.93	28 Ni 58.71
		29 Cu 63.55	30 Zn 65.37
		31 Ga 69.72	32 Ge 72.59
		33 As 74.92	34 Se 78.96
		35 Br 79.90	36 Kr 83.80
		37 Te 83.30	
		38 I 126.90	
		39 Xe 131.30	
		40 At (210)	
		41 Rn (210)	
		42 Po (222)	
		43 Tc 98.91	44 Ru 101.07
		45 Rh 102.91	46 Pd 106.42
		47 Ag 107.87	48 Cd 112.40
		49 In 114.82	50 Sn 118.69
		51 Sb 121.75	52 Te 127.60
		53 I 131.30	
		54 Xe (210)	
		55 At (210)	
		56 Rn (222)	
		57 La 138.91	58 Hf 178.49
		59 Ta 180.95	60 W 183.85
		61 Re 186.21	62 Os 190.21
		63 Ir 192.22	64 Pt 195.09
		65 Au 196.97	66 Hg 200.59
		67 Tl 204.37	68 Bi 207.19
		69 Pb 208.98	70 Po (210)
		71 At (210)	72 Rn (222)
		73 Ac (227)	

3	4	5	6	7	0
5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 131.30	54 Xe (210)
81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po (210)	85 At (210)	86 Rn (222)





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INSTRUCTIONS: Answer Any three of the four questions.

Each question carries 25 Marks.

SOLUTION ONE (THERMOCHEMISTRY) [25 marks]

a) State Hess's Law. [1]

If a reaction is carried out in a series of steps, the enthalpy (ΔH) for the reaction will be equal to the sum of the enthalpy changes for the individual steps.

b) Consider the following reaction:



(i) Calculate the amount of heat transferred when 2.4 g of Mg(s) reacts at constant pressure.

[3]

For Mg(s):

$$2.4 \text{ g} \times \frac{1 \text{ mol}}{24 \text{ g}} = 0.1 \text{ mol} \times \frac{-1204 \text{ kJ}}{2 \text{ mol}} = -60.2 \text{ kJ} \quad [3]$$

(ii) How many grams of MgO(s) are produced during an enthalpy change of 96.0 kJ? [3]

For MgO(s)

$$96 \text{ kJ} \times \frac{2 \text{ mol}}{-1204 \text{ kJ}} \times \frac{40 \text{ g}}{1 \text{ mol}} = 6.4 \text{ g} \quad [3]$$

(iii) How many kilo joules of heat are absorbed when 7.50 g of MgO(s) are decomposed into Mg(s) and O₂(g) at constant pressure. [3]

$$7.5 \text{ g} \times \frac{1 \text{ mol}}{40 \text{ g}} \times \frac{+1204 \text{ kJ}}{2 \text{ mol}} = 113 \text{ kJ} \quad [3]$$

c) Identify each process as endothermic or exothermic and indicate the sign of ΔH . [3]

a. Sweat evaporating from skin

Sweat evaporating from skin cools the skin and is therefore endothermic, with a positive ΔH . [1]

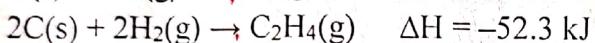
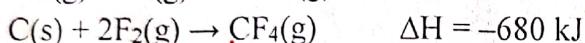
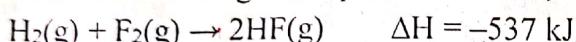
b. Water freezing in a freezer

Water freezing in a freezer releases heat and are therefore exothermic, with a negative ΔH . The refrigeration system in the freezer must remove this heat for the water to continue to freeze. [1]

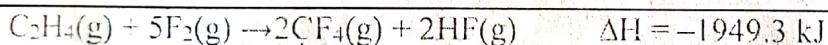
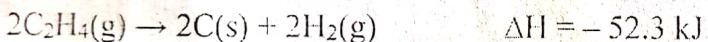
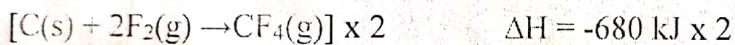
c. Wood burning in a fire

Wood burning in a fire releases heat and is therefore exothermic, with a negative ΔH . [1]

d) From the following enthalpies of reaction;

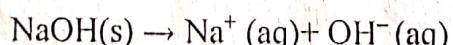


Calculate the ΔH for the reaction of $C_2H_4(g)$ with $F_2(g)$ to make $CF_4(g)$ and $HF(g)$. [6]



~~-2381.7 kJ~~

e) When a 6.50 g sample of solid NaOH dissolves in 100.0g of water in a coffee-cup calorimeter, the temperature rises from 21.6°C to 37.8°C . Calculate the ΔH (in kJ/mol NaOH) for the solution process. (Assume the specific heat of the solution formed is 4.18 J/g-K) [5]



$$q_{\text{solution}} = (100 \text{ g water} + 6.5 \text{ g NaOH}) \times (37.8^\circ\text{C} - 21.6^\circ\text{C}) \times 4.18 \frac{\text{J}}{\text{g}^\circ\text{C}} = 7.21 \times 10^3 \text{ J}$$

$$\Delta H = \frac{7.21 \text{ kJ}}{6.5 \text{ g}} \times \frac{39.9 \text{ g NaOH}}{1 \text{ mol NaOH}} = 44.3 \text{ kJ/mol}$$

SOLUTION TWO (ATOMIC STRUCTURE AND PERIODICITY) [25 marks]

Answer Key

a) $\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34} \text{ Js}}{(1 \times 10^{-3} \text{ kg})(1 \text{ ms}^{-1})} = \frac{6.626 \times 10^{-34} \text{ kgm}^2 \text{s}^{-2} \text{s}}{1 \times 10^{-3} \text{ kgms}^{-1}} = 7 \times 10^{-31} \text{ (2 marks)}$

b) $\Delta E = R_H \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right) = 2.18 \times 10^{-18} \text{ J} \left(\frac{1}{5^2} - \frac{1}{2^2} \right) = -4.58 \times 10^{-19} \text{ J}$ (2+2+1 marks)

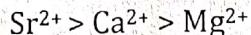
The negative sign indicates that this is energy associated with an emission process. We will omit the minus sign for ΔE to calculate wave length.

$$\lambda = \frac{c}{\vartheta} = \frac{ch}{\Delta E} = \frac{(3.00 \times 10^8 \text{ ms}^{-1})(6.63 \times 10^{-34} \text{ Js})}{4.58 \times 10^{-19} \text{ J}}$$

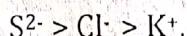
$$= 4.34 \times 10^{-7} \text{ m} = 4.34 \times 10^{-7} \text{ m} \times \frac{1 \text{ nm}}{1 \times 10^{-9} \text{ m}} = 434 \text{ nm}$$

Balmer series

- c) (i) A sublevel with $n = 1$ can have only $l = 0$, not $l = 1$. The only possible sublevel name is 1s. [2]
 (ii) A sublevel with $l = 3$ is f-sublevel, not a d-sublevel. The name should be 4f. [2]
 (iii) A sublevel with $l = 1$ can have only ml of $-1, 0, 1$, not -2 . [2]
 d) (i) These are all from group 2, so size decreases up the group [2]



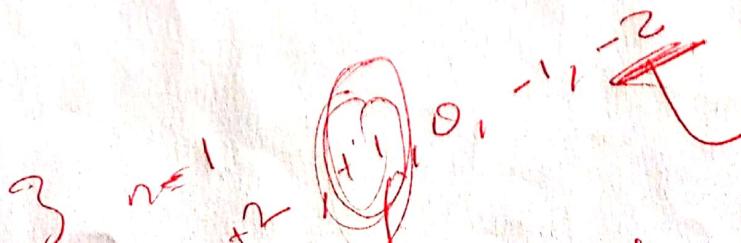
(ii) These ions are isoelectronic. S^{2-} has a lower effective nuclear charge than Cl^- , so it is larger. K^+ is a cation, and has the highest effective nuclear charge, so it is smallest [2]



(iii) Au^+ has lower charge than Au^{3+} , [2]



- e) Write electron configuration of each transition metals, and predict whether it is paramagnetic
 (a) Mn^{2+} ($Z = 25$) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$ or $[\text{Ar}]3d^5$, there are 5 unpaired electrons, so Mn^{2+} is paramagnetic. [2]
 (b) Cr^{3+} ($Z = 24$) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$ or $[\text{Ar}]3d^3$, there are 3 unpaired electrons, so Cr^{3+} is paramagnetic. [2]
 (c) Hg^{2+} ($Z = 80$) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^4 5s^2 4d^{10} 5p^6 4f^{14} 5d^{10}$ or $[\text{Xe}] 4f^{14} 5d^{10}$, it has no unpaired electrons, so not paramagnetic (it is diamagnetic) [2]



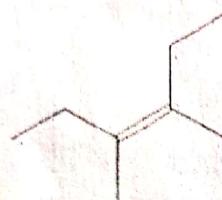
SOLUTION THREE (ORGANIC CHEMISTRY) [25 Marks]

ANSWERS

a) Draw the structural formulas for the following compounds [3]:

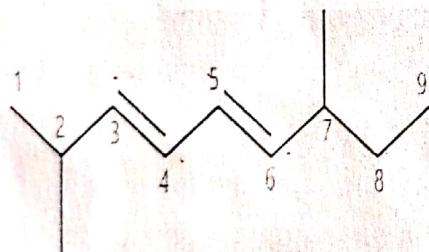
- i) Cis-3, 4-dimethyl-3-hexene ii) 6, 6-Dimethyl-2, 4-nonadiene iii) Methyl Ethanoate

i)

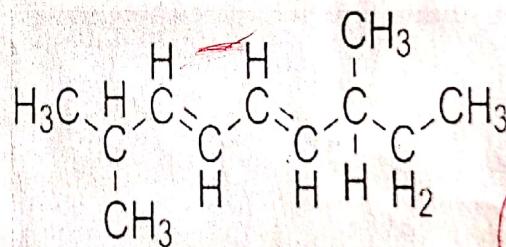


or [1]

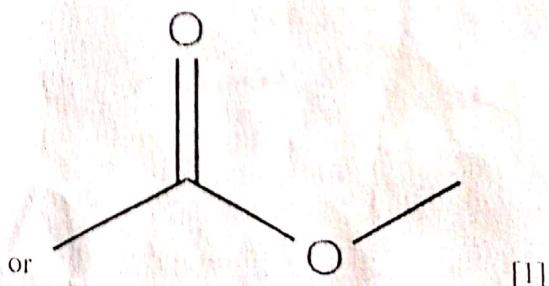
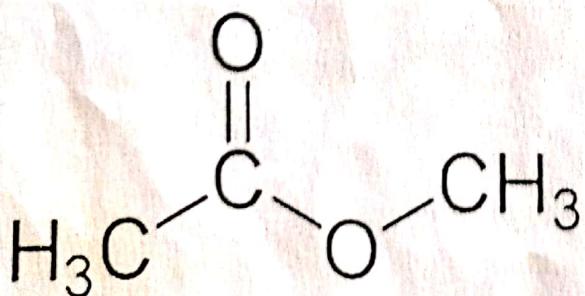
ii)



or



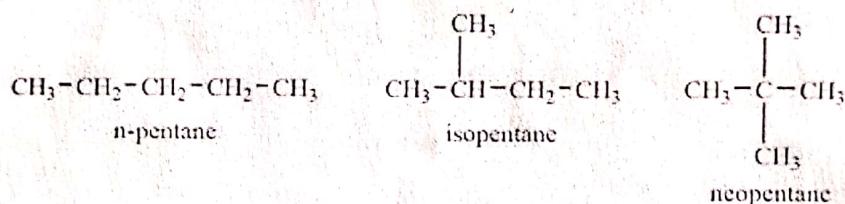
a)
(iii)



1. Draw any two possible structures for the following molecular formulas and name them [4]:
 i) C₅H₁₂ ii) C₅H₈

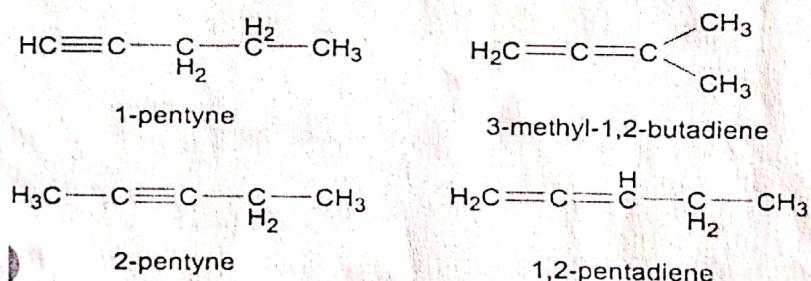
Give 1 mark for the correct structure and 1 mark for the correct name of the structure (any of the two structure below).

i)

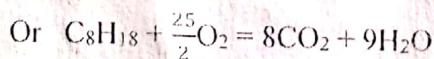
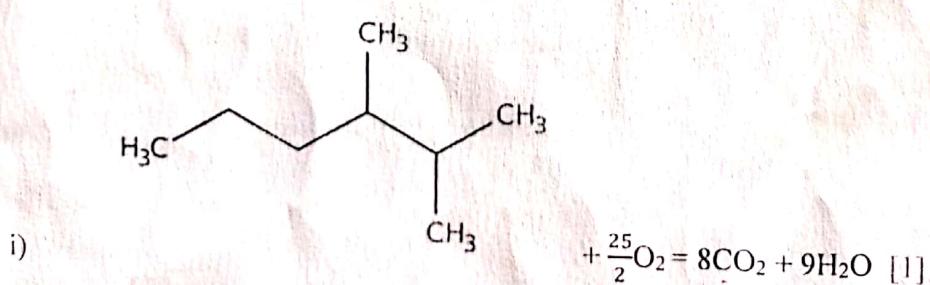


N-pentane/pentane, Isopentane/ 1-methylbutane and neopentane/2, 2-dimethylpropane

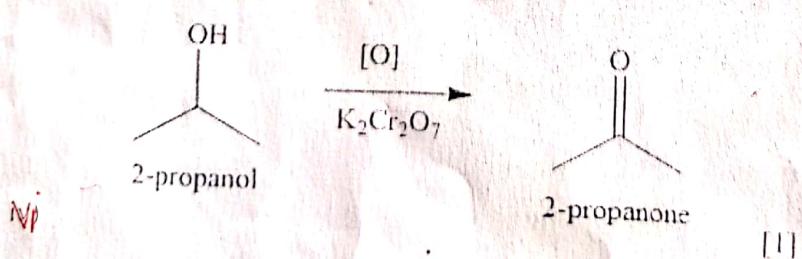
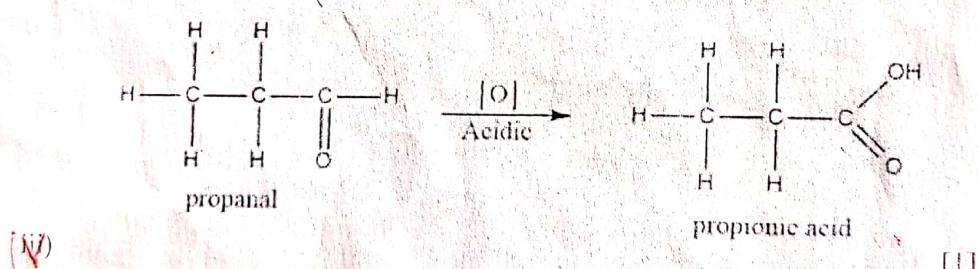
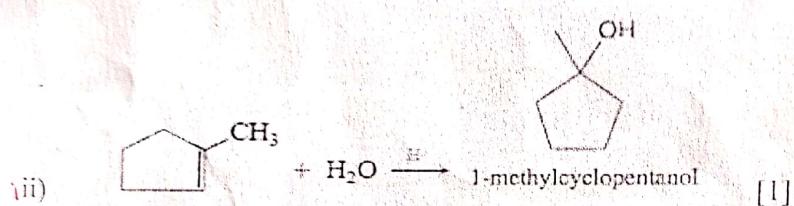
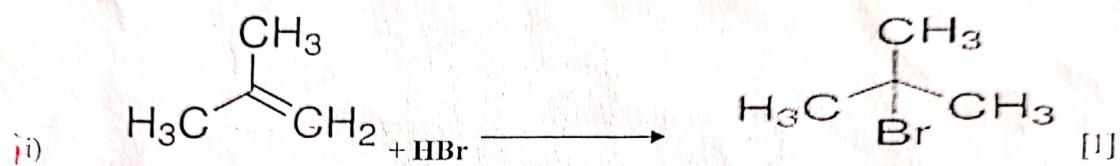
ii)



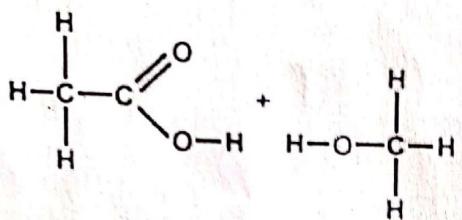
- b) Predict and draw the major products of the following reactions:



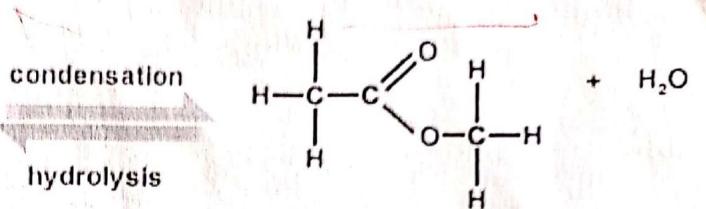
Deduct half mark if the equation is not balanced



Q) Complete the following reaction:



ethanoic acid + methanol
[1]

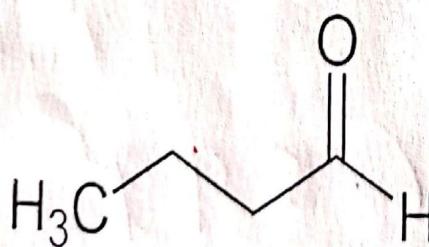


methyl ethanoate + water

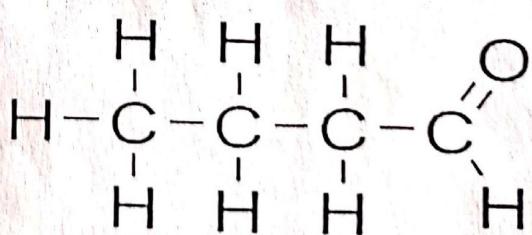
- D i) What name is given to the type of reaction mentioned above?
Esterification [1]
- ii) State the IUPAC name of the product formed
Methyl Ethanoate [1]
- iii) State the IUPAC names of the reactants used
Ethanoic acid and methanol [2] (one mark for each correct answer)
- e) Draw and name the structure of the compound with four carbon atoms that belongs to each of the following families of organic compounds:
[8]
- i) Aldehydes ii) Ketones iii) Carboxylic acids iv) Ester

Give one mark for the correct structure and one mark for the correct name

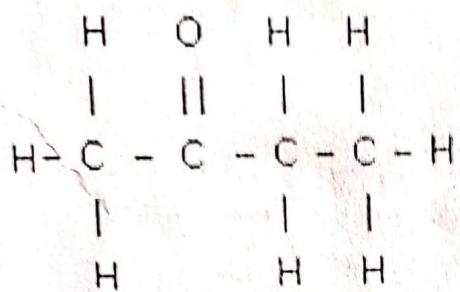
- i) Butanal [1] mark



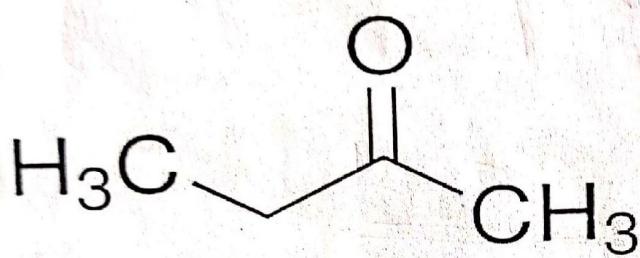
- ii) 2-butanone [1] mark



[1] mark

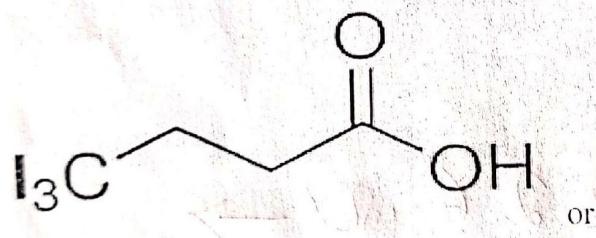


or

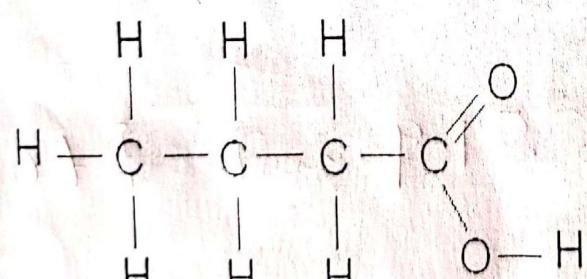


[1] mark

- iii) iii) butanoic acid [1]

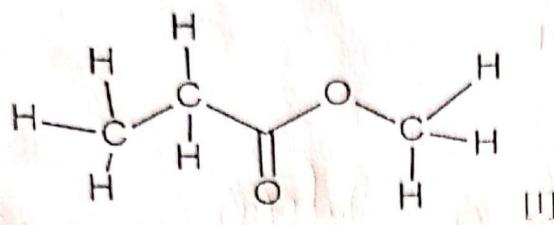


or

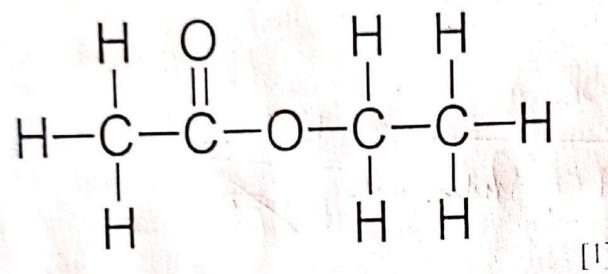


- iv) iv) any one of the following: ethyl ethanoate or methyl propanoate or propyl methanoate

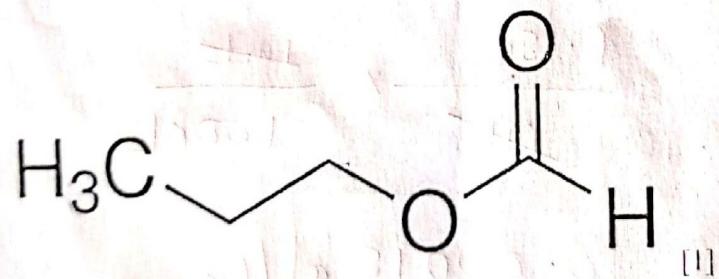
propyl methanoate [1]



Ethyl ethanoate [1]



Methyl propanoate [1]



SOLUTION FOUR (CHEMICAL BONDING) [25 Marks]

CHEMICAL BONDING (ANSWER KEY)

- a) Answer the following short answer questions: [4]
- Which of the following elements, Be, B, C, and N has the smallest ionization energy?
 - Which of these elements Li, O, Ne, & Na has the largest atomic radius?
 - Electron Affinity is the energy change associated with the addition of an electron to a gaseous atom.
 - The Lattice Energy is the change in energy that takes place when separated gaseous ions are packed together to form an ionic solid.
- b) Complete the following table by indicating whether the given molecules are polar or non-polar. Further, indicate what intermolecular forces exist in each given substance. [4]

Substance	Polarity	Intermolecular force
Carbon dioxide	Non-polar	Van der waals/London dispersion forces
Ammonia	Polar	Hydrogen bonding
Silicon tetrachloride	Non-polar	Van der waals/London dispersion forces
Sulfur dioxide	Polar	Dipole-dipole forces

- c) Consider the cyanate ion, NCO^- :
- Draw all the possible Lewis structures for the cyanate ion [6]
- Structure 1

$$\left[\begin{array}{c} +2 \quad 0 \quad -1 \\ | \quad \quad | \quad | \\ : \ddot{\text{N}} \text{---} \ddot{\text{C}} \equiv \ddot{\text{O}} : \end{array} \right]^-$$

Structure 2

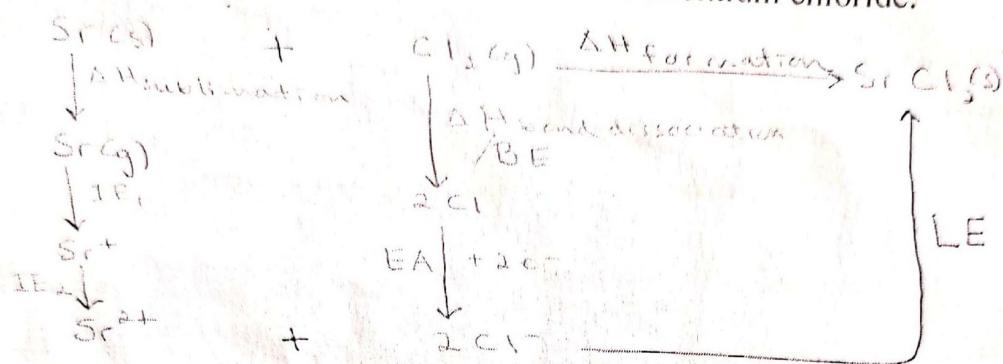
$$\left[\begin{array}{c} -1 \quad 0 \quad 0 \\ | \quad \quad | \quad | \\ \ddot{\text{N}} = \ddot{\text{C}} = \ddot{\text{O}} : \end{array} \right]^-$$

Structure 3

$$\left[\begin{array}{c} 0 \quad 0 \quad -1 \\ | \quad \quad | \quad | \\ : \ddot{\text{N}} \equiv \ddot{\text{C}} \text{---} \ddot{\text{O}} : \end{array} \right]^-$$
- Among the possible Lewis structures you have drawn, identify the best structure. Justify your choice. [3]
- Structure 3 is the best structure
- Reasons: It has the fewest charge (1 mark) and puts the negative charge on O which is more electronegative than N (1 mark)
- [2]
- What is the molecular geometry of the cyanate ion? [2]
- Linear

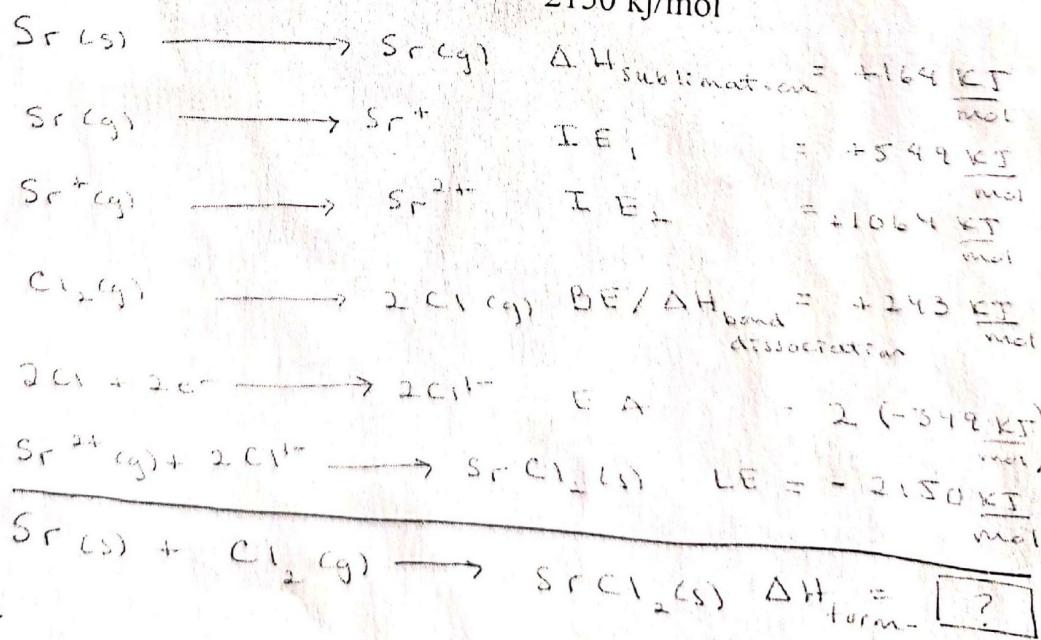
d) Answer the following question based on strontium chloride

a. Draw Born-Haber cycle for the formation of strontium chloride.



b. Use the following data to calculate the enthalpy of formation of strontium chloride. Write all thermochemical equations for the steps of the cycle.

The enthalpy of sublimation of strontium	+ 164 kJ/mol
First ionization energy for strontium	+ 549 kJ/mol
Second ionization energy for strontium	+ 1064 kJ/mol
The enthalpy of dissociation of chlorine, Cl₂	+ 243 kJ/mol
The electron affinity of chlorine, Cl	- 349 kJ/mol
Lattice energy of strontium chloride	- 2150 kJ/mol



$$\begin{aligned} \Delta H_{\text{formation}} &= \Delta H_{\text{sublimation}} + I.E_1 + I.E_2 + BE + 2EA + LE \\ &= (164 + 549 + 1065 + 243 + 2(-349)) + (-2150) \text{ kJ/mol} \\ &= -828 \text{ kJ/mol} \end{aligned}$$