



Chemistry ACSEE

**Past Paper Questions and
Answers by Topic**

Contents

Form V

1.0 THE ATOM

2.0 CHEMICAL BONDING

3.0 GASES

4.0 RELATIVE MOLECULAR MASSES IN SOLUTION

5.0 TWO COMPONENT LIQUID SYSTEMS

6.0 ENERGETICS

7.0 PERIODIC CLASSIFICATION

8.0 SELECTED COMPOUNDS OF METALS

9.0 ALIPHATIC HYDROCARBONS

10.0 AROMATIC HYDROCARBONS

11.0 HALOGEN DERIVATIVES OF HYDROCARBONS

12.0 HYDOXYL COMPOUNDS

13.0 CARBONYL COMPOUNDS

14.0 CARBOXYLIC ACIDS AND DERIVATIVES

Form VI

1.0 CHEMICAL EQUILIBRIUM

2.0 CHEMICAL KINETICS

3.0 ELECTRO CHEMISTRY

4.0 ACIDS, BASES, AND SALTS

5.0 SOLUBILITY, SOLUBILITY PRODUCT AND IONIC PRODUCT

6.0 EXTRACTION OF METALS

7.0 TRANSITION ELEMENTS

8.0 AMINES

9.0 POLYMERS

10.0 ENVIRONMENTAL CHEMISTRY

11.0 SOIL CHEMISTRY

12.0 CHEMICAL ANALYSIS

Form V
1.0 THE ATOM

2021 PAST PAPERS

1. (a) Differentiate the following terms: (1 mark)
(i) Isotopy from isotopes. (1 mark)
(ii) Atomic spectrum from photon. (1 mark)
(iii) Continuous spectrum from line spectrum.
- (b) Calculate the frequency of a wave in a visible region formed following the emission of energy by an electron falling from energy level $n = 4$ to the ground level. (5 marks)
- (c) List two uses of mass spectrometer. (2 marks)

Q1(a)	<p>(i) Isotopy is the existence of atoms of the same element with the same atomic number but different mass numbers while isotopes are atoms of the same element with the same atomic number but different mass numbers.</p>
	<p>(ii) Atomic spectrum is a discontinuous series of bright spectral lines produced by emission of energy from excited atoms while photon is a small packet of light energy which defines the particulate nature of light.</p>
	<p>(iii) Continuous spectrum is a band of continuous bright spectral lines with no dark spaces between them while line spectrum is a discontinuous series of bright spectral lines separated by dark spaces in between them.</p>

(b)	<p>Sln:</p> <p>Data given:</p> <p>Initial energy level (n_2) = 4</p> <p>Ground energy level (n_1) = 2</p> <p>Req: frequency of wave emitted (f)</p> <p>from,</p> <p>Rydberg's equation</p> $\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$ $\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{4^2} \right)$ $\frac{1}{\lambda} = R_H \times 0.1875$ <p>but $R_H = 1.09678 \times 10^7 \text{ m}^{-1}$</p> $\frac{1}{\lambda} = 1.09678 \times 10^7 \text{ m}^{-1} \times 0.1875$ $\lambda = 4.863 \times 10^{-7} \text{ m}$
-----	--

Q(b)	<p>but from:</p> $c = f \lambda$ $f = \frac{c}{\lambda}$ <p>Now, $c = 3 \times 10^8 \text{ m/s}$</p> $f = \frac{3 \times 10^8 \text{ m/s}}{4.863 \times 10^{-7} \text{ m}}$ $= 6.17 \times 10^{14} \text{ Hz}$ <p>∴ The frequency of the wave emitted is $6.17 \times 10^{14} \text{ Hz}$.</p>
(c)	<ul style="list-style-type: none"> → Finding the relative atomic masses of elements → Determining the number of isotopes and relative abundances of isotopes an element has

Extract 1.1: A sample of good responses in question 1

2020 PAST PAPERS

5. (a) (i) State four postulates of Dalton's atomic theory. (2 marks)
(ii) Why different atoms have different chemical properties. Briefly explain. (1 mark)

- (b) Write the chemical symbol (${}^Z_A X$) and orbital electronic configuration for the atoms described in the following table:

S/n	Number of Neutrons	Number of Electrons
(i)	13	11
(ii)	7	8
(iii)	17	18
(iv)	16	16

(4 marks)

- (c) Calculate the minimum energy required to remove an electron from the hydrogen atom in its ground state. (3 marks)

jai	<p>i/ Matter are made up of 'smallest indivisible particle called atom'</p> <p>ii/ Atom can not be created nor destroyed</p> <p>iii/ Atoms of the same element are the same.</p> <p>iv/ Atoms of different elements are different.</p>
a.ii	<p>Different atoms have different chemical properties due to difference in their atomic number which is responsible for chemical properties of a substance. Since different occupy different atomic number hence can not have the same chemical properties.</p>

S.b.	Y	2s 1s
	W	1s 2s
	W	2s 1s
	W	3s 1s
	The orbital configuration are	
	Y	[He] $\begin{array}{ c c c c c } \hline 2s & & 2p & & 3s \\ \hline 1s & 1s & 1s & 1s & 1s \\ \hline \end{array}$ [1]
	W	[He] $\begin{array}{ c c c c c } \hline 2s & & 2p & & \\ \hline 1s & 1s & 1s & 1s & 1s \\ \hline \end{array}$
	W	[Ne] $\begin{array}{ c c c c c } \hline 2s & & 2p & & \\ \hline 1s & 1s & 1s & 1s & 1s \\ \hline \end{array}$
	W	[Ne] $\begin{array}{ c c c c c } \hline 2s & & 2p & & \\ \hline 1s & 1s & 1s & 1s & 1s \\ \hline \end{array}$
S.C.	$n_1 = 1$	$n_2 = \infty$
	From $E = \frac{hc}{\lambda}$.	
	$E = hc - \frac{1}{\lambda}$.	
	$\frac{1}{\lambda} = R_H (\frac{1}{n_{12}} - \frac{1}{n_2})$.	
	$\frac{1}{\lambda} = 1.09678 \times 10^7 (\frac{1}{2^2} - \frac{1}{\infty^2})$.	
	$\frac{1}{\lambda} = 1.09678 \times 10^7 (\frac{1}{4^2} - 0)$	
	since $\frac{1}{\infty} = 0$	

Sc	$\frac{1}{\lambda} = 1.09678 \times 10^7$
	$\lambda = 9.11267 \times 10^{-8}$
	$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{9.11267 \times 10^{-8}}$
	$E = 2.181 \times 10^{-18} \text{ J}$
	\therefore The minimum energy required is $2.181 \times 10^{-18} \text{ J}$

Extract 5.1: A sample of correct responses in question 5

2019 PAST PAPERS

1. (a) Use s, p, d, f notation to designate atomic orbitals with the given pairs of quantum numbers n and l .
- $n = 2$ and $l = 1$.
 - $n = 3$ and $l = 2$.
 - $n = 4$ and $l = 3$.
 - $n = 3$ and $l = 0$.
- (2 marks)
- (b) For the following sets of quantum numbers, state which are allowable and which are not allowable. Briefly explain your answer.
- $n = 2; l = 2; m_l = 0; m_s = +\frac{1}{2}$.
 - $n = 3; l = 1; m_l = 0; m_s = -\frac{1}{2}$.
 - $n = 1; l = 0; m_l = +1; m_s = +\frac{1}{2}$.
 - $n = 3; l = 2; m_l = +2; m_s = -\frac{1}{2}$.
- (2 marks)
- (c) Define the following phrases:
- Atomic number.
 - Mass number.
- (1 mark)
- (d) A nucleus of certain element is presented as $^{58}_{27}X$. What is the number of electrons and neutrons in atom X? Show your work clearly.
- (1 mark)
- (e) Clearly state four postulates of Planck's quantum theory as derived from black body radiation.
- (4 marks)

1	a) i) 2P ii) 3d iii) 4F iv) 3S.
	b) i) not allowable, because for $n=2$, l can not be 2.
	c) allowable because for $n=2$, two values $l=1, m_l=0, m_s=\pm\frac{1}{2}$ are available.

	<p>(ii) Not allowable, because for $l=0$, m_l can not be +1, for $l=0$, $m_l = 0$.</p>
	<p>(iv) Allowable.</p>
c)	<p>i) Atomic number refers to the total number of protons in an atom.</p>
	<p>ii) Mass number refers to the total number of protons and neutrons present in an atom.</p>
d)	<p>Given $\frac{^{52}X}{27}$</p> <p>Number of electrons = Number of protons (Z)</p> <p>From $\frac{^{52}X}{27} = \frac{A}{Z} X$,</p> <p>the number of electrons, $= Z = 27$.</p> <p>Also $A = Z + N$</p> <p>$N = 52 - 27$</p> <p>$= 25$.</p> <p>\therefore number of electrons = 27</p> <p>number of neutrons = 25.</p>
e)	<ul style="list-style-type: none"> - Any radiation is associated with energy. - The energy is absorbed or emitted in quanta. - Energy is directly proportional to the frequency of radiation.
v)	<p>Quanta are emitted or absorbed in whole numbers, (there are no fraction of quanta).</p>

Extract 1.1: A sample of correct responses in question 1.

2019 PAST PAPERS

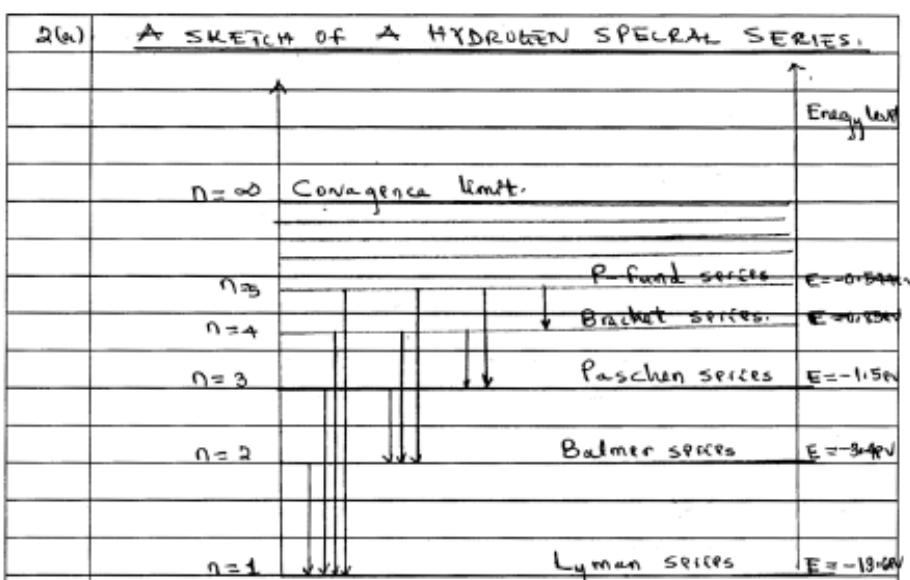
2. (a) Sketch a hydrogen spectral series based on Bohr atom energy level. (2 marks)
- (b) (i) How does a mass spectrograph of a pure element is used to detect the presence of isotopes? (1 mark)
- (ii) The following data were obtained for a certain pure element:

Isotope	Mass of isotope	Natural abundance (%)
1	28.0	92.0
2	29.0	5.0
3	30.0	3.0

Calculate the relative atomic mass of an element. (2 marks)

- (c) (i) Use wave and particle models for energy of a particle to derive the de Broglie equation. (3 marks)

- (ii) Calculate the wavelength of an α -particle having mass of 6.6×10^{-27} kg moving with a speed of 10^5 cm s $^{-1}$. Show your work clearly including manipulations of units. (2 marks)



(b) (i) Due to the different deflection of positively charged ions cause the number of electrons to neutralize the positively charged ions to be different which cause the production of current transferred to the amplifier and drawn on the chart recorder at the peak.

- The number of peak = The number of isotopes
- The different in deflection caused by the different in mass to charge ratio ($\frac{m}{q}$)

(ii) From

$$\text{The relative atomic mass} = \sum (\text{Abundance} \times \text{Mass of isotope}) / 100\%$$

$$2(a) (ii) R.A.M = \frac{92 \times 28 + 29 \times 5 + 8 \times 30}{100}$$

$$R.A.M = 28.11.$$

\therefore The relative atomic mass of an element is 28.11.

2(c). (i). From The Einstein Equation:

$$E = mc^2 \quad (i)$$

But the particle moves as wave properties in which

$$E = hf,$$

$$\text{where } f = \frac{c}{\lambda}.$$

$$E = hc \quad (ii).$$

Since the energy is the same

$$mc^2 = hc$$

$$c = \lambda f$$

$$mc = \frac{h}{\lambda}$$

$$\lambda = \frac{h}{mc}$$

(ii). Where λ is the de-Broglie wavelength.

h is the planck's constant

m is the mass of the particle.

c is the speed of the particle.

\therefore The De Broglie equation is:

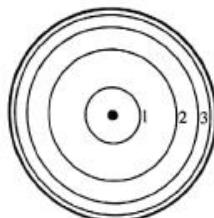
$$\lambda = \frac{h}{mc}$$

2.(c)	(i) from:
	$\lambda = \frac{h}{mc}$
	But $m = 0.6 \times 10^{-27} \text{ kg}$,
	$c = 10^8 \text{ cm s}^{-1}$
	$c = 10^8 \times 10^{-2} \text{ m s}^{-1}$
	Because,
	$1 \text{ cm} = 10^{-2} \text{ m}$.
	$h = 6.63 \times 10^{-34} \text{ Js}$,
	$\therefore \lambda = \frac{6.63 \times 10^{-34} \text{ Js}}{(6.6 \times 10^{-27} \times 10^8 \times 10^{-2}) \text{ kg} \times \text{m s}^{-1}}$
	$\lambda = 1.0045 \times 10^{-10} \frac{\text{Js}^2}{\text{kg m}}$
	$\lambda = 1.0045 \times 10^{-10} \frac{\text{Kg} \times \text{m}^2 \text{s}^{-2} \cdot \text{s}^2}{\text{kg m}}$
	$\lambda = 1.0045 \times 10^{-10} \text{ m.}$
	\therefore The wavelength is $1.0045 \times 10^{-10} \text{ m.}$

Extract 2.1: A sample of correct responses in question 2.

2018 PAST PAPERS

1. (a) Study carefully the Bohr's atomic model of hydrogen atom shown below then answer the questions that follow.



- (i) State three basic postulates which led to Bohr's atomic model. Include mathematical expressions, if any, which qualify the postulate. (3 marks)
- (ii) In a single sketch of Bohr's atom, show how Lyman and Paschen spectral series are formed. (2 marks)
- (b) The energy difference between ground and excited state of atoms of a certain element was found to be $4.4 \times 10^{-19} \text{ J}$. Calculate the wavelength and wavenumber of the photons that excited the atoms. Show your work clearly including manipulations of units. (3 marks)
- (c) Dalton's atomic theory consists of four main postulates. For each of the two postulates given below, briefly describe an experiment or a discovery which is against the postulate.
- (i) Atoms can neither be created nor destroyed.
- (ii) All atoms of the same element are alike. (2 marks)

1. (a) i) Bohr's postulates on atomic model.	
<ul style="list-style-type: none"> - Electrons in an atom tend to occupy stationary states whereas in these states they do not emit any form of energy - The angular momentum of the orbits of electrons is an integral multiple of $\frac{nh}{2\pi}$. $mvf = \frac{nh}{2\pi}$	
<ul style="list-style-type: none"> - Electrons tend to jump from lower energy levels to higher energy levels, and on doing this they emit energy in form of quanta. 	
ii)	

1: (b) Given:

$$\text{Energy difference } \Delta E = 4.4 \times 10^{-19} \text{ J}$$

$$\text{Energy } \Delta E = n h f$$

$$\Delta E = n \frac{h c}{\lambda}$$

$$4.4 \times 10^{-19} \text{ J} = 6.6 \times 10^{-34} \text{ Js} \times 3 \times 10^8 \text{ m/s}$$

$$\lambda$$

$$\lambda = \frac{1.98 \times 10^{-25} \text{ Jm}}{4.4 \times 10^{-19} \text{ J}}$$

$$\lambda = 4.5 \times 10^{-7} \text{ m}$$

$$\Rightarrow \text{Wavelength} = 4.52 \times 10^{-7} \text{ m.}$$

$$\text{Wavenumber } \nu = \frac{1}{\lambda}$$

$$= \frac{1}{4.52 \times 10^{-7} \text{ m}} = 2.212 \times 10^6 \text{ m}^{-1}$$

$$\Rightarrow \text{Wavenumber} = 2.212 \times 10^6 \text{ m}^{-1}$$

(c) i) It is not true that atoms can neither be created nor destroyed due to the discovery of nuclear bombardment activities which lead to breaking of atoms into smaller particles.

1.	(c) i/ Not all atoms of the same element are alike due to the discovery and existence of <u>isotopes</u> . Isotopes are atoms of the same element with similar atomic number but different mass number. For example $^{12}_{6}\text{C}$ and $^{14}_{6}\text{C}$.
----	---

Extract 1.1 shows that the candidate correctly stated Bohr's postulates, gave the discoveries against Dalton's atomic theory and stated correctly the five gas laws. Furthermore, the candidate correctly performed the calculations in part (b) and wrote relevant responses in part (c).

2017 PAST PAPERS

1. (a) Distinguish between the following:
 - Isotopes and isotopy.
 - Azimuthal quantum number and magnetic quantum number.
 - Atomic mass unit and relative atomic mass.(3 marks)
- (b) The mass spectrographic measurements of an element X whose atomic number is 31 indicated peaks at 79.21, 11.2 and 9.59. The isotopic masses are 69, 70 and 71 atomic mass unit (a.m.u) respectively.
 - Write the conventional symbols for the three isotopes.
 - Calculate the relative atomic mass of X.
 - Explain why atomic weights of elements are not whole numbers.(1.5 marks)
(3 marks)
(1 mark)
- (c) The mass number of two atoms, A and B with the same atomic number are 235 and 238 respectively. If A contains 143 neutrons in its nucleus, find the number of neutrons and electrons in B.
 (1.5 marks)

1	a)
	D <u>isotopes</u> are the atoms of the same element with the same atomic number but <u>different</u> in mass number. whereas, Isotopy is a tendency of the element to have atoms with same number of protons but different in number of neutrons.

ii) Azimuthal quantum number is a quantum number that describes the shapes of atomic orbitals whereas

Magnetic quantum number is a quantum number that shows orientation of degenerate orbitals.

iii) Atomic mass unit is a $\frac{1}{12}$ th mass of one Carbon-12 atom.

whereas Relative atomic mass is the average

b) $^{69}_{31}X$, $^{70}_{31}X$ and $^{71}_{31}X$

$$\text{ii) } R.A.M = \frac{\sum (\text{Isotopic mass} \times \text{Intensity})}{\text{Total intensity}}$$

$$R.A.M = \frac{69 \times 21 + 70 \times 11.2 + 71 \times 9.59}{21 + 11.2 + 9.59}$$

$$= \frac{6930.58}{100}$$

$$= 69.3098$$

\therefore Relative atomic mass is 69.3098 a.m.u

iv) This is due to the existence of the isotopes in a particular element.

c) For element A, number of protons = 143 mass number = 235	
$\text{Number of protons, } Z = z - N$ $= 235 - 143$ $= 92$	
Number of neutrons $N = 235 - 92$ Number of neutrons, $N = 238 - 92$ $= 146$	
Therefore, Number of electrons of B is 92 Number of neutrons of B is 146	

In Extract 1.1, the candidate was able to distinguish the given terms. He/she correctly wrote the conventional symbols and was able to explain why the relative atomic weights are not whole numbers. He/she also managed to find the number of neutrons and electrons in element B.

2016 PAST PAPERS

- Answer any four (4) questions from this section.
- (a) State the following:
 - Postulates of Bohr's atomic model.
 - Shortcomings of the Bohr's atomic model.(4 marks)
 - (b) An electromagnetic radiation of wavelength 2420 Å is sufficient to ionize the sodium atom. Calculate the ionization energy of sodium atom in kJmol^{-1} .
(3 marks)
 - (c) Calculate the wave number of the longest wavelength transition in Balmer series of hydrogen.
(3 marks)

1(a) Postulates of Bohr's atomic Model.

- ⇒ Electron revolve in an atom in a certain circular path called orbit.
- ⇒ Each orbit is associated with energy and called energy level or energy shell.
- ⇒ The angular momentum of electron in an atom is quantized and given by

$$mv r \geq \frac{h}{2\pi}$$

- ⇒ When electron gain energy they move to the higher energy level and when they lose energy they move to the lower energy level.

⇒ The energy of various energy levels of hydrogen is given by $E = -\frac{13.6 \text{ eV}}{n^2}$

(ii) Shortcomings of the Bohr's atomic Model.

- ⇒ Bohr's could not explain spectra of multielectron atom.
- ⇒ Bohr's could not explain fine structure of an electron.
- ⇒ Bohr's could not explain presence of Zeeman and Stark effect.
- ⇒ Bohr's could not explain three dimension of an electron rather regard electron to be flat.

1(b) Given Data

$$\lambda \text{ (wavelength)} = 2420 \text{ Å} = 2420 \times 10^{-10} \text{ m}$$

From :

$$\text{Planck's equation}$$

$$E = hf$$

$$f = \frac{c}{\lambda}$$

$$E = \frac{hc}{\lambda}$$

$$E = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{2420 \times 10^{-10}}$$

$$E = 8.219 \times 10^{-19} \text{ J}$$

$$E = 8.219 \times 10^{-22} \text{ kJ}$$

Then .

$$ExNA = 8.219 \times 10^{-22} \text{ kJ} \times 6.02 \times 10^{23} \text{ mol}^{-1}$$

$$E = 494.78 \frac{\text{kJ}}{\text{mol}}$$

Hence ionization energy of Sodium atom is
 494.78 kJ/mol .

1(c) Given; Balmer series.

For the longest wavelength:

$$n_1 = 2$$

$$n_2 = 3$$

From Rydberg equation:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

$$v = \frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

$$v = R_H \left(\frac{1}{2^2} - \frac{1}{3^2} \right)$$

$$v = 1.09678 \times 10^7 \left(\frac{1}{4} - \frac{1}{9} \right)$$

$$v = 1523305.556 \text{ m}^{-1}$$

Hence wavenumber of the longest wavelength
is $1523305.556 \text{ m}^{-1}$.

In Extract 1.1, the candidate stated well the postulates of Bohr's atomic model but failed to state only one shortcoming of the model. The candidate also correctly calculated the ionization energy of sodium atom and was able to calculate the wave number of the longest wavelength transition in the Balmer series of hydrogen atomic spectrum.

2015 PAST PAPERS

10. (a) Distinguish between the following:

- (i) atomic number from mass number
- (ii) a photon from a quanta.

(2 marks)

(b) A photon was absorbed by a hydrogen atom in its ground state and the electron was promoted to the fifth orbit. When the excited atom returned to its ground state, visible radiation and other quanta were emitted.

- (i) Briefly explain the transitions made by the electron for the excited atom to return to its ground state.
- (ii) Calculate the wavelength of a photon emitted during a transition from the $n_1 = 5$ state to the $n_2 = 2$ state in the hydrogen atom given that $\Delta E = 2.18 \times 10^{-18}$

$$J\left[\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)\right].$$

(8 marks)

10 b ii) ans.

from:

$$\Delta E = h\nu$$

where

h = Planck's constant

ν = frequency

ν = velocity of light
Wavelength

$$\nu = \frac{c}{\lambda}$$

$$\Delta E = hc/\lambda$$

$$\lambda = \frac{hc}{\Delta E} \text{ wins m.s.}$$

$$\lambda = \frac{6.63 \times 10^{-34} J s \times 3 \times 10^8 m/s}{4.578 \times 10^{-19}}$$

$$\lambda = 4.34469 \times 10^{-7} m$$

$$\lambda \approx 4.3447 \times 10^{-7} m$$

$$\therefore \text{Ans wavelength} = 4.3447 \times 10^{-7} m$$

Extract 10.1 shows an example of the answers which indicate how the candidate managed to score all marks allocated to part b(ii). The candidate put forward relevant formula with definition of all symbols. Eventually, the candidate managed to do the associated calculations clearly and accurately.

2016 PAST PAPERS

2. (a) Define the following:
 (i) principal quantum number
 (ii) azimuthal quantum number. (2 marks)
- (b) Given the quantum number, $n = 3$. Answer the following questions:
 (i) List all possible orbitals present in this quantum energy.
 (ii) Write possible values of m_l and m_s for this quantum number. (3 marks)
- (c) The mass spectrum of an element enables the relative abundance of each isotope of the element to be determined. Data relating to mass spectrum of an element X whose atomic number is 35 is as indicated in the table below. Study the data and answer the questions that follows:
- | Mass Number of Isotopes | Relative Abundance |
|-------------------------|--------------------|
| 79 | 50.5% |
| 81 | 49.5% |
- (i) Define the term isotope.
 (ii) Write the conventional symbols for the two isotopes of element X.
 (iii) Calculate the relative atomic mass of X to three significant figures. (5 marks)

Q(9)(i) principal quantum number:

Are quantum number that describe size and energy of the orbital in which electron are found.

Principal quantum number are denoted as follows:

$$n=1 = K - L$$

$$n=2 = L$$

$$n=3 = M$$

$$n=4 = N$$

(ii) Azimuthal quantum numbers:

Are quantum numbers that describe the shapes of subshell in which electron resides.

It can have integral value of (0 to $n-1$)

(where n = principal quantum number).

2(b) Given $n=3$

(i) When $n=3$:

$\lambda = 0, 1, 2$

n	3					
λ	0	1	2			
m	0	-1, 0, 1	-2, -1, 0, 1, 2			
M_l	$\pm\frac{1}{2}$	$\pm\frac{1}{2}, \frac{1}{2}$	$\pm\frac{1}{2}, \frac{1}{2}, \frac{1}{2}$	$\pm\frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}$	$\pm\frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}$	$\pm\frac{1}{2}$

possible orbitals present in this quantum energy

s -orbital $\lambda=0$

p -orbital $\lambda=1$

d -orbital $\lambda=2$

(ii) Possible values of M_l are $0, -1, 0, 1, -2, -1, 0, 1, 2$

Possible values of M_s are

$\pm\frac{1}{2}, \pm\frac{1}{2}, \pm\frac{1}{2}, \pm\frac{1}{2}, \pm\frac{1}{2}, \pm\frac{1}{2}, \pm\frac{1}{2}, \pm\frac{1}{2}$

(iii) Conventional symbols are ^{79}X , ^{81}X

(iv) From

$$R.A.M = \frac{\text{relative abundance} \times (\text{atomic mass})}{\text{total atomic mass}}$$

$$= \frac{50.5 \times 79 + 49.5 \times 81}{100}$$

$$= 79.99$$

$$\approx 80.0$$

||

Hence the relative atomic mass of X is 80.0

2(c) Isotopes

These are atoms having the same atomic number but different atomic mass.

Example



In Extract 2.1, the candidate correctly answered all the parts of the question.

2015 PAST PAPERS

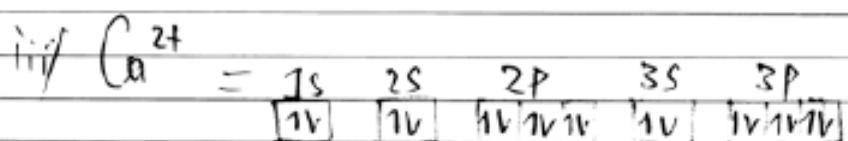
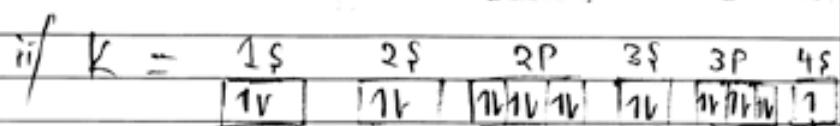
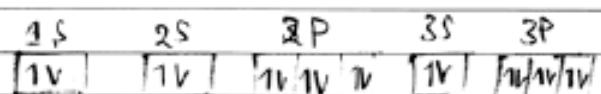
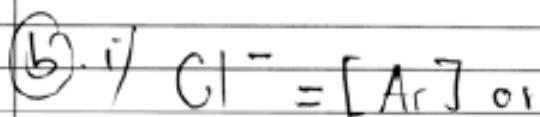
1. (a) State the following:
- (i) Pauli's exclusion principle.
 - (ii) Aufbau building principle.
 - (iii) Hund's rule of maximum multiplicity.
 - (iv) Half-filled and full-filled orbital rule. (4 marks)
- (b) Write down the electronic configuration of each of the following species using orbital diagrams:
- (i) Cl^-
 - (ii) K
 - (iii) Ca^{2+}
 - (iv) F. (4 marks)
- (c) Element Z occurs naturally as a mixture of ^{69}Z and ^{71}Z .
- (i) Briefly explain the significance of the numbers 69 and 71 and give a term which describes these two components in the natural element.
 - (ii) If ^{69}Z and ^{71}Z have relative atomic mass of 69.8, find the percentages of ^{69}Z and ^{71}Z in a sample of Z. (2 marks)

1. Q. i/ Pauli's exclusion principle states that
"No two electrons in an orbital may have
all the four quantum numbers alike"

if Aufbau building principle states that
"When electrons are filled in orbitals
with different energy values, electrons
will be filled to orbitals with low
energy level then followed to orbitals
with a higher energy level".

iii/ Hund's rule states that
"When electrons are filled in orbitals
of the same energy level pairing
is not allowed until all orbital
are filled, and if pairing begins
they will spin in antitclockwise
direction".

1 @. iv) Half-filled and full-filled orbital rule states that "the filling of electrons will be filled first to an orbital with higher energy level before that of lower energy level, so as to obtain a stable electronic configuration of either half filled or full filled" example in Chromium and Copper.



1	(B) iv	$F = \frac{1S}{1V} \frac{2S}{1V} \frac{2P}{1V \ 1V \ 1}$
---	--------	--

Q. if the numbers 69 and 71 describes their difference as these are two isotopes of the same element and (69 and 71) are their atomic masses respectively that shows their difference.

the term is Isotopes that describes these two elements.

ii) Soln:-

From formula

$$R.A.M = (\text{Abundance} \times \text{Mass number})$$

$$\Rightarrow 69.8 = \left(\frac{69 \times x}{100} \right) + \left[\frac{71 \times [100-x]}{100} \right]$$

$$69.8 = 69x + 7100 - 71x$$

$$2x = 120, x = 60.$$

thus, percentage of ^{69}Z is 60% and ^{71}Z is 40%

In Extract 1.1, the candidate gave correct definitions of the enquired terms, wrote the electronic configurations of the species as required and finally he/she applied relevant formulas and substituted correct values and eventually, obtained accurate percentages of ^{69}Z and ^{71}Z in a sample of Z.

2.0 CHEMICAL BONDING

2021 PAST PAPERS

2. (a) Identify a more energetically stable compound among the following pairs:
 (i) NaBr and NaBr₂
 (ii) ClO₄ and ClO₄⁻
 (iii) OF₄ and SeF₄
 (iv) SO₄ and XeO₄ (4 marks)

(b) Although the Valency Shell Electron Pair Repulsion theory (VSEPR) predicts correctly the CH₄ and NH₃ molecular geometries (or shapes), it does not account for the differences in (H-C-H) and (H-N-H) bonds whose angles are 109.5° and 107.3°, respectively. Give reasons for the deviations. (4 marks)

(c) Giving a reason, classify the type of bond involved in each of the following chemical equations:

(i) Ca: + 2 ·Cl: → [Ca]²⁺([·Cl:]⁻)₂

(ii) H⁺ + ·F: → H: ·F: (2 marks)

2 (a) (i) NaBr
(ii) ClO_4^-
(iii) SeF_4
(iv) $\text{S Xe } \text{SO}_4$

(b) The difference in the bond angle between CH_4 and NH_3 is due to the presence of lone pair which tend to repel hence reducing the bond angle in NH_3 .

Consider:

In NH_3 , presence of lone pair which repels the bonding electrons in $(\text{N}-\text{H})$ bond hence reducing size of angle but in $\text{C}-\text{H}_3$, there is no lone pair hence little repulsion.

2	<p>(c)</p> <p>(i) The Ionic bond; because there is transfer of electrons from one to other creating the opposite charge ion which attract each other.</p> <p>(ii) Covalent bond since there is the sharing of the electron one from H^+ and one from F^-.</p>
---	---

Extract 2.1: A sample of correct responses in question 2

2020 PAST PAPERS

6. (a) Differentiate:
 (i) electrovalent bond from octet rule.
 (ii) lone pair from bonding pair of electrons. (2 marks)
- (b) Using sketches, briefly explain three possible overlaps that can occur during sigma bond formation. (3 marks)
- (c) Give two reasons for the observed difference in bond strength between sigma and pi bonds in compounds. (2 marks)
- (d) Predict the geometry of ammonia, basing on the Valence Shell Electron Pair Repulsion (VSEPR) theory. (3 marks)

6 (a) (i) Electronegative bond - Is the chemical bond that is formed by transfer of electrons from metal to non-metal example in NaCl while

Octet rule state that "An atom can gain, lose or share electron(s) and acquire the duplet or octet configuration (state)".

(ii) Lone pair, are valence electrons which do not take part in a chemical bond formation while

Bonding pair electrons are valence electrons which takes part in chemical bond formation

6 (b) Sigma bond is formed by end to end overlapping of atomic orbital

sketch



σ (b) Sigma bond is formed by end to end overlapping of atomic orbitals

(i) by Overlapping of s and s orbital Example formation of H₂, formation of H



overlapping region

(ii) by Overlapping of s and p orbital Example formation of HF



overlapping region

(iii) by Overlapping of p-p orbitals Example formation of F₂



overlapping region

6 (c) The reasons for the observed differences are

(i) Sigma bond is relatively stronger than pi bond (pi bonds are weaker than sigma bond).

(ii) The free rotation about sigma bond is not possible, the free rotation about pi bond is possible.

6 (d)

Molecule NH_3
from VSEPR

Number of hybrid orbitals = Number of lone pairs + number of sigma bond

Number of lone pair = Number of unpaired valence electrons
or central atom - Total number of bonds

$$= \frac{5-3}{2}$$

$$= 1 \text{ lone pair}$$

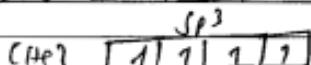
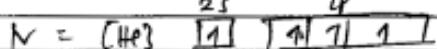
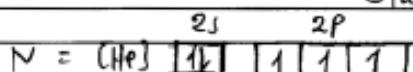
$$\text{Sigma bond} = 3$$

Then

$$\begin{aligned} \text{Number of hybrid orbitals} &= 3 + 1 \\ &= 4 = \text{sp}^3 \end{aligned}$$

6 (e) or

Consider the structure of nitrogen at ground state



From

$$\text{Number of hybrid orbital} = \text{sp}^3$$

There is one lone pair

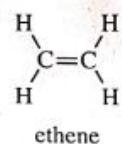
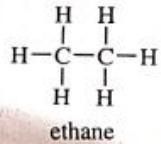
sp^3 — Tetrahedron structure

On removal of lone pair the

structure becomes distorted tetrahedral

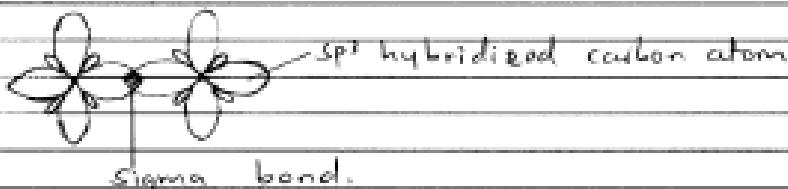
2019 PAST PAPERS

3. (a) Use the following chemical structures of ethane and ethene molecules to answer the questions that follow.



- (i) What are the hybridizations of carbon atoms in each compound? (1 mark)
- (ii) Use well labeled diagrams to describe types of C-C bonds in each compound. (3 marks)
- (iii) In ethane molecule, each C-H has a bond length of 1.09 Å and C-C has bond length of 1.54 Å. Briefly explain this observation. (0.5 mark)
- (vi) The C-C double bond in ethene (bond length 1.34 Å) is shorter than C-C single bond in ethane (bond length 1.54 Å). Briefly explain this observation. (0.5 mark)
- (b) In chemical bond formation, the ionization enthalpy and electron affinity are involved. Briefly describe how:
- (i) Ionic bond formation is favoured by ionization enthalpy and electron affinity.
- (ii) Covalent bond formation is favoured by ionization enthalpy and electron affinity. (2 marks)
- (c) Briefly describe the following phrases. Give one example of a chemical structure for each:
- (i) Hydrogen bond.
- (ii) Coordinate covalent bond. (3 marks)

3m	(i) Hybridization of carbon in ethane is sp^3 hybridization
	Hybridization of carbon in ethene is sp^2 hybridization
3m	(ii) In ethane



3m	(iii) In ethene
	<p>π-bond</p> <p>sp^2 hybridized carbon atom</p> <p>Sigma bond</p>

3(a) (iii) In C-H bond there is a maximum overlapping of the s-orbital and p-orbital therefore forming a short bond length as compared to C-C bond where there is partial overlapping of the p-orbitals.

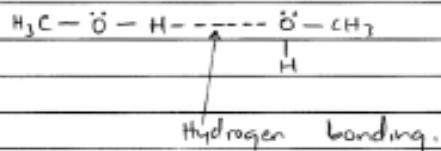
3(b) (iv) In C=C double bond there is both lateral and sideways overlapping of the p-orbitals. therefore forming a shorter bond compared to C-C single bond where there exists only sideways overlap of p-orbitals.

3(b) (ii) In ionic bond formation, the metal should have low ionisation enthalpy so that it can easily lose an electron and the non-metal should have high electron affinity so that it can gain the electron easily.

3(b) (iii) In covalent bond formation, the metal should have high ionisation enthalpy so that losing an electron won't be easy and the non-metal together with the metal should have nearly equal electron affinity.

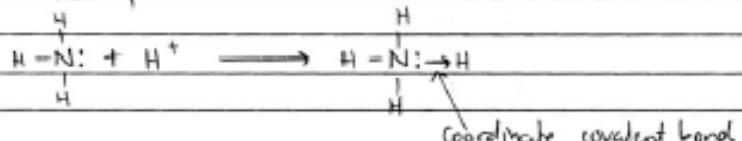
3(c) (i) Hydrogen Bond is a type of bond formed between hydrogen and a most electronegative atom present in a molecule.

Example:



3(c) (ii) Coordinate covalent bond is a type of chemical bond formed when the shared pair of electrons between atoms is contributed by only one atom.

3(c) (ii) Example:



Extract 3.2: A sample of good responses in question 3.

2018 PAST PAPERS

10. (a) Use appropriate examples to differentiate between dative and covalent bonds. (1.5 marks)
- (b) With the help of sketches, briefly explain the following concepts:
- Two types of hydrogen bonding, giving one example for each. (1 mark)
 - Why *ortho*-nitrophenol has lower boiling point than *para* isomer? (1.5 marks)
 - Ethene has a planar geometry. (1.5 marks)
 - Methane has tetrahedron geometry. (1.5 marks)
- (c) (i) State two conditions that are necessary for the formation of hydrogen bond. (1 mark)
(ii) State two effects of hydrogen bonding. (1 mark)
(iii) How many *s*- and *p*-bonds are formed between C-C in ethyne? (1 mark)

10. a) Dative bond is the force of attraction formed when the bonding shared electrons are contributed by one atom (Lewis base) while covalent bonds are the forces of attraction formed when the shared electrons are contributed by both bonding atoms.

Example of dative bond.

$\text{NH}_3 + \text{H}^+ \rightarrow [\text{H}-\text{N}-\text{H}]$

• Example of covalent bond.

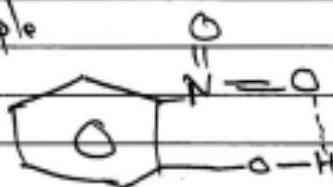
CH_4 .

(a-b) i) There are two types of hydrogen bonding.

a) Intramolecular hydrogen bond.

- This is the type of hydrogen bond that is formed between the same molecule. The molecular formula here has more than one functional group.

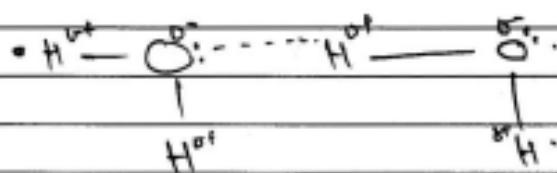
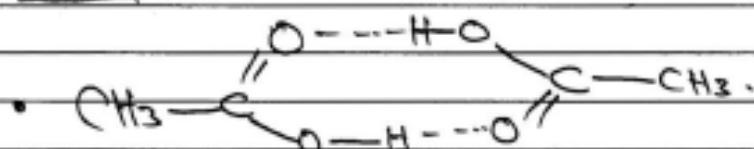
Example



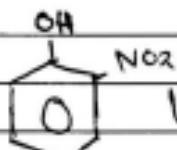
b) Intermolecular (H_2O) hydrogen bond.

- Is the type of hydrogen bond formed between the two different molecules.

Example.



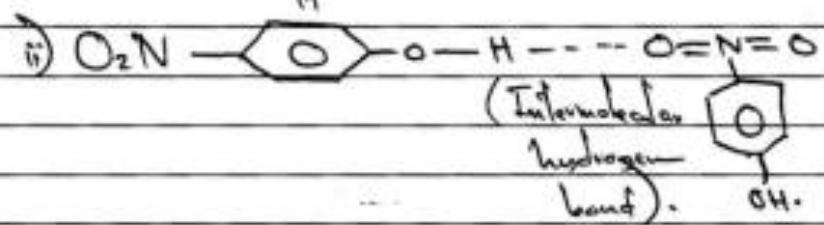
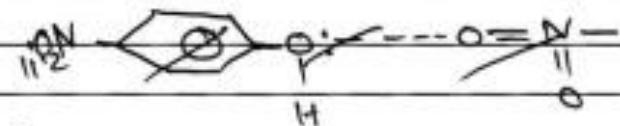
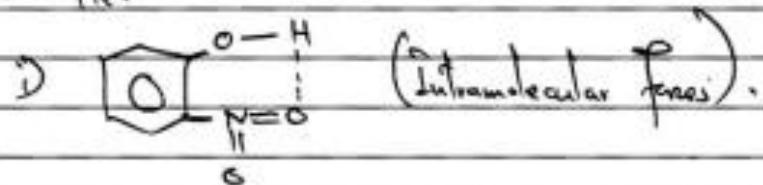
(c-d) ii)



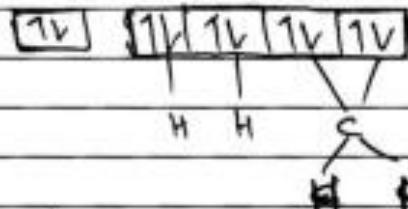
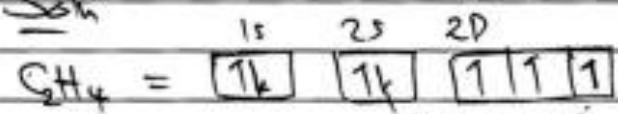
has lower boiling point

than para isomer because (ortho-nitrophenol)

for (b) it forms intramolecular force of attraction which are weak compared to cat para-isomer which forms intermolecular force of attraction. Compiling of hydrogen and the atom with boiling point, because intermolecular fo hydrogen bond are strong than intramolecular hydrogen bond. Also steric hindrance plays a part on determining boiling point example.

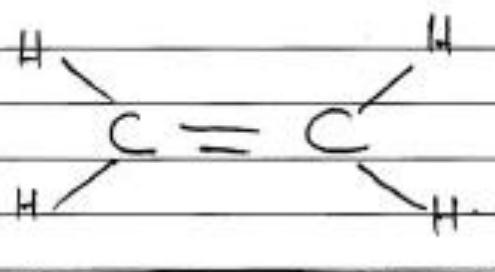


(e)(iii)

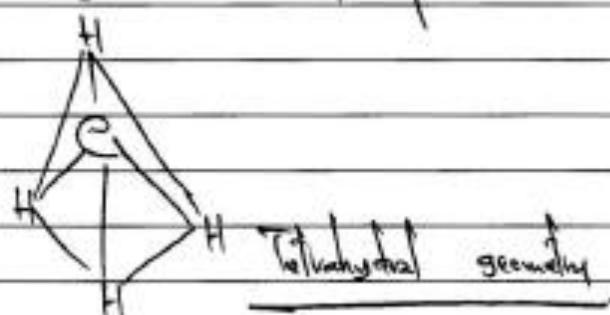


Et₂O has a planar geometry because

10 (a) It forms sp^2 hybridization, which have planar geometry.



10 (b) (i) Methane has tetrahedral geometry. This is because methane has four bonded atoms and thus forms sp^3 hybridization in which also there are no lone pair.



10 c). Conditions for formation of hydrogen bond.

- Hydrogen atom shall be bonded to the most electronegative atom.
- The most electronegative atom must have atleast one lone pair.
Example, Oxygen, Nitrogen.

16. c) ii)	<p><i>Effects of hydrogen bond.</i></p> <ul style="list-style-type: none"> - It determines solubility of compounds. - It determines high boiling point and melting point.
c) iii)	<p>In ethyne; σ-bonds formed is only one while p-bonds are two. ie $H-C\equiv C-H$.</p> <ul style="list-style-type: none"> - The middle bond is σ-bond. - The other two adjacent are the p-bonds.

In Extract 10.1 the candidate responded correctly to the items in part (a) and (c). However, he/she failed to justify the tetrahedron geometry of methane in part (b)(iv).

2018 PAST PAPERS

5. (a) Classify the bonds in the following compounds as ionic, polar covalent or covalent.

(i) HCl(g)	(ii) NaCl(s)	(iii) NCl ₃
(iv) Methane	(v) Tetrachloromethane	(vi) CO ₂

(2.5 marks)

- (b) For each of the following compounds, show from electron configurations the type of hybrid orbital of the underlined atom and draw the geometry of the corresponding molecule.

(i) Be <u>Cl</u> ₂	(ii) <u>C</u> Cl ₄	(iii) <u>C</u> ₂ F ₄	(4.5 marks)
-------------------------------	-------------------------------	--	--------------------

- (c) Study carefully the information in the following table, then answer the questions that follow.

Name	Molecular weight	Boiling point, °C
Diethyl ether	74	35
<i>n</i> -butyl alcohol	74	118
Propionamide	73	213

- (i) Account on the high boiling point of *n*-butyl alcohol compared to diethyl ether, while the two compounds have the same molecular weight. **(1.5 marks)**
- (ii) Account on the low boiling point of *n*-butyl alcohol compared to propionamide despite its high molecular weight. **(1.5 marks)**

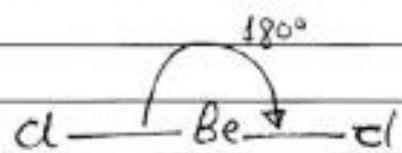
5.	(a) (i)	
	Compounds	Classification
(i)	HCl(g)	Polar covalent
(ii)	NaCl(s)	Ionic
(iii)	NCl ₃	Polar covalent
(iv)		
(v)	Tetrachloromethane (CCl ₄)	Covalent
(vi)	CO ₂	Covalent

5	(b) (i)	<u>Be</u> Cl ₂
		Electronic configuration, q ₄ Be
		1s ² 2s ² 2p
		(1s) (2s) (2p)
		Hybridization [He] 1 1

5 (b) (i)

Type of hybrid orbital is sp

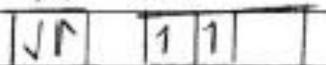
Geometrical shape is linear



(ii) C_2Cl_4

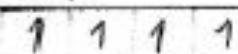
Electronic configuration of ${}^6\text{C}$

${}^6\text{C} = [\text{He}] \ 2s^2 \ 2p$



Upon hybridization

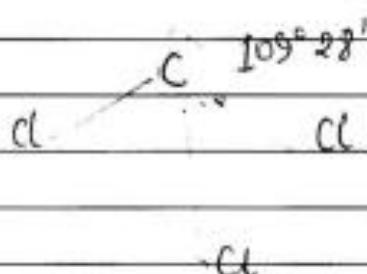
${}^6\text{C} = [\text{He}] \ 2\text{sp}^3$



Type of hybrid orbital is sp^3

Geometrical shape is Tetrahedral.

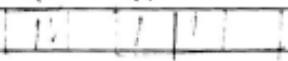
Cl



5 (b) (iii) C_2F_4

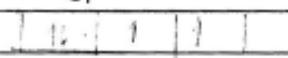
$\begin{array}{c} H \\ | \\ F \end{array}$
Electronic configuration of $_6C$

$_6C = [He] 2s 2p$

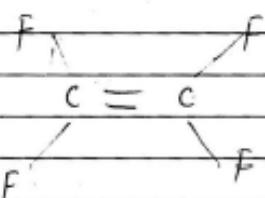


Hybridized:

$_6C = [He] SP^2$



Type of hybrid orbital is SP^2



(c)(i) The high boiling point of *n*-butyl is due to hydrogen bonding between oxygen atom and hydrogen atom in -OH group. But in Diethyl ether hydrogen bonding does not exist since the oxygen atom is bonded to two carbon atoms which are less electronegative.

5 (c) (ii) Since propionamide contains nitrogen atom at the amide group and nitrogen is more electronegative than oxygen, the hydrogen bonding in *n*-butyl which is between oxygen and hydrogen is relatively weaker than that which exists in *n*-butyl propionamide between Nitrogen atom and other hydrogen atom. This is an account for low boiling point in *n*-butyl alcohol.

In Extract 5.1, the candidate clearly classified most of the compounds in part (a) and followed a correct approach to attain the geometry of the molecules in part (b). In part (c), he/she referred correctly to the concept of hydrogen bonding to account for the stated observation.

2017 PAST PAPERS

2. (a) Define the following:
(i) Dative bonding.
(ii) Ionic bonding.
(iii) Valence electrons. (1.5 marks)
- (b) Summarise three major ideas of the Valence Shell Electron Pair Repulsion (VSEPR) theory. (1.5 marks)
- (c) Outline four differences between sigma and pi bonds. (4 marks)
- (d) Determine the name of a geometrical structure and one example of the molecule formed from the following hybridized orbitals.
(i) sp^3 .
(ii) sp^2 .
(iii) sp . (3 marks)

2017 (a) Dative bonding - is the covalent bonding which involves one-sided sharing of electrons, that is one atom contributes a pair of electrons (donor atom) and another accepts a pair into its empty orbital (acceptor atom) in a bond formation. Example in NaN_3 and $BeCl_2$.

2017 (b) Ionic bonding - is the interaction between oppositely charged ions through the electrostatic force of attraction, it involves transfer of electrons from the metals to non-metals during the ionic bond formation.

(c) Valence electrons - these are the electrons in the outermost shell of the atoms which are involved in chemical reactions through being shared or donated to another atom.

- (b)
- The paired electrons in a bond tend to stay as far as possible to one another so that to minimize repulsions and maintain stability of the covalent bond formed.
 - The strength of electron repulsion decreases in the following order lone pair-lone pair > lone pair-bond pair > bond pair-bond pair
 - The number of electrons around a central metal determines the geometry of the compound formed (covalent compound) and the shape is determined by their spatial orientation in the space.

	Sigma bond	Pi bond
(i)	- Formed through maximum overlapping of atomic orbitals	- Formed through minimum overlapping of atomic orbitals
(ii)	- Free rotation about the bond is allowed	- No free rotations about the bond are possible.
(iii)	- Has one region of maximum electron density (cloud)	- Has two regions of maximum electron density (cloud)
(iv)	- Stable due to head on overlapping	- Unstable due to sideways overlapping
(v)	Tetrahedral structure example CH_4	
(vi)	Trigonal planar structure example BF_3 AlCl_3	
(vii)	Linear geometry example BeCl_2	

In Extract 2.1, the candidate managed to define dative bonding, ionic bonding and valence electrons, and was able to summarize the ideas of VSEPR theory. She/he outlined the four differences between sigma and pi bonds, as well as determined the name of a geometrical structure.

2016 PAST PAPERS

(5 MARKS)

3. (a) Give reasons for the following observations:

- Both sodium and hydrogen occur in group IA of the periodic table, yet the melting point of sodium chloride is 800°C while that of HCl is -114°C .
- Sodium chloride is soluble in water but not in benzene.
- Although both oxygen and sulphur are in the same group of the periodic table, the hydride of oxygen (H_2O) is a liquid but the hydride of sulphur (H_2S) is a gas at room temperature.

(3 marks)

- (b) (i) Study the following compounds: hydrogen sulphide (H_2S), ammonia (NH_3), hydrofluoride (HF), chloroform (CHCl_3) and ethanoic acid (CH_3COOH). With reasons, describe the compounds which contain and those which do not contain hydrogen bond.
- (ii) Briefly explain why dimethyl ether is more volatile than ethanol although their molecular weights are the same.

3a)	To give reasons for the given observations
i.	Melting point of NaCl is high while that of HCl is -124°C because NaCl is an ionic compound while HCl is a covalent compound and hence therefore the intermolecular forces in HCl are weak van der waal forces while those in NaCl are strong electrostatic force of attraction making it to have a very high melting point. NaCl is salt because of the large electronegativity difference between Na and Cl atoms.
ii.	Sodium chloride is soluble in water but not in benzene because water is a polar solvent while benzene is a non polar solvent. Water being a polar solvent it can form bonds with Na^+ and Cl^- from chlorine and hence therefore NaCl dissolves in water.
iii)	H_2O is liquid while H_2S is gaseous because water has O-H bond in which hydrogen atom is bonded to O a small highly electronegative atom and hence therefore hydrogen bonding exists in water breaking it to have much more intermolecular forces than H_2S which has no hydrogen bonding and therefore H_2O becomes liquid while H_2S is gas due to weak intermolecular forces of attraction between its molecules.

b) i) Compounds showing hydrogen bonding are given below:

Compound	Reason for having H-bonding.
NH_3	- There is a N-H in which hydrogen is bonded to a small highly electronegative atom N making the bond polar and hence enabling hydrogen bonding to occur.
HF	- There is a H-F in which hydrogen is bonded to a small highly electronegative atom F making the bond polar and hence enabling hydrogen bonding to occur.
CH_3COOH	- There is a O-H bond in which hydrogen is bonded to a small highly electronegative O atom making the bond polarized hence enabling hydrogen bonding to occur.

Compounds which do not contain hydrogen bonding.

Compound	Reason for not forming H-bonding
CHCl_3	- chlorine is too large to allow hydrogen bonding to occur.
H_2S	- Sulphur is not highly electronegative to polarise the bond to allow H-bonding to occur.

3b)ii. Dimethyl ether (CH_3OCH_3) is more volatile than ethanol ($\text{CH}_3\text{CH}_2\text{OH}$) because it has weak intermolecular forces as it cannot form hydrogen bonding and hence because it has a high vapour pressure making it more volatile than ethanol which has a C-H bond which enables it to undergo hydrogen bonding which are strong intermolecular forces which lower its vapour pressure and hence making it less volatile.

In Extract 3.1, the candidate presented correct answers to all parts of the question.

2015 PAST PAPERS

9. (a) Giving examples, briefly explain each of the following:
 - (i) Hydrogen bonding
 - (ii) Coordinate bond
 - (iii) Van der Waal forces. (3 marks)

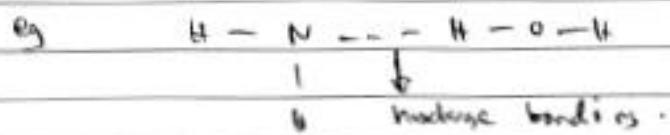
- (b) For each of the following pairs of substances, predict which substance has a higher melting point, and give reason for each choice you make.
 - (i) CH_3CH_3 and CH_3OH
 - (ii) CO_2 and H_2
 - (iii) HCl and H_2O
 - (iv) Al and Mg
 - (v) Si and Na. (5 marks)

- (c) Describe the hybridization of beryllium in beryllium chloride (BeCl_2). (2 marks)

Q@

(i) Hydrogen bonding.

Is the electrostatic force of attraction formed between hydrogen atom bonded to one molecule and the other electronegative atom of the same molecule.



(ii) Coordinate bond.

Is the type of covalent bond in which the shared electron pairs are donated by one atom as formation bond holding H^+ and NH_3^- together in ammonium.

(iii) Vander wall force

Are weak electrostatic forces formed between two covalent molecules. Eg bond hold together carbon monoxide molecules.

(b) (i) $(\text{H}_2\text{O})_n$ has a higher melting point because its molecules are associated together by hydrogen bonding formed between adjacent OH groups.

(ii) CO_2 has melting point than H_2 due to strong Vander wall force holding the molecules of CO_2 together due to because of its large molecular mass than H_2 .

9 (b)	<p>iii) H₂O has high boiling point than HCl because water molecules are held together by strong hydrogen bonds. In HCl, Cl is not more electronegative enough to form hydrogen bonding.</p> <p>(iv) Al has high melting point than Mg due to strong metallic bond holding the atom of aluminium together caused by its large number of valency electrons and small atomic size than Mg.</p> <p>(v) Si has high melting point than Na due to the presence of giant forces holding the silicon atoms together in a lattice.</p>
-------	--

Extract 9.1 is one of the good answers. The responses indicate that the candidate is acquainted with sufficient knowledge of properties of substances due to the chemical bonding which exist in them.

3.0 GASES

2021 PAST PAPERS

10. (a) Show how Boyle's law and Charle's law are special cases of the ideal gas law. (3 marks)
- (b) (i) Theoretically, ideal gasses cooled to a temperature of -273.15°C will occupy zero (0) volume. With reason(s) comment on whether gases practically occupy zero volume at such temperature. (2 marks)
- (ii) Molecule A is twice as heavy as molecule B. Which of these has higher kinetic energy at any temperature? Give a reason. (1 mark)
- (c) Briefly explain the following:
- (i) Liquid ammonia bottle is cooled before opening the seal.
 - (ii) The tyre of an automobile is inflated to a slightly lower pressure in summer than in winter. (2 marks)
- (d) A 1.0 litre sample of dry air at 25°C and 786 mmHg contains 0.925 g of nitrogen gas (N_2) and other gases. Considering dry air to behave ideally, calculate the:
- (i) mole fraction of N_2 in the gas sample. (1 mark)
 - (ii) partial pressure of N_2 in the gas sample (in mmHg). (1 mark)
- (e) The volume of 200 cm^3 of oxygen gas required 250 seconds to diffuse through a porous membrane. Under the identical conditions, 200 cm^3 of gas 'Z' diffused in 177 seconds. Calculate the relative molecular mass of gas 'Z'. (3 marks)

10(b)	Required to show that : Boyle's law and charles' law are special cases of ideal gas law.
	Mathematical expression of Boyle's law .
	$V \propto \frac{1}{P}$ (i)
	Mathematical expression of charles' law .
	$V \propto T$ (ii)
	On combining expression (i) and (ii)
	$V \propto \frac{T}{P}$
	$PV \propto T$
	$PV = kT$
	k is determined experimentally and it is Universal gas constant , R .
	$PV = RT$
	For n moles of a gas .
	$PV = nRT$
	Hence boyle's and charles' law are special cases of ideal gas law .

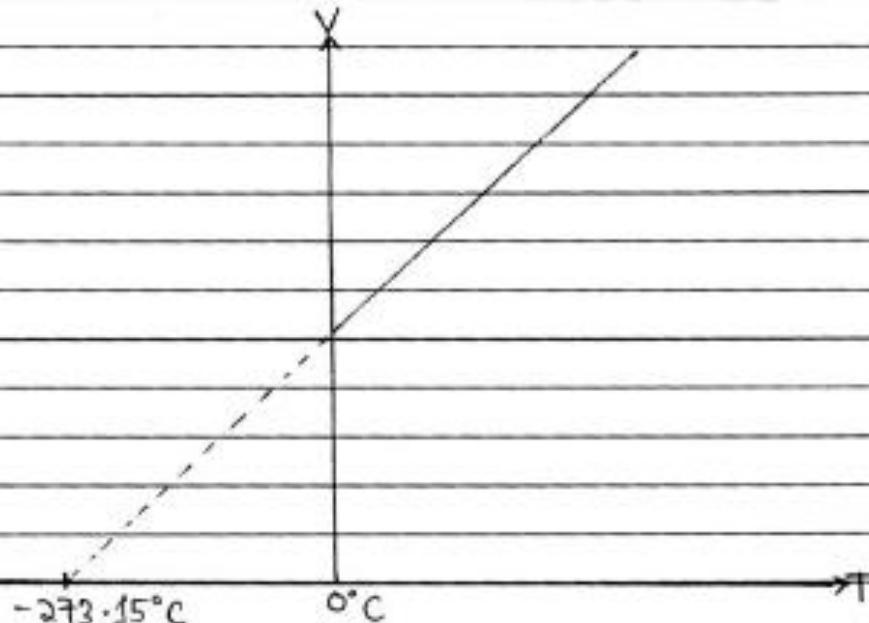
10(b) (i) Theoretically when ideal gas is cooled to a temperature of -273.15°C will occupy zero volume because

- Ideal gas obey Charles law, Charles law state that volume is directly proportional to absolute temperature. So when it is cooled below zero, means that volume decreases to zero.

- And also at -273.15°C , pressure is low thus intermolecular forces of attraction are also low, and hence the particle / molecules of gas are far apart hence zero volume.

Consider the graph below

GRAPH OF VOLUME AGAINST
TEMPERATURE OF IDEAL GAS.



10(b) (i)

$$K.E \propto T$$

$$K.E = \frac{3}{2} kT$$

Hence both molecules have the same energy at any temperature because kinetic energy depends on T and not mass.

10(c) (i) Liquid Ammonia bottle is cooled before opening the seal, because at room temperature the vapour pressure of ammonia is high, so when the bottle is opened, it is likely that explosion will occur. So it is cooled in order to decrease vapour pressure.

(ii) The tyre of an automobile is inflated to a lower pressure in summer than winter because, when large pressure is applied, the temperature of gas molecules increases and so collision and the tyre might burst.

10(d)

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$P = \frac{786}{760} \text{ atm}$$

$$V = 10 \text{ litre}$$

$$T = 298 \text{ K}, T = t + 273 = 25 + 273$$

$$T = 298 \text{ K}$$

Jc(d)

$$n_T = \frac{786}{760} \times 1$$
$$= 0.9821 \times 298$$

$$n_T = 0.0423 \text{ mol.}$$

$$\text{Molar mass} = \frac{\text{mass}}{\text{molar mass}}$$
$$= \frac{0.925}{28}$$

$$n_{N_2} = 0.033 \text{ mol}$$

(i) Mole fraction

$$X_{N_2} = \frac{n_{N_2}}{n_T}$$
$$= \frac{0.033}{0.0423}$$
$$= 0.78$$

$$(ii) P_T = n_T R T$$

$$P_{N_2} V = n_{N_2} R T$$

$$\frac{P_T}{P_{N_2}} = \frac{n_T}{n_{N_2}}$$

$$P_{N_2} = \frac{n_{N_2} \times P_T}{n_T}$$

$$P_{N_2} = 0.78 \times 786$$

$$P_{N_2} = 613.08 \text{ mmHg}$$

10(d) from Graham's law of diffusion

$$\text{rate} = \frac{1}{\sqrt{\text{density}}}$$

density, ρ or M_r

$$\text{Rate} = \frac{1}{\sqrt{M_r}}$$

Rate of O_2 = volume of O_2
Time taken

$$\frac{R_{O_2}}{R_2} = \frac{200}{256}$$

Rate of gas Z = volume of Z
Time taken

$$= \frac{200}{177}$$

$$\frac{R_{O_2}}{R_Z} = \frac{M_Z}{M_{O_2}}$$

$$\frac{200}{256} \div \frac{200}{177} = \frac{M_Z}{\sqrt{32.0}} \text{ mol}$$

$$M_Z = 16.04 \text{ g/mol}$$

∴ The relative molecular mass of
gas Z is 16.04

Extract 10.1: A sample of good responses in question 10

2020 PAST PAPERS

7. (a) A 0.25 moles of air has entered a diesel engine at a pressure of 1.05×10^5 Pa and a temperature of 27°C. Assuming that air is ideal, calculate:
- the volume it occupies. (3 marks)
 - its temperature, immediately after compression to one twentieth of its original volume where the pressure rises to 7.0×10^6 Pa. (3 marks)
- (b) A 42 g of nitrogen gas and 8 g of hydrogen gas are mixed in a 10 litre vessel at 20°C. Calculate the partial pressure of each gas and the total pressure of the gas mixture. (4 marks)

7.	(a)	Number of moles, $n = 0.25$ moles
		Pressure, $P_1 = 1.05 \times 10^5$ Pa.
		Temperature, $T_1 = 27^\circ\text{C}$ (300K).
		Assumption: Air is ideal.
	(i)	Volume occupied by required for ideal gas $P_1 V_1 = n R T_1$ $V_1 = \frac{n R T_1}{P_1}$ where, R = universal gas constant = $8.31 \text{ J mol}^{-1} \text{ K}^{-1}$
		$V_1 = \frac{0.25 \text{ moles} \times 8.31 \text{ J mol}^{-1} \text{ K}^{-1} \times 300 \text{ K}}{1.05 \times 10^5 \text{ Pa}}$ = $5.9857 \times 10^{-3} \text{ m}^3$
	(ii)	Temperature required when compression to $\frac{1}{20}$ of original volume, where temperature now is 7×10^6 Pa. Data: T_2 : Required $P_2 = 7 \times 10^6$ $V_2 = \frac{1}{20} V_1$
		From: combined equation $P_1 V_1 = P_2 V_2$ $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ $\frac{1.05 \times 10^5 \times V_1}{300} = \frac{7 \times 10^6 \times \frac{1}{20} V_1}{T_2}$ $T_2 = \frac{7 \times 10^6 \times 300}{1.05 \times 10^5 \times 20}$ = 1000 K. \therefore Temperature is 1000 K

7.	(b)	Data.
		mass of nitrogen, m _N = 42 g.
		mass of hydrogen, m _H = 8 g.
		Volume of a vessel, V = 10 dm ³ .
		Temperature of vessel, T = 20 °C (293 K).
		Solution
		From, Number of moles = $\frac{m}{M}$
		Molar fraction for hydrogen = $\frac{\text{Number of moles for hydrogen}}{\text{Total moles}}$
		number of moles for hydrogen = $\frac{8}{2} = 4 \text{ mol}$
		Since $\frac{2}{2+14} = 0.14$
		∴ Molar fraction of hydrogen = 0.14.
		Number of moles for nitrogen, m _N = $\frac{42}{(14 \times 2)} = 1.5 \text{ mol}$
		Since molar mass for nitrogen = 1.5 mol. $14 \times 2 = 28$.
		Molar fraction for hydrogen, X _H = $\frac{0.14}{0.14 + 1.5} = 0.073$.
		Molar fraction for nitrogen, X _N = $1 - 0.073 = 0.927$.
		Then partial pressure for hydrogen
		P _H = $X \cdot P_{\text{total}}$
		$\therefore P_H = \frac{0.14 \times 10}{10} = 0.14 \text{ atm}$
		P _N = $0.927 \times 10 = 9.27 \text{ atm}$
		∴ Partial pressure for hydrogen is 0.14 atm.
		Partial pressure for nitrogen
		P _N = $\frac{m}{V} RT$
		$\therefore P_N = 1.5 \times 10 \times 0.0821 \times 293$
		$= 3.608 \text{ atm}$
		∴ Partial pressure for nitrogen is 3.608 atm
		Total pressure, P
		P = P _H + P _N
		$= 0.14 + 3.608$
		$= 3.748 \text{ atm}$
		∴ Total pressure is 3.748 atm

Extract 7.1: A sample of correct responses in question 7

2019 PAST PAPERS

7. (a) Use the kinetic gas equation to explain the following concepts:
- The pressure exerted by an ideal gas increases when it is heated at constant volume.
 - The volume occupied by an ideal gas increases when it is heated at constant pressure.
- (4.5 marks)
- (b) A flammable gas made up of only carbon and hydrogen is generated by certain anaerobic bacteria in sewage drains. A pure sample of a gas was found to effuse through a certain porous barriers in 1.50 minutes. Under the same conditions of temperature and pressure it takes 4.73 minutes for an equal volume of bromine gas to effuse through the same barrier. Calculate the molar mass of the unknown gas and suggest the name of the gas. (Molecular mass of bromine = 159.8 g/m)
- (2 marks)
- (c) In the determination of the molecular weight of chloroform vapour by Hofmann's method, the following results were obtained:
 Weight of liquid in bulb = 0.2704 g; Volume of vapour = 110 cm³; Temperature of vapour = 99.6 °C; Atmospheric pressure = 747 mmHg; Vapour pressure of water vapour at 99.6 °C = 285.2 mmHg. Calculate the relative molecular weight of chloroform if 1 dm³ of H₂ at S.T.P. weighs 0.09 g. In your calculations, show your work clearly including manipulations of units.
- (3.5 marks)

7	<p><i>Q</i>) Because when an ideal gas is heated the kinetic energy of gas molecules increases which increase the speed of gas molecules and the collision of gas molecules themselves and the wall of the container thus the pressure of an ideal gas increase at constant volume.</p> <p>i.e From $PV = \frac{1}{3} Nm\bar{c}^2$ or $PV = nRT$</p> <p>$P \propto \frac{1}{m\bar{c}^2}$ at constant V</p> <p>$P \propto T$ at Constant V</p>
	<p><i>Q</i>) Because when an ideal gas is heated the kinetic energy of the gas increase and hence their speed also increase which tend to cause the ideal gas molecules to move far away from each other and hence the volume occupied by an ideal gas</p>

7) Increases provided that pressure remains constant.

$$\text{ie } PV = \frac{1}{3} Nmc^2$$

$$V = \frac{1}{3} Nmc^2 / P$$

$$= \frac{2}{3} \cdot \frac{1}{2} Nmc^2 / P$$

$$\text{Since } \frac{1}{2} Nmc^2 = KE \propto T$$

$$V \propto T \text{ where } \frac{1}{P} = \text{constant}$$

7 b) Solution

time in sample X, $t_1 = 1.5 \text{ min}$

time in Br gas, $t_2 = 4.73 \text{ min}$

Molar mass of X = ?

Mr of Br = 159.8 g/m

From

Graham diffusion law

$$\frac{t_1}{t_2} = \sqrt{\frac{M_X}{M_{Br}}}$$

$$\frac{1.5 \text{ min}}{4.73 \text{ min}} = \sqrt{\frac{M_X}{159.8 \text{ g/m}}}$$

$$\left(\frac{1.5}{4.73}\right)^2 = \frac{M_X}{159.8 \text{ g/m}}$$

$$0.1 \times 159.8 \text{ g/m} = M_X$$

$$M_X = 15.98 \text{ g/mol}$$

Since C₂H₄ = 16 ; 15.98 ≈ 16

∴ The molar mass of unknown gas is 15.98

The gas is methane. (C₂H₄)

7	c) Solution
	Dato
	Weight of liquid in bulb = 0.2704g
	Volume of vapour = 110cm³ = 0.11dm³
-	Temperature of vapour = 99.6°C = 373.6K
	Vapour pressure of water vapor = 285.2mmHg
	Relative molecular weight of CCl_4 = ?
	Volume of H_2 gas at STP = 1dm³
	Mass of H_2 = 0.09g.
	Atmospheric pressure = 747mmHg
	From
	Vapour pressure of chloroform = $(747 - 285.2)$
	$P_{\text{CHCl}_3} = 461.8 \text{ mmHg} = 0.608 \text{ atm}$
	From $PV = nRT$
	$PV = mRT$
	$n = \frac{m}{M}$
	$M = \frac{mRT}{PV}$
	$= \frac{(0.2704 - 0.09) \text{ g R.T}}{PV}$
	Since V at STP = 1dm³
	at 99.6°C, $V = ?$, $P = 285.2 \text{ mmHg}$
	$P_1 V_1 = P_2 V_2$
	$1 \text{ dm}^3 \times 1 \text{ atm} = 0.375 \text{ atm} \times V_2$
	$V_2 = \frac{1 \text{ dm}^3}{0.375}$
7	$V = 2.667 \text{ dm}^3$
	From
	$M = \frac{(0.2704 \text{ g} \times 0.0821 \text{ atm dm}^{-1} \text{ K}^{-1} \text{ mol}^{-1}) \times 273.6 \text{ K}}{0.608 \text{ atm} \times 2.667 \text{ dm}^3}$
	$= M = 3.4 \text{ g/mol}$

Extract 7.2: A sample of correct responses in question 7.

2019 PAST PAPERS

8. (a) State the following gas laws, then provide their mathematical expressions:
- Boyle's law.
 - Charles' law.
 - Graham's law.
 - Dalton's law of partial pressures. (2 marks)
- (b) State five assumptions of the kinetic theory of gasses. (2.5 marks)
- (c) 50 cm³ of carbon dioxide at $1 \times 10^5 \text{ Nm}^{-2}$ are mixed with 150 cm³ of hydrogen at the same pressure. If the pressure of the mixture is $1.0 \times 10^5 \text{ Nm}^{-2}$, calculate the partial pressure of hydrogen gas. (2.5 marks)
- (d) In 5 minutes, 15 cm³ of argon effuse through a pinhole. What volume of xenon will effuse through the same pinhole under the same condition? [Atomic masses: Ar = 39.95, Xe = 131.29] (3 marks)

8(a)	<p>(i) Boyle's law states that ;</p> <p>" The volume 'V' of a fixed mass of gas is inversely proportional to its pressure 'P' at constant temperature."</p> <p>That is : $V \propto \frac{1}{P}$</p> $P_1 V_1 = P_2 V_2 = \text{constant}$
8(b)	<p>(ii) Charles' law states that ;</p> <p>" The volume of a fixed mass of gas is directly proportional to its absolute temperature at constant pressure."</p> <p>That is ; $V \propto T$</p> $\frac{V_1}{T_1} = \frac{V_2}{T_2} = \text{constant}$

Ques (iii) Graham's law states that;
 "The rate of diffusion or effusion of a gas is inversely proportional to the square root of its density when Temperature and pressure are kept constant."

That is; $R \propto \frac{1}{\sqrt{\rho}}$

$$R_1 \sqrt{\rho_1} = R_2 \sqrt{\rho_2} = \text{constant}$$

Ques (iv) Dalton's law of partial pressures. States that;

"When a mixture of two or more than two gases are enclosed in a vessel, the total pressure exerted by the gas is equal to the sum of the partial pressures of the gas when present alone in a vessel."

That is; $P_{\text{total}} = P_A + P_B$.

Ques (v) Assumptions of Kinetic theory of gases;

(i) A gas consists of small particles that are in random motion and there exist collision between gas particles themselves and a collision between a gas particle and the wall of a container thus exerting pressure.

8(b)	<ul style="list-style-type: none"> (ii) The kinetic energy of the gas particles is directly proportional to the absolute temperature of the gas. (iii) The collision between the gas particle and the walls of the container is perfectly elastic. (iv) The intermolecular forces between gas particles is negligible. (v) The volume of the gas particles is negligible compared to the volume of the container. (vi) Force of gravity has no influence on the motion of a gas particle.
------	--

8(c)	<p>Given :</p> <p>Volume of carbon dioxide, $V_{CO_2} = 50 \text{ cm}^3$</p> <p>Volume of hydrogen, $V_H_2 = 150 \text{ cm}^3$.</p> <p>Total pressure, $P_T = 1.0 \times 10^5 \text{ N m}^{-2}$</p> <p>According to Boyle's law :</p> $P_1 V_1 = P_2 V_2$ <p>But : $P_1 = 1 \times 10^5 \text{ N m}^{-2}$</p> $V_1 = 50 \text{ cm}^3$ $V_2 = 50 \text{ cm}^3 + 150 \text{ cm}^3 = 200 \text{ cm}^3$ $\therefore P_2 = \frac{P_1 V_1}{V_2}$
------	--

$$8(1) \quad P_1 = \frac{1 \times 10^5 \times 50}{200}$$

$$P_1 = 25,000 \text{ Nm}^{-2}$$

According to Dalton's law of partial pressure:

$$P_1 = P_2 + P_{H_2}$$

$$P_{H_2} = P_1 - P_2$$

$$P_{H_2} = 1 \times 10^5 - 25,000$$

$$P_{H_2} = 75,000 \text{ Nm}^{-2}$$

$$\therefore \text{Partial pressure of Hydrogen} = 75,000 \text{ Nm}^{-2}$$

8(b) from Graham's law of effusion;

$$\frac{R_1}{R_2} = \sqrt{\frac{M_2}{M_1}}$$

where; M_2 is molecular mass of Xenon = 131.29
 M_1 is molecular mass of argon = 39.95

Given; Rate of diffusion of argon, $R_1 = V/t_1$

Since; $t_1 = t_2$

$$\frac{V_1}{V_2} = \sqrt{\frac{M_1}{M_2}}$$

$$\frac{15 \text{ cm}^3}{V_2} = \sqrt{\frac{131.29}{39.95}}$$

$$\frac{15 \text{ cm}^3}{V_2} = 1.8128$$

$$V_2 = \frac{15 \text{ cm}^3}{1.8128}$$

$$V_2 = 8.274 \text{ cm}^3$$

$$\text{Volume of Xenon} = 8.274 \text{ cm}^3$$

Extract 8.1: A sample of correct responses in question 8.

2018 PAST PAPERS

2. (a) State the following:
- Boyle's law.
 - Charles' law.
 - Avogadro's law.
 - Dalton's law of partial pressure.
 - Graham's law of diffusion.
- (2.5 marks)
- (b) (i) A certain amount of a gas was found to occupy 100cm^3 at 33°C and $97 \times 10^3 \text{ Nm}^{-2}$. Calculate the volume of the gas at standard temperature and pressure. Show your work clearly including manipulations of units. [$1 \text{ atm} = 101.3 \times 10^3 \text{ N m}^{-2}$]. (2 marks)
- (ii) At 1.0 atmosphere pressure and 30°C , 1.236 g of a gas was found to occupy a volume of 512 cm^3 . Calculate the relative molecular mass of the gas. Show your work clearly including manipulations of units. (2 marks)
- (c) The compressibility factor, Z , is used to test the ideality or non-ideality of real gases.
- Write an expression for compressibility factor, Z . (0.5 marks)
 - At what values of Z a real gas shows ideal behavior, positive and negative deviation from ideality? (1.5 marks)
- (d) A gas was found to diffuse through a porous material 1.49 times faster than chlorine gas. Calculate the molecular mass of the gas giving your answer in two decimal places. [Molecular mass of chlorine = 71.0 g mol^{-1}]. (1.5 marks)

Q2	<p>i) Boyle's law "The volume of a fixed mass of a gas is inversely proportional to the pressure provided that absolute temperature is kept constant" $P \propto \frac{1}{V}$</p> <p>ii) Charles' law. "The volume of a fixed mass of a gas is directly proportional to the absolute temperature provided that pressure remains constant" $V \propto T$</p> <p>iii) Avogadro's law "Equal volume of gases at standard pressure and temperature contains the same number of moles at standard temperature and pressure" $V \propto n$.</p> <p>iv) Dalton's law of partial pressure "The total pressure exerted by the mixture of different gases in the container is equal to the summation of the partial pressure of the individual gaseous molecules in the container at standard temperature and pressure provided that the gases do not react" $P_T = P_A + P_B$</p> <p>v) Graham's law of diffusion "The rate of diffusion of the gases through a medium is inversely proportional to their the square root of their densities at standard temperature and pressure" $R \propto \frac{1}{\sqrt{\rho}}$</p>
----	--

O2 b) i) soln:

$$\text{Data: initial volume } (V_1) = 100 \text{ cm}^3$$

$$\text{Initial temperature } (T_1) = 33^\circ\text{C} = 306 \text{ K}$$

$$\text{Initial pressure } (P_1) = 97 \times 10^3 \text{ N/m}^2$$

final to

$$\text{Standard temperature } (T_2) = 273 \text{ K}$$

$$\text{Standard pressure } (P_2) = 101.3 \times 10^3 \text{ N/m}^2$$

$$\text{Standard volume } (V_2) = ?$$

From the General gas equation:

$$\frac{PV}{T} = \text{constant} = 1 \text{ L}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = \frac{P_1 V_1 T_2}{P_2 T_1}$$

$$V_2 = \frac{97 \times 10^3 \text{ N/m}^2 \times 100 \text{ cm}^3 \times 273 \text{ K}}{101.3 \times 10^3 \text{ N/m}^2 \times 306 \text{ K}}$$

$$V_2 = 85.43 \text{ cm}^3$$

∴ The volume of a gas at standard temperature
and pressure is 85.43 cm^3

Q2 c) i) Compressibility factor used to determine ideality or non-ideality of real gases is given by the expression

$$Z = \frac{PV}{nRT}$$

where; P = Pressure of a gas

V = Volume of a gas

n = Number of moles of a gas

T = Absolute temperature.

R = Universal molar gas constant

ii) A real gas shows ideal behaviour when the value of compressibility (Z) is equal to one

i.e $Z = 1$ ideal gas

$$\text{ie, } Z = \frac{PV}{nRT}$$

when $Z = 1$.

$$1 = \frac{PV}{nRT}$$

$$PV = nRT$$

A real gas shows positive deviation when the value of compressibility (Z) is greater than one.

$$Z > 1$$

$$\frac{PV}{nRT} = Z > 1 \quad \begin{matrix} \text{positive deviation} \\ \text{real gas.} \end{matrix}$$

Q2 (b) i) A real gas shows negative deviation when compressibility factor (z) is less than one

$$z < 1$$

$$\frac{PV}{nRT} = z < 1 \quad \text{negative deviated gas}$$

d) soln.

Given:

$$\text{Rate of diffusion of } \text{N}_2 = R_G$$

$$\text{Rate of diffusion of chlorine gas} = R_{\text{Cl}_2}$$

But Given that:

$$R_G = 1.49 R_{\text{Cl}_2}$$

From Graham's law of diffusion:

$$R_G = \frac{k}{\sqrt{f_G}}$$

$$R_{\text{Cl}_2} = \frac{k}{\sqrt{f_{\text{Cl}_2}}}$$

$$\frac{R_G}{R_{\text{Cl}_2}} = \left(\frac{1}{\sqrt{f_G}} \right) \left(\frac{\sqrt{f_{\text{Cl}_2}}}{k} \right) = \frac{\sqrt{f_{\text{Cl}_2}}}{\sqrt{f_G}}$$

But: from ideal gas equation $f \propto M^{-1}$

$$\text{then, } \frac{R_G}{R_{\text{Cl}_2}} = \frac{M_{\text{Cl}_2}}{M_G}$$

O2	④	$R_G = \sqrt{\frac{M_{CH_4}}{M_{O_2}}}$
		$(1.49)^2 = \left(\sqrt{\frac{71.08 \text{ mol}}{M_{O_2}}} \right)^2$
		$M_{O_2} = \frac{71.08 \text{ mol}}{2.2201} = 31.989 \text{ mol}$
		$\therefore \text{Molecular mass of a gas is } 31.989 \text{ mol.}$

In Extract 2.1 the candidate stated the required gas laws supported with proper mathematical expressions, stated correctly the values of constant Z and used proper formulae to calculate the required parameters.

2018 PAST PAPERS

3. (a) State the meaning of an ideal gas. (1 mark)
- (b) State two postulates of kinetic molecular theory of gases which are incorrect for real gases. Express their corresponding corrections and derive the van der Waals' equation. (6 marks)
- (c) Calculate the pressure exerted by 1.00 mole of methane in a 250 mL container at 300 K. Show your work clearly including units manipulations. [van der Waals' constants $a = 2.253 \text{ (dm}^3\text{)}^2 \text{ atm mol}^{-2}$; $b = 0.0428 \text{ dm}^3 \text{ mol}^{-1}$] (3 marks)

3a. Ideal gas is a gas which obeys ideal gas equation ($PV = nRT$) at all conditions of temperature and pressure; but also obeys Raoult's Law

b.

The two postulates:

- The volume of the gas molecules is negligible compared to the total volume of the container
- The molecular force of attraction is negligibly small between the colliding particles

corrections;

Volume correction

Since the volume of the gas tends to be not negligible compared to the total volume of the container; thus to correct the situation; the excess volume must be reduced so as to satisfy ideal gas equation. Hence a constant a or b is introduced which signify the size of the molecule

i.e

$$\text{Volume corrected} = V - nb$$

where n = number of moles of the gas

b Volume (V) = volume of real gas

Pressure correction

Since the ~~pos~~ intermolecular forces of attraction between molecules is not negligible So; the molecules attacking / colliding with the walls of the container will hit the container with a less pressure than when there were no intermolecular force. So the pressure of the real gas is less than that of ideal and so; to correct it is experimentally done that:

$$P_{\text{corrected}} = P + P'$$

where

$$P' \propto \left(\frac{n}{V}\right)^2 \quad \text{where } n/V = \text{concentration}$$

$$P' = \frac{a n^2}{V^2}$$

where a signify the force of attraction of the molecules

So;

from Ideal gas equation

$$PV = nRT$$

The new one derived , that is, Vander waal's equation is

$$(P_{\text{corrected}})(V_{\text{corrected}}) = nR\bar{T}$$

$$\left(P + \frac{a n^2}{V^2}\right) \left(V - nb\right) = nR\bar{T}$$

c. Data given:

$$n = 1 \text{ mol}$$

$$V = 250 \text{ mL} \approx 0.25 \text{ dm}^3$$

$$T = 300 \text{ K}$$

$$a = 2.253 \text{ (dm}^3\text{)}^2 \text{ atm mol}^{-2}$$

$$b = 0.0428 \text{ dm}^3 \text{ mol}^{-1}$$

Required: Pressure.

SOLN

from van-der-waal's equation

$$\left(P + \frac{an^2}{V^2} \right) (V - nb) = nRT$$

$$\left(P + \frac{2.253 \text{ (dm}^3\text{)}^2 \text{ atm mol}^{-2} (1)^2}{(0.25 \text{ dm}^3)^2} \right) (0.25 \text{ dm}^3 - (1)(0.0428 \text{ dm}^3))$$

$$(P + 36.048 \text{ atm mol}^{-2}) (0.25 \text{ dm}^3 - 0.0428 \text{ dm}^3 \text{ mol}^{-1}) = RT$$

$$(0.25 \text{ dm}^3 P - 0.0428 \text{ dm}^3 \text{ mol}^{-1} P + 9.012 \text{ atm dm}^3 \text{ mol}^{-2} - 1.5428544 \text{ atm mol}^{-2} \text{ dm}^3) = RT$$

$$0(0.25 \text{ dm}^3 - 0.0428 \text{ dm}^3 \text{ mol}^{-1}) + 9.012 \text{ atm dm}^3 \text{ mol}^{-2} - 1.5428544 \text{ atm mol}^{-2} \text{ dm}^3 =$$

$$0.0821 \text{ atm mol}^{-1} \text{ K}^1 \text{ dm}^3 \times 300$$

$$P(0.2072 \text{ dm}^3 \text{ mol}^{-1}) + 1.47 \text{ atm dm}^3 \text{ mol}^{-2} = 24.63 \text{ atm mol}^{-1}$$

$$P = \frac{17.16 \text{ atm dm}^3 \text{ mol}^{-1}}{0.2072 \text{ dm}^3 \text{ mol}^{-1}}$$

$$= 82.8 \text{ atm}$$

Extract 3.1 shows responses from a candidate who gave a correct definition of an ideal gas, stated two correct postulates and derived the van der Waals' equation accordingly. He/she computed the value of pressure clearly using the van der Waals' equation and manipulated the units correctly.

2017 PAST PAPERS

3. (a) (i) Write two similarities between diffusion and effusion. (1 mark)
- (ii) The rate of effusion of unknown gas was measured to be 24.0 mL/min. Under the same conditions, the measured rate of effusion of pure methane was 47.8 mL/min. What is the molar mass of the unknown gas? (3 marks)
- (b) Using the kinetic theory of gases, state four properties of an ideal gas. (2 marks)
- (c) A sample of ammonia gas with a volume of 3.5 dm³ at a pressure of 1.68 atm was compressed to a volume of 1.35 dm³ at constant temperature.
- (i) Calculate the final pressure of the gas. (3 marks)
- (ii) Name and state the governing gas law in question 3(c)(i). (1 mark)

3	a) i) - Both diffusion and effusion involve the movement of gas molecules.
	- Both the rate of diffusion and effusion of a gas is inversely proportional to square root of the density of a gas.
	ii) Let the rate of effusion of unknown gas be R_u and that of pure methane R_m .
	Molar mass of methane (CH_4) = $(12 + 4) \text{ g mol}^{-1}$ $M_m = 16 \text{ g mol}^{-1}$
	By Graham's law of effusion or diffusion of a gas
	$R \propto \frac{1}{\sqrt{s}}$
	but $s = \text{density}$ $s \propto \text{molar mass}$.
	$\frac{R_u}{R_m} = \sqrt{\frac{M_m}{M_u}}$
	$\frac{24 \text{ mL min}^{-1}}{47.8 \text{ mL min}^{-1}} = \sqrt{\frac{16}{M_u}}$
3	a) ii) $\left(\frac{24}{47.8} \right)^2 = \frac{16}{M_u}$
	$M_u = \frac{16}{\left(\frac{24}{47.8} \right)^2}$
	$M_u = 63.47 \text{ g mol}^{-1}$
	∴ The molar mass of the unknown gas is 63.47 g mol^{-1}

$$3 \quad a) \text{ ii) } \left(\frac{24}{47.8} \right)^2 = \frac{16}{M_u}$$

$$M_u = \frac{16}{\left(\frac{24}{47.8} \right)^2}$$

$$M_u = 63.47 \text{ g mol}^{-1}$$

\therefore The molar mass of the unknown gas is 63.47 g mol^{-1}

- b) - The average kinetic energy of the molecules of an ideal gas is directly proportional to its absolute temperature.
- The intermolecular forces between molecules of an ideal gas is negligible.
- The pressure exerted by an ideal gas is due to the collision of the gas particles and the walls of the container contained.
- The collision between the molecules of an ideal gas and the collision between the molecules and the walls of the container

3 b) is perfectly elastic collision

c) i) Since the temperature is constant.

By using Boyle's Law

$P \propto \frac{1}{V}$

$$P_1 V_1 = P_2 V_2$$

$$P_1 = 1.68 \text{ atm}$$

$$V_1 = 3.5 \text{ dm}^3$$

$$V_2 = 1.35 \text{ dm}^3$$

$$P_2 = ?$$

$$\therefore P_2 = \frac{P_1 V_1}{V_2}$$

$$P_2 = \frac{1.68 \text{ atm} \times 3.5 \text{ dm}^3}{1.35 \text{ dm}^3}$$

$$P_2 = 4.356 \text{ atm}$$

\therefore The final pressure of the gas is
 4.356 atm .

(ii) The law governing is Boyles Law.

- Boyles Law state that, "At constant temperature conditions, the volume of a fixed mass of a gas is inversely proportional to its pressure".

In Extract 3.1, the candidate managed to write two similarities between diffusion and effusion, calculate the molar mass of the unknown gas, stated correctly the four properties of an ideal gas and calculated the final pressure of the gas. He/she also named and stated Boyles law which governed part 3 (c) (i) of the question.

2017 PAST PAPERS

4. (a) Define the following:
- Relative density of a gas.
 - Normal density of a gas.
- (1 mark)
- (b) Show that the relative molecular mass of a gas is twice its relative vapour density. (3 marks)
- (c) (i) A determination of the density of ethanoic acid vapour at 1 atm pressure and 400 K gave a result of 2.74 g/dm³. Assuming ideal condition, calculate the apparent molecular weight of ethanoic acid under these conditions.
(ii) What can you deduce from your results in 4(c)(i)? Briefly explain. (3.5 marks)
- (d) A 0.0721 g of water vaporised at 150 °C and 755 mmHg pressure occupied a volume of 140 cm³. Show that the relative molecular mass of water vapour proves the formula for steam. (2.5 marks)

4(a) Relative density of a gas is the ratio of the density of a gas to the density of hydrogen gas.

i) Normal density is the ratio of mass of a gas per unit volume.

$$\begin{aligned} \text{(b)} \quad \text{Vapour density } V.D. &= \frac{\text{Density of gas}}{\text{Density of hydrogen gas}} \\ &= \frac{\text{mass of one mole of gas}}{\text{mass of equal mole of hydrogen gas}} \end{aligned}$$

$$\begin{aligned} \text{But} \quad & \\ \text{mass of one mole} &= \text{molar mass of gas} \\ &= \frac{\text{molar mass of gas}}{\text{molar mass of hydrogen gas}} \end{aligned}$$

$$\text{M.M.} \quad \text{molar mass of hydrogen gas} = 2.0 \text{ mol}$$

$$V.D. = \frac{\text{molar mass of gas}}{2.0 \text{ mol}}$$

$$\therefore \text{molar mass of gas} = 2 \times V.D.$$

∴ Relative molecular mass of gas = 2 × vapour density

4@i) from ideal gas equation

$$PV = nRT$$

$$PV = \frac{M}{Mr} RT$$

$$Mr = \frac{M RT}{PV}$$

where $Mr = \text{apparent molecular mass}$

$P = \text{pressure}$

$V = \text{volume}$

$T = \text{temperature}$

$$\text{Given: } T = 40^\circ\text{K},$$

$$P = 1 \text{ atm}$$

$$M = 2.94 \text{ g/mol}$$

$$R = 0.0221$$

$$\begin{aligned} Mr &= \frac{2.94 \times 0.0221 \times 40}{1} \\ &= 29.198 \\ &= 90.9 \text{ mol} \end{aligned}$$

\therefore Apparent molecular weight is 90.9/mol

i) Actual molecular weight of CH_3COOH

$$= (12 + 3 + 12 + 1) + 2$$

$$= 60 \text{ g/mol}$$

\therefore Apparent molecular weight of ethanoic acid is greater than actual because ethanoic acid undergoes association in aqueous solution.

4. (a) From ideal gas equation
 $PV = nRT$

DVZ M a-

$$Mr = \frac{m \rho T}{PV}$$

10

MZ 0'0721

$$T = 150^\circ C = 429 \text{ K}$$

$$V_3 = 14.3 \text{ cm}^3 = 14.3 \times 10^{-3} \text{ m}^3$$

$\beta = 0.56 \text{ Nm}^{-1}$

MW2 0°74' x 0°0821 x 423

760 x 10^{-3}

- 19 -

Since the relative molecular mass of water obtained from ideal gas equation equal to that of the actual (H_2O) molecular mass.

In Extract 4.1, the candidate managed to define relative density and normal density of a gas, and was able to calculate the apparent molecular weight of ethanoic acid. He/she also correctly explained why the apparent molecular weight of ethanoic acid was greater than the actual relative molecular mass.

2016 PAST PAPERS

4. (a) State why was it necessary to modify the ideal gas equation and show how the modified equation looks like. Define all symbols in the equation. (4 marks)

(b) Briefly explain why beyond certain temperatures gases cannot be liquefied. (2 marks)

(c) One mole of diethyl ether occupies 1.5 litres at 227 °C. Calculate the pressure if the Van der Waals constants for diethyl ether are: $a = 17.38 \text{ atm} \cdot \text{litre}^2 \text{mol}^{-1}$ and $b = 0.134 \text{ litre mol}^{-1}$. (4 marks)

$\Delta p =$ ① It was necessary to modify the ideal gas equation because the force of attraction between the molecules of the gas is considered and also the volume of the molecule of the gas is not negligible.

The modified equation

$$\left(P + \frac{n^2 a}{V^2}\right)(V - b n^2) = n R T$$

Where -

P = Pressure of gas in the container

n = number of mole

V = Volume of the gas in the container

a and b are the constants of the deviation from the Ideal to real gas.

$\Omega =$

T = Change in Temperature in the gas container.

② When the temperature rises also the kinetic energy of the gas molecular increases so the result the gas molecules move far apart.

From each other in the randomly motion following one another and with the way of the consumer in that stage it is impossible for the molecule of the gas to come again and form liquid.

(c)

(i)

Name system

$$\text{Number of mol} (n) = 1$$

$$\text{Volume } (V) = 1.5 \text{ dm}^3$$

$$\text{Temperature } (T) = 22^\circ\text{C} = 300 \text{ K}$$

$$a = 17.38 \text{ atm l/mol}^2$$

$$b = 0.134 \text{ l/mol}^2$$

$$\rho = 0.082 \text{ atm mol}^{-1}\text{K}^{-1}$$

Required to find pressure

$$\text{From } \left(P + \frac{n^2 a}{V^2} \right) (V - nb) = nRT$$

where $n = 1$

$$\left(P + \frac{a}{V^2} \right) (V - b) = RT$$

$$\left(P + \frac{17.38}{1.5^2} \right) (1.5 - 0.134) = 0.082 \times 300$$

$$(P + 7.724) (1.366) = (0.082 \times 300)$$

$$(P + 7.724) (1.366) = 41.05$$

$$1.366P + 10.551 = 41.05$$

$$1.366P = 41.05 - 10.551$$

$$1.366P = 28.499$$

$$P = 20.749$$

$$1.366$$

$$\therefore P = 22.32 \text{ atm}$$

$$\therefore \text{Pressure} = 22.32 \text{ atm}$$

2016 PAST PAPERS

5. (a) Define the following terms with reference to gases:
- critical temperature
 - critical volume
 - critical pressure.
- (3 marks)
- (b) From ideal gas equation, derive the relationship between density of a gas in grams per dm^3 , the gas pressure in atmospheres, the temperature (T) in kelvin, the relative molecular mass of a gas (Mr) and the gas constant, R .
(3 marks)
- (c) A certain dry gas is composed of 21% by volume of oxygen, 1% of argon and 78% of nitrogen.
 Find its density in gdm^{-3} at 20 °C and 98.65 kNm^{-2} pressure.
(4 marks)

S(a) (i) Critical Temperature

- Is the temperature above which a gas cannot liquefy no matter how much pressure is applied on it.

(ii) Critical volume

- Is the temperature of volume of a gas at its critical temperature.

(iii) Critical pressure

- Is the pressure required to liquefy a gas at its critical temperature.

S(b) Recall the ideal gas equation

$$PV = nRT$$

$$\text{But } n = \frac{\text{mass}}{\text{molar mass}} = \frac{M}{\text{Mr}}$$

$$PV = \frac{MRT}{\text{Mr}}$$

$$P = \frac{(M)RT}{V \text{Mr}} \quad \therefore \text{Density, } \delta = \frac{M}{V}$$

$$P = \frac{\delta RT}{\text{Mr}}$$

$$\delta = \frac{PMr}{RT}$$

Where δ = density of a gas in g per dm^3
 and all other symbols carry their indicated meaning

50

Recall, for a gas:

$$n \propto V \quad (\text{Avogadro's eqn})$$

Hence composition by volume = composition
by moles (mass)

$$n \propto m$$

Then

$$\text{M}_r = \% \text{O}_2 \times M_r \text{O}_2 + \% \text{Ar} \times M_r \text{Ar} + \% \text{N}_2 \times M_r \text{N}_2$$

$$M_r = (0.21 \times 32.0) + (40 \times 0.0) + (78 \times 28.0)$$

$$M_r = 6.72 \text{ g/mol} + 0.49 \text{ mol} + 21.64 \text{ g/mol}$$

$$M_r = 28.96 \text{ g/mol}$$

Recall

$$f = \frac{PM_r}{RT}$$

Given:

$$P = 98.65 \times 10^3 \text{ Nm}^{-2} = 0.97 \text{ atm}$$

$$M_r = 28.96 \text{ g/mol}$$

$$R = 0.0821 \text{ atm mol}^{-1} \text{ K}^{-1}$$

$$T = 20^\circ\text{C} = 293 \text{ K}$$

Then

$$f = \frac{0.97 \text{ atm} \times 28.96 \text{ g/mol}}{0.0821 \times 293}$$

$$f = 1.1678 \text{ g/dm}^3$$

The density of the gas is 1.1678 g/dm³

In Extract 5.1, the candidate answered correctly all parts of the question but gave an incomplete definition for critical volume and critical pressure. The candidate used correct formula and properly computed the molecular mass and the density of the gases inquired.

2015 PAST PAPERS

(3.5 marks)

5. (a) 60 cm³ of a certain gas was collected at 60 °C and 1.05 × 10⁵ Nm⁻². Calculate the volume of the gas at stp. (3 marks)
- (b) When 0.5 dm³ of O₂ and 1.0 dm³ of CO₂ were mixed at 27 °C, the total pressure in the vessel was found to be 1.2 atm. Calculate;
- (i) partial pressure of each gas
 - (ii) the mass of each gas.
- (7 marks)

05 (a) Data given:

$$\text{Volume of gas} = 60\text{cm}^3 = 0.06\text{L}$$

$$\text{Temperature (T)} = 60^\circ\text{C} + 273 = 333\text{K}$$

$$\text{Pressure (P)} = 1.05 \times 10^5 \text{Nm}^{-2} = 1.0363 \text{ atm.}$$

To calculate volume of the gas

at STP = ?

$$6\text{mole} = 22.4 \text{dm}^3$$

From ideal gas equation

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$n = \frac{1.0363 \times 0.06\text{L}}{0.082 \times 333}$$

$$\text{No. of mole} = 2.277 \times 10^{-3} \text{ mole}$$

$$\text{Hence number of moles} = 2.277 \times 10^{-3}$$

from the formula of

$$\text{Number of moles} = \frac{\text{Volume}}{GmV}$$

$$2.2771 \times 10^{-3} \text{ mole} = \frac{\text{Volume}}{22.4 \text{ L}}$$

$$\text{Volume} = 2.2771 \times 10^{-3} \times 22.4 \text{ L}$$

$$\text{Volume} = 0.051002 \text{ L or } 51 \text{ cm}^3$$

05 (a) Hence the volume of a gas at STP is $= 51 \text{ cm}^3$.

(b) Data given:

$$\text{Volume of O}_2 = 0.5 \text{ dm}^3$$

$$\text{Volume of N}_2 = 1.0 \text{ dm}^3$$

$$\text{Temperature (T)} = 27 + 273 = 300 \text{ K}$$

$$\text{Total pressure (P}_T) = 1.2 \text{ atm}$$

To calculate

(i) Partial pressure of each.

From ideal gas equation

$$PV = nRT$$

$$P_{\text{O}_2} = \frac{PV}{nR}$$

$$P_{\text{O}_2} = \frac{1.2 \times 0.5}{0.082 \times 300}$$

$$P_{\text{O}_2} = 0.02437 \text{ atmos}$$

$$\text{Number of moles of O}_2 = 0.02437 \text{ mole}$$

and and

$$\text{Area} = \frac{PV}{RT}$$

$$(\text{Area}) = \frac{1.2 \times 1}{0.082 \times 300}$$

$$(\text{Area}) = 0.04818 \text{ molar}$$

number of mole of $\text{CO}_2 = 0.04818$

Q5(b) $n_{\text{O}_2} = 0.02419 \text{ moles}$

$$n_{\text{CO}_2} = 0.04818 \text{ moles}$$

Total number of mole = $0.02419 + 0.04818$

$$n_T = 0.0732 \text{ mole}$$

Hence:

$$P_{\text{O}_2} = \frac{\text{Area}}{n_T} \times P_T$$

$$P_{\text{O}_2} = \frac{0.02419 \times 1.2}{0.0732}$$

$$P_{\text{O}_2} = 0.3999 \text{ atm}$$

and

$$P_{\text{CO}_2} = \frac{n_{\text{CO}_2} \times P_T}{n_T}$$

$$P_{\text{CO}_2} = \frac{0.04818 \times 1.2}{0.0732}$$

$$P_{\text{CO}_2} = 0.79967 \text{ atm}$$

∴ Hence partial pressure of oxygen
= 0.8999 atm and partial
pressure of Carbon dioxide gas
is $P(CO_2) = 0.79967$ atm.

(ii) To calculate the mass of each
gas

Ans: b/w from formula

$$\text{Number of moles} = \frac{\text{mass}}{\text{molar mass}}$$

$$n(O_2) = \frac{m(O_2)}{M(O_2)}$$

$$0.02439 = \frac{m}{32}$$

$$\underline{\text{Mass of oxygen}} = 0.78048 \text{ g}$$

and.

$$\text{Number of moles}(CO_2) = \frac{m(CO_2)}{M(CO_2)}$$

$$0.04878 = \frac{m(CO_2)}{44}$$

$$\underline{M(CO_2) = 2.146 \text{ g.}}$$

In Extract 5.1, the candidate put forward relevant formulae for the approaches he/she applied in all parts in the calculation of the values required by the question.

2015 PAST PAPERS

3. (a) Describe two assumptions of kinetic theory of gases that are not obeyed by real gases
 (2 marks)

- (b) (i) Differentiate between diffusion and effusion for gases.
 (ii) Uranium and fluorine form a gaseous compound, UF_6 . It is proposed that the ^{235}U and ^{238}U isotopes be separated by gaseous diffusion of the $^{235}\text{UF}_6$ and $^{238}\text{UF}_6$ compounds. Which gas would diffuse more rapidly, and by how much?
 (5 marks)

(c) A general equation for the breakdown of glucose in a human body can be presented as follows:



If 856 g of $\text{C}_6\text{H}_{12}\text{O}_6$ is consumed by a person over a certain period, what is the mass of CO_2 produced?
 (3 marks)

3a.	i/ The absence of intermolecular forces between molecules of a gas. ii/ Neglecting the volume of a gas molecule compared to the total volume occupied by molecules.
b.	i/ Diffusion refers to the process where the gas molecules move from a region of high concentration to the region of low concentration. While Effusion refers to the process where a gas escapes through a narrow hole.
ii/ Given	^{235}U compound, $^{235}\text{UF}_6$ and $^{238}\text{UF}_6$.
	Soln
	From Graham's law of diffusion
	$R \propto \sqrt{\frac{1}{M}}$
	From the given compounds $^{238}\text{UF}_6$ has large molar mass hence
	it will have slow rate of diffusion.

	$\therefore R_1 \propto \sqrt{\frac{1}{Mr_1}}$
	$R_2 \propto \sqrt{\frac{1}{Mr_2}}$

3 Let R_1 be for $^{137}\text{UF}_6$ and R_2 be for $^{238}\text{UF}_6$

$$Mr_1 \text{ for } ^{238}\text{UF}_6 = 235 + 19 \times 6 = 349 \text{ g/mol}$$

$$Mr_2 \text{ for } ^{238}\text{UF}_6 = 238 + 19 \times 6 = 352 \text{ g/mol}$$

$$\therefore \frac{R_1}{R_2} = \sqrt{\frac{Mr_2}{Mr_1}}$$

$$\frac{R_1}{R_2} = \sqrt{\frac{352}{349}}$$

$$R_1/R_2 =$$

$$R_1 = 1.0043 R_2$$

\therefore The compound will have its diffusion which is greater by a factor of 1.0043 of the other compound.

Q) Given.



Given mass combined per one portion is 856 g.

Required to find mass CO_2 produced.

Soln

From the equation

$$\text{Total mass of } \text{C}_6\text{H}_{12}\text{O}_6 = 180 \text{ g.}$$

$$6\text{CO}_2 = 264 \text{ g.}$$



$$x = 1255.47 \text{ g.}$$

\therefore The mass of CO_2 produced is 1255.47 g.

In Extract 3.1, the candidate responded concisely to the question and arranged the work properly with appropriate formulas and calculations

4.0 RELATIVE MOLECULAR MASSES IN SOLUTION

2021 PAST PAPERS

3. (a) Calculate the partial vapour pressure of water in a mixture of 36 g of water and 32 g of methanol at 298 K, if the vapour pressure of pure water at 298 K is 3.2 kPa. (4 marks)
- (b) A candle wax is approximately a non-volatile organic compound with molecular formula C₂₂H₄₆ and soluble in carbon tetrachloride. Calculate the vapour pressure of a solution made by dissolving 10 g of the wax in 40 g of carbon tetrachloride at 23 °C, if the carbon tetrachloride has a vapour pressure of 100 mmHg at 23 °C. (4 marks)
- (c) Comment on the observation that, further dilution of 0.1 M KCl solution causes the observed relative molecular mass to approach the theoretical value 37.3. (2 marks)

3.	(a) Given that
	Mass of water (m_{H_2O}) = 36 g
	Mass of methanol (m_M) = 32 g
	Number of moles of water
	$n_{H_2O} = \frac{\text{mass of water}}{\text{molar mass of water}}$
	$n_{H_2O} = \frac{m}{M_p} n_{H_2O} = \frac{m_{H_2O}}{M_p}$
	$n_{H_2O} = \frac{36}{18} = 2 \text{ mol}$
	$M_p = (2 + 16) \text{ g/mol} = 18 \text{ g/mol}$
	$n_M = \frac{\text{mass of methanol}}{\text{molar mass of methanol}}$

$$\text{methyl alcohol} (\text{CH}_3\text{COOH}) = (12+3+16+1) \text{ mol} = 32 \text{ mol}$$

$$n_{\text{H}_2\text{O}} = 22.9 = 1 \text{ mol}$$

$$32 \text{ mol}$$

$$n_{\text{H}_2\text{O}} = 1 \text{ mol}$$

$$\text{mole fraction of water } x_{\text{H}_2\text{O}} = \frac{n_{\text{H}_2\text{O}}}{n_{\text{H}_2\text{O}} + n_{\text{CH}_3\text{COOH}}}$$

$$x_{\text{H}_2\text{O}} = 2 \text{ mol} = \frac{2}{32+1} = 0.67$$

$$X_{\text{H}_2\text{O}} = 0.67$$

$$\text{partial pressure of water} = X_{\text{H}_2\text{O}} \cdot P_{\text{H}_2\text{O}}$$

$$P_{\text{H}_2\text{O}} = X_{\text{H}_2\text{O}} \cdot P_{\text{H}_2\text{O}}$$

$$P'_{\text{H}_2\text{O}} = 0.67 \times 3.2 \text{ kPa}$$

$$P'_{\text{H}_2\text{O}} = 2.144 \text{ kPa}$$

∴ Partial vapour pressure of water is 2.144 kPa

(b) Given that

$$\text{Mass of wax (mw)} = 105$$

$$\text{Mass of carbon tetrachloride (mc)} = 40.5$$

3. Vapour pressure of carbon tetrachloride = 7 mm Hg

$$\text{From Raoult's Law } \Delta P = X_{\text{Cu}} \cdot P_{\text{Cu}}$$

$$\text{Number of moles of wax (nw)} = \frac{\text{mass (mw)}}{\text{molar mass}}$$

$$\text{Molar mass of CCl}_4 = (12+35.5 \times 4) = 154.5 \text{ g/mol}$$

$$M_r \text{ of CCl}_4 = 154.5 \text{ g/mol}$$

$$\text{Number of moles } n_w = \frac{105}{154.5} = 0.67 \text{ mol}$$

$$\text{Number of moles of carbon tetrachloride}$$

$$n_c = \frac{\text{mass (mc)}}{\text{molar mass (Mr)}}$$

$$\text{Molar mass of CCl}_4 = (12+35.5 \times 4) = 154.5 \text{ g/mol}$$

$$M_r \text{ of CCl}_4 = 154.5 \text{ g/mol}$$

$$\text{Number of moles } n_c = \frac{40.5}{154.5} = 0.26 \text{ mol}$$

$$n_c = 0.26 \text{ mol}$$

mole fraction of solute

$$X_{\text{Cu}} = \frac{n_w}{n_w + n_c}$$

$$X_{\text{Cu}} = 0.67 / (0.67 + 0.26)$$

$$X_{\text{Cu}} = 0.67 / 0.93$$

$$X_{\text{Cu}} = 0.72$$

$$\Delta P = X_{\text{Cu}} \cdot P_{\text{Cu}}$$

$$\Delta P = 0.72 \times 70 \text{ mm Hg} = 50.4 \text{ mm Hg}$$

$$\Delta P = P_{\text{atm}} - P_{\text{soln}}$$

$$P_{\text{atm}} = P_{\text{Cu}} - \Delta P$$

$$P_{\text{atm}} = 70 \text{ mm Hg} - 50.4 \text{ mm Hg}$$

$$P_{\text{atm}} = 19.6 \text{ mm Hg}$$

∴ The vapour pressure of the solution is 19.6 mm Hg

∴	From the dilution law $cV = \text{constant}$ since there is further dilution the dissociation of the KCl solution assumed to be 1. (it totally dissociate) From equation $\text{KCl} \rightarrow \text{K}^+ + \text{Cl}^-$ $n=2$ (aq) (aq) (aq)
	Since $\alpha = 1$. Recall $\alpha = \frac{i-1}{n-1}$
	$\alpha = 1 - 1$
	$i = \alpha + 1 = 1 + 1 = 2$
	$i = 2$
	But $i = \frac{\text{Expected Molar mass}}{\text{observed molar mass}}$
	Observed molar mass = $\frac{\text{Expected}}{i}$
	Expected Molar mass $\text{KCl} = (39 + 35.5)\text{g/mol}$
	Molar mass $= 74.5\text{ g/mol}$
	Observed Molar mass = $\frac{74.5\text{ g/mol}}{2} = 37.25\text{ g/mol}$
	∴ Observed Molar mass be 37.25 g/mol

Extract 3.1: A sample of correct responses in question 3

2020 PAST PAPERS

8. (a) (i) Differentiate between cryoscopic constant and ebullioscopic constant. (2 marks)
(ii) Derive an expression relating the van't Hoff factor (i) and the degree of dissociation (α). (2 marks)
(iii) Briefly, explain the effect of degree of dissociation of a solute on the boiling point of a solution. (1 mark)
- (b) What mass of ethylene glycol, $\text{C}_2\text{H}_6\text{O}_2$, the main component of antifreezing agent which must be added to a 10.0L of water to produce a solution for use in a car radiator, that freezes at -23.3°C ? Assume that the density of water is exactly 1 g/mL and cryoscopic constant is $1.86^\circ\text{C kg/mol}$. (4 marks)
- (c) A 0.120 g of haemoglobin, the protein which carries oxygen in the blood was dissolved in 200 cm³ of benzene at 20°C . The solution exerted an osmotic pressure of 25.6 Pa. Find the relative molecular mass of haemoglobin. (3 marks)
- (d) A 1% solution of sodium chloride freezes at -0.604°C . Calculate the degree of dissociation of the sodium chloride if the molal freezing point depression constant for water is $1.86^\circ\text{C kg/mol}$. (3 marks)

Q

a)

i) cryoscopic constant is the freezing point depression obtained when one mole of ^{non-volatile} solute is dissolved in a solvent of the kilogram (1000g) while Ebulloscopic constant is the boiling point elevation obtained when one mole of ^{one non-volatile} solute is dissolved into a solution containing one Kilogram (1000g) of a solvent.

ii) expression relating vant Hoff's Factor (γ) and degree of dissociation (α)

Consider



Initial: 1 0 0

At time = t 1 - α αx αy

Total number of moles initially $n_i = 1$ = Number moles expected

Total number of moles after time t n_f = Number of moles obtained

$$n_f = 1 - \alpha + (\alpha x + \alpha y) \text{ or } 1 - \alpha + \alpha(x+y) = n_f$$

$$n_f = 1 + \alpha(N-1)$$

From:

γ = observed colligative property
expected colligative property

$\gamma = \frac{n_f}{n_i}$ = Observed number of moles

Expected number of moles

$$\gamma = \frac{1 + \alpha(N-1)}{1}$$

$$\gamma - 1 = \alpha(N-1)$$

$$\alpha = \frac{\gamma - 1}{N-1}$$

\therefore Relationship between γ and α is

$$\alpha = \frac{\gamma - 1}{N-1}$$

Q 9)

a) The effect of degree of dissociation of a solute on the boiling point of a solution is that if dissociation increases number of molecules hence colligative properties; thus boiling point of a solution is raised (here Δ boiling point elevation).

$$\text{b) Volume of water } V = 10 \times 10^3 \text{ cm}^3 = 10000 \text{ cm}^3$$

$$\text{Density of water } \rho = 1 \text{ g/ml} = 1 \text{ g/cm}^3$$

$$\text{Cryoscopic constant } K_f = 1.86^\circ\text{C kg/mol}$$

From Raoult's law

$$\Delta T = \frac{k_f \times m \times 1000}{M_r \times \rho \times V}$$

$$Wt = \rho V$$

$$\Delta T = \frac{k_f \times m \times 1000}{M_r \times \rho \times V}$$

$$m = \frac{\Delta T \times M_r \times \rho \times V}{k_f \times 1000}$$

$$M_r \text{ of } \text{C}_2\text{H}_6\text{O}_2 = (12 \times 2 + 6 + 16 \times 2) = 62 \text{ g/mol}$$

$$\Delta T = 27.3^\circ\text{C} = 27.3^\circ\text{C}$$

$$\text{Then } m = 27.3^\circ\text{C} \times 0.29 \text{ mol} \times 1 \text{ g/cm}^3 \times 10000 \text{ cm}^3 \\ 1.86^\circ\text{C kg/mol} \times 1000$$

$$m = 7766.67 \text{ g}$$

\therefore Mass required is 7,766.67 g of $\text{C}_2\text{H}_6\text{O}_2$

$$\text{c) Given } m = 0.12 \text{ g}, V = 200 \text{ cm}^3 = 200 \times 10^{-6} \text{ m}^3$$

$$T = 70^\circ\text{C} = 293 \text{ K}; P = 25.6 \text{ Pa}$$

8

c)

$$\text{From } PV = nRT$$

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

$$M_r = \frac{mRT}{PV} = \frac{(0.12 \times 8.314 \times 29)}{25.6 \times 200 \times 10^{-6}} \text{ g/mol}^{-1}$$

$$M_r = 57,066.328 \text{ g/mol}$$

$$\therefore M_{\text{Molar mass}} = \underline{\underline{57,066.328 \text{ g/mol}^{-1}}}$$

d)

$$\text{freezing point depression } \Delta T = 0.604$$

$$\text{freezing point depression constant } K_f = 1.86 \text{ K kg/mol}$$

From Raoult's law

$$\Delta T = \frac{K_f \times m \times 1000}{M_r \times w_t}$$

$$\text{but } m = \frac{1}{100} M_r$$

$$\text{and } w_t = \frac{99}{100} m_f$$

$$\text{then } \Delta T = \frac{K_f \times 1000 \times 1000}{M_r \times \frac{99}{100} M_r}$$

$$\Delta T = \frac{K_f \times 1000}{99 M_r}$$

$$M_r = \frac{K_f \times 1000}{99 \Delta T} = \frac{(1.86 \times 1000)}{99 \times 0.604} \text{ g/mol}$$

$$\underline{\underline{M_r = 31.106}}$$

8 d)

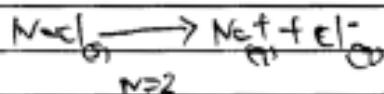
Molar mass observed $M_r = 31.1062 \text{ mol}$ Normal molar mass of NaCl $M = 58.53 \text{ mol}$ From Raoult-Hoff's Factor $\alpha = \frac{\text{observed molar mass}}{\text{expected molar mass}}$ $\alpha = \frac{58.53 \text{ mol}}{31.1062 \text{ mol}}$

$$\alpha = 1.881$$

Also from

$$\alpha = \frac{C-1}{N-1}$$

for NaCl:



$$\text{Then } \alpha = \frac{C-1}{N-1} = \frac{1.881 - 1}{2-1} = 0.881$$

 $\therefore \text{Degree of dissociation } \alpha = 0.881$

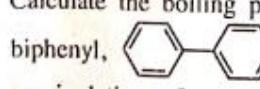
Extract 8.1: A sample of appropriate responses in question 8

2019 PAST PAPERS

5. (a) (i) Boiling point of a solvent is elevated by addition of a non-volatile solute. Briefly explain. (1 mark)
- (ii) Arrange the following aqueous solutions in order of increasing freezing point: 0.01 M $\text{C}_2\text{H}_5\text{OH}$; 0.01 M $\text{Ba}_3(\text{PO}_4)_2$; 0.01 M Na_2SO_4 ; 0.01 M KCl; 0.01 M Li_3PO_4 . Provide clear reason(s) for the arrangement. (2 marks)

- (b) You are provided with the following information:

Entry	Value
Molal boiling point constant for benzene, K_b	$2.53 \text{ } ^\circ\text{C kg mol}^{-1}$
Molal freezing point constant for benzene, K_f	$5.12 \text{ } ^\circ\text{C kg mol}^{-1}$
Boiling point of benzene	$80.1 \text{ } ^\circ\text{C}$
Freezing point of benzene	$5.5 \text{ } ^\circ\text{C}$

Calculate the boiling point and freezing point of a solution made by dissolving 2.40 g of biphenyl, , in 75.0 g of benzene, . Show your work clearly including manipulations of units. (3 marks)

- (c) An aqueous solution of urea, $\text{CO}(\text{NH}_2)_2$ at a concentration of 1.754 g dm^{-3} is isotonic at the same temperature with an aqueous solution of sugar at a concentration of 10.00 g dm^{-3} . Calculate the relative molecular mass of sugar. (4 marks)

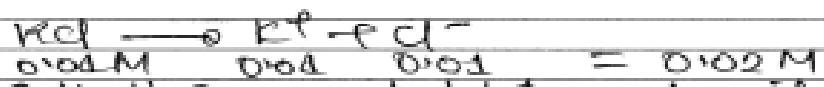
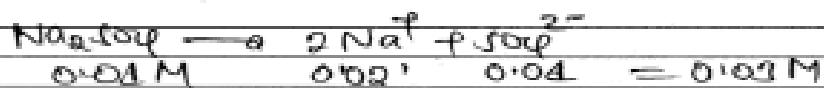
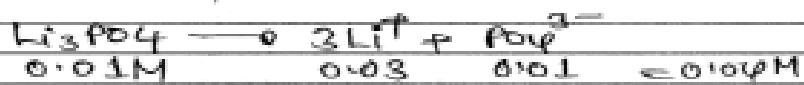
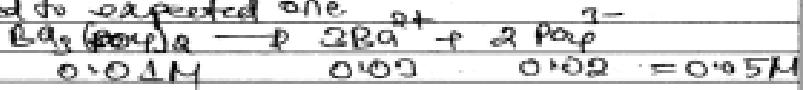
5(i) When non-volatile solute is added the concentration of solvent decrease and some occupy the surface of solvent and hence escaping tendency of solvent decreases and hence amount of temperature required to make vapour pressure of solution equal to atmospheric pressure increases and hence boiling point is elevated. As non-volatile solute lower vapour pressure.

(ii)



Increasing freezing point

5 This is because of dissociation of the solution as the observed depression of freezing point is different compared to expected one.



CaHCO_3 is non-electrolyte or dissociates partially and hence it remains 0.01 M.

$\Delta T \propto C$
and hence high C means more depression in freezing point

(b)

Data given

$$K_b = 2.47, K_f = 5.18, T_0 = 80.4^\circ\text{C}$$

$$T_f = 50^\circ\text{C}, M_1 = 246, M_{12} = 767$$

calc

(D) Boiling point

$$\Delta T = K_b m$$

but molality = $\frac{n \cdot \text{moles}}{\text{mass of solvent}}$

$$\text{molar mass} = \frac{\text{mass}}{\text{molar mass}}$$

$$\text{molar mass of biphenyl} = 254.9/\text{mol}$$

$$5 \quad n \text{ moles} = \frac{0.49}{1549 \text{ mol}} \\ = 0.00321558 \text{ moles}$$

$$\text{Molality} = \frac{0.00321558 \text{ moles}}{0.75 \times 10^3 \text{ kg}} \\ = 0.00428 \text{ molal.}$$

$$\Delta T = K_b \times m.$$

$$0.7 = 2.53 \times$$

$$\Delta T = 2.53 \text{ kg mol}^{-1} \times 0.00428 \text{ molal.}$$

$$\Delta T = 0.5257^\circ\text{C}$$

$$T_f = T_0 + \Delta T.$$

$$T_f = 80.1^\circ\text{C} + 0.5257^\circ\text{C.}$$

$$= 80.6257^\circ\text{C.}$$

Boiling point of solution = 80.6257°C

freezing point

$$\Delta T = K_f \cdot m.$$

$$\Delta T = \frac{K_f \cdot m_{\text{sol}}}{M_r \times M_{\text{av}}}.$$

$$\Delta T = 5.12 \text{ kg mol}^{-1} \times 0.49 \cdot \\ 0.49 \text{ mol} \times 0.75 \times 10^3 \text{ kg.}$$

$$\Delta T = 1.0639^\circ\text{C.}$$

$$T_f = T_0 - \Delta T.$$

$$T_f = 5.5^\circ\text{C} - 1.0639^\circ\text{C} \\ = 4.4361^\circ\text{C.}$$

Freezing point of solution = 4.4361°C

5(c)

Data given
Concentration = 1.7549 dm^{-3}
 $C_2 = 10.09 \text{ g/dm}^3$

$$Mr = ?$$

~~for 2~~

From osmotic pressure law.

$$\Pi \cdot V = nRT$$

$$\Pi = CRT$$

For urea

$$\Pi_1 = CR_1 \quad \dots \quad (i)$$

For sugar

$$\Pi_2 = C_2 R T \quad \dots \quad (ii)$$

But for isotonic $\Pi_1 = \Pi_2$.

$$C_1 R T = C_2 R T$$

but RT are constant

$$C_1 = C_2$$

$$\left(\frac{\text{mass Concentration}}{\text{molar mass}} \right)_1 = \left(\frac{\text{mass Concentration}}{\text{molar mass}} \right)_2$$

$$\text{molar mass of urea} = 12 + 16 + (16 + 2) \times 2$$

$$= 60 \text{ g/mol}$$

$$\frac{1.7549 \text{ dm}^{-3}}{60 \text{ g/mol}} = \frac{10.09 \text{ g/dm}^3}{Mr_2}$$

$$1.7549 \text{ M}_2 = 10 \times 60 \text{ g/mol}$$

$$M_2 = \frac{(10 \times 60) \text{ g/mol}}{1.7549}$$

$$Mr_2 = 342.0759 \text{ mol}$$

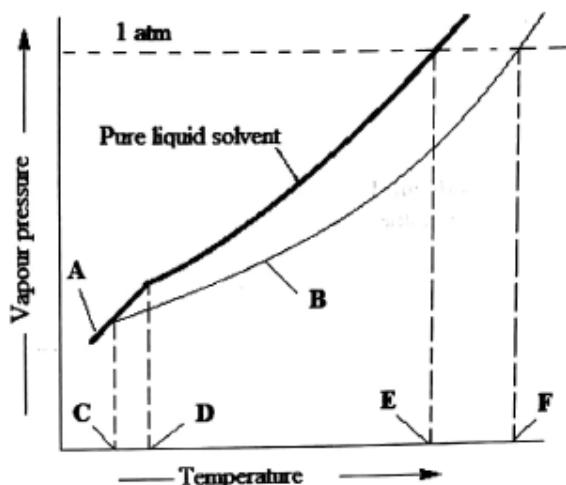
\therefore Relative molecular mass of sugar = 342.

Extract 5.2: A sample of correct responses in question 5.

2018 PAST PAPERS

7. (a) State the four colligative properties useful for determination of molecular masses. (2 marks)

(b) Study the following diagram and then answer the subsequent questions.



- (i) Give the titles of the locations labeled **A**, **B**, **C**, **D**, **E** and **F**. (3 marks)
(ii) Give the names for the difference given by **F-E** (i.e., **F** minus **E**) and **D-C** (i.e., **D** minus **C**). (2 marks)
- (c) Ammonium chloride solution was dissolved in pure water to make a 25% solution. Calculate the temperature at which this solution freezes. The molal boiling point constant for $\text{NH}_4\text{Cl} = -1.86 \text{ }^{\circ}\text{C}$ kg mol^{-1} ? In your calculations, assume that the addition of the salt does not change the volume of water; show your work clearly including manipulations of units. (3 marks)

- 7 a) i) Lowering of water pressure
 ii) Boiling point elevation
 iii) Freezing point depression
 iv) Osmotic pressure.

- 7 b), c) A: Solid phase of solvent
 B: Liquid phase of solution
 C: Freezing temperature of solution
 D: Freezing temperature of pure solvent
 E: Boiling temperature of pure solvent
 F: Boiling temperature of solution.

$(F-E)$: Boiling point elevation.
 $(D-C)$: Freezing point depression.

c. Let

The mass of water = 100g
 Mass of Ammonium chloride = 25g.

From

$$\Delta T_b = K_b \times \frac{m_s}{M_{s_1} \times w_s}$$

$$K_b = 1.86^\circ\text{C kg mol}^{-1}$$

$$M_{s_1} = 53.5 \text{ g mol}^{-1}$$

$$w_s = 100 \text{ g}$$

$$\Delta T_b = -1.86 \times 25 \times$$

$$= -1.86^\circ\text{C kg mol}^{-1} \times 25 \text{ g} \times 100$$

$$53.5 \text{ g mol}^{-1} \times 100 \text{ g}$$

$$\Delta T_b = -8.69^\circ\text{C}$$

7 c)

From

$$\Delta T = \bar{T}_{f(w)} - \bar{T}_{f(m)}$$

$$\Delta T_b = \bar{T}_{f(m)} - \bar{T}_{f(w)}$$

$$= -8.69^\circ\text{C} - \bar{T}_{f(m)} - 0^\circ\text{C}$$

$$\bar{T}_{f(m)} \approx -8.69^\circ\text{C}$$

' The solution freezes at -8.69°C .

In Extract 7.2 the candidate mentioned correctly the colligative properties, labeled the diagram appropriately in part (b) and demonstrated a good approach in calculating the value of temperature change in part (c).

2018 PAST PAPERS

3. (a) Nitrobenzene ($C_6H_5NO_2$) and water form a mixture of immiscible liquids which boils at $99\text{ }^{\circ}\text{C}$. Calculate the percentage by mass of nitrobenzene in the distillate when the mixture is distilled at $1.013 \times 10^5\text{ Pa}$ given that the vapour pressure of water at $99\text{ }^{\circ}\text{C}$ is $9.749 \times 10^4\text{ Pa}$. Show your work clearly including manipulations of units.[Molar masses: nitrobenzene = 123 g mol^{-1} , Water = 18 g mol^{-1}] **(2 marks)**

(b) Water (b.p. $100\text{ }^{\circ}\text{C}$) and phenylamine (b.p. $184\text{ }^{\circ}\text{C}$) form a mixture of immiscible liquids that boils at $98\text{ }^{\circ}\text{C}$. With the aid of a diagram, show how steam distillation of this mixture can be achieved. **(3 marks)**

(c) Show how the equation for the partition law of solute “ x ” dissolved in two immiscible solvents A and B will be represented when solute “ x ”: **(1.5 marks)**

 - (i) Associate in solvent A and remain normal in solvent B.
 - (ii) Dissociate in solvent A and associate in solvent B.
 - (iii) Dissociate in solvent B and remain normal in solvent A.

(d) Fifty (50) grams of the acid are dissolved in one litre (1000 cm^3) of water. The distribution coefficient of the acid between ether and water is 3. A volume of 1000 cm^3 of ether is available for use in the extraction process. Two experiments were performed to extract acid from water. In the first experiment, 1000 cm^3 of ether were used once, i.e., single extraction. In the second experiment, two extractions were performed, each using 500 cm^3 of ether. Compare the amounts of the acid left in the aqueous solution in each case and recommend the best method to extract the acid from water. **(3.5 marks)**

Page 5 of 7

8	<p>(a) $\frac{P_{nitr}}{P_{total}} = \frac{N_{nitr}}{N_{total}}$</p> $\frac{P_n}{P_w} = \frac{M_n}{M_w} \cdot \frac{M_{nitr}}{M_{water}}$ $P_n + P_w = 1.013 \times 10^5 \text{ Pa}$ $P_n = 1.013 \times 10^5 - P_w$ $P_n = (1.013 \times 10^5 - 9.749 \times 10^4) \text{ Pa}$ $P_n = 3810 \text{ Pa}$ $\frac{M_n}{M_w} = \frac{P_n}{P_w} \cdot \frac{M_{nitr}}{M_{water}}$ $= \frac{3810 \text{ Pa}}{1.013 \times 10^5} \cdot \frac{3810 \text{ Pa}}{9.749 \times 10^4 \text{ Pa}} \times \frac{123 \text{ g/mol}}{18 \text{ g/mol}}$ $\frac{M_n}{M_w} = \frac{468630}{1754820}$ $\frac{M_n}{M_w} = 0.2671$ $M_{nitr} = 0.0 \quad M_n = 0.2671 M_w$ $M_{Total} = M_w + M_n = 1.2671 M_w$ $\% M_n = \frac{M_n}{M_{Total}} \times 100 = \frac{0.2671 M_w \times 100}{1.2671 M_w} = 21.1\%$ <p>The percentage by mass of nitrobenzene is 21.1%</p>
---	--

8	(b)	<p>Steam from steam chamber</p> <p>mixture of water and phenylamine</p> <p>cold water in</p> <p>cooling system</p> <p>cold water out</p> <p>pure phenyl amine</p>
<p>A steam from steam chamber is allowed to enter into vessel containing water and phenylamine where as it leave with phenylamine, on passing a cooling system phenylamine cools and liquidify into the collecting vessel.</p>		
	(b) (i)	$K_d = \frac{[x] \text{ in solvent B}}{\sqrt[n]{[x] \text{ in solvent A}}}$ <p>n - is degree of association</p>
	(ii)	$(iii) K_d = \frac{[x] \text{ in Solvent A}}{[x] \text{ in solvent B} (1 - \alpha)}$ <p>α - is the degree of dissociation</p>
	(d)	$(d) W_r = W_0 \left(\frac{V_b}{V_b + V_a K_d} \right)^n$ <p>where W_r - remained solute in residue solvent</p> <p>W_0 - is the initial amount of solute in extractive solvent</p> <p>V_b and V_a - are volumes of residue and extractive solvent respectively</p> <p>n - number of extraction</p> <p>K_d - partition coefficient</p>

8	(d) 1 st case $V_b = 1000 \text{ cm}^3$ $V_a = 1000 \text{ cm}^3$ $n = 1$
	$w_r = 50 \left(\frac{1000}{1000 + 3(1000)} \right)^1 \text{ g}$
	$w_r = \frac{50}{4} \text{ g}$
	$w_r = 12.5 \text{ g}$
	2 nd case $V_b = 1000 \text{ cm}^3$ $V_a = 500 \text{ cm}^3$ $n = 2$
	$w_r = 50 \left(\frac{1000}{1000 + 3(500)} \right)^2 \text{ g}$
	$w_r = 8 \text{ g}$
	By using single extraction volume remain is 12.5g while by using two extracts volume remain is 8g Best method to extract is by using the two extraction where each extraction uses 500cm ³

In Extract 8.2, the candidate carried out the calculations in parts (a), (c), and (d) in the appropriate manner and gave the required description of the process of steam distillation in part (b).

2017 PAST PAPERS

5. (a) (i) Give the meaning of osmotic pressure of a solution. (1 mark)
(ii) Briefly explain in terms of vapour pressure why the freezing point of a solution is lower than that of a pure solvent. (1 mark)
- (b) When water and ice are mixed, the temperature of the mixture is 0 °C, but, if methanol (CH₃OH) and ice are mixed, a temperature of +10 °C is readily attained. Explain why the two mixtures show such different temperature behaviours. (2 marks)
- (c) Calculate the molar mass of Y given that a solution of 60 g of Y in 1 dm³ of water exerts an osmotic pressure of $4.31 \times 10^5 \text{ Nm}^{-2}$ at 25 °C. (2.5 marks)
- (d) A 0.003 kg of acetic acid (CH₃COOH) is added to 500 cm³ of water. If 23% of the acid is dissociated, what will be the depression in freezing point? (K_f for water = 1.86 °Ckg/mol, density of water = 0.997 g/cm³). (3.5 marks)

- 5 a) i) Osmotic pressure of a solution is the minimum pressure which should be applied in the solution to prevent the movement of solvent molecules through the solution through a semi-permeable membrane
- ii) Freezing point of a solution is the temperature in which liquid and solid phases have the same vapour pressure.
- On addition of non-volatile solute to a pure solvent, the surface of the pure solvent will be occupied by the molecules of non-volatile solute hence reducing the escaping tendency of the molecules of the pure solvent hence resulting to lowering of the vapour pressure of the pure solvent.
 - As a result low temperature will be required for liquid and vapour phase of the solution to have the same vapour pressure. Therefore the freezing point of a solution is lower than that of a pure solvent.

5 b) The mixture of methanol and ice, at temperature of $+10^{\circ}\text{C}$ is readily attained because methanol is highly volatile, when added to water ice increases the vapour pressure of ice hence the vapour pressure of the solution is higher than pure ice. This results to increase in freezing point of ice to $+10^{\circ}\text{C}$. While the mixture of ice and water lowers the temperature of 0°C due to absence of non-volatile solute.

c) By using $\Pi = \frac{nRT}{V}$

Where symbols stand their usual meaning

$$T = 298\text{ K.}$$

$$V = 1\text{ dm}^3.$$

$$\text{but } 1\text{ dm}^3 = 1 \times 10^{-3}\text{ m}^3.$$

$$V = 1 \times 10^{-3}\text{ m}^3.$$

$$\Pi = 4.31 \times 10^5 \text{ Nm}^{-2}.$$

$$R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$n = \frac{\Pi V}{RT}$$

$$n = \frac{4.31 \times 10^5 \text{ Nm}^{-2} \times 1 \times 10^{-3}\text{ m}^3}{8.31 \text{ J mol}^{-1} \text{ K}^{-1} \times 298\text{ K}}$$

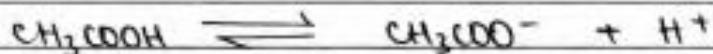
$$\text{number of moles of Y (n_y)} = 0.174 \text{ moles.}$$

$$5) c) \eta_y = \frac{\text{mass of } Y \text{ (g)}}{\text{Molar mass of } Y \text{ (gmol}^{-1}\text{)}}$$

$$\begin{aligned} \text{Molar mass of } Y \text{ (gmol}^{-1}\text{)} &= \frac{\text{mass of } Y \text{ (g)}}{\eta_y} \\ &= \frac{60}{0.174} \\ &= 344.83 \text{ gmol}^{-1} \end{aligned}$$

\therefore The molar mass of Y is 344.83 gmol^{-1}

d) The dissociation of acetic acid.



Initially	1	0	0
At equilibrium	$1 - \alpha$	α	α

$$i = 1 - \alpha + \alpha + \alpha$$

$$i = 1 + \alpha$$

$$i = 1 + 0.23$$

$$i = 1.23$$

Where i is vant Hoff's factor.

By freezing point depression:

$$\Delta T_f = i K_b m$$

$$\text{molality} = \frac{\text{number of moles of solute (n)}}{\text{mass of solvent in kg}}$$

5 a) $n = \frac{0.003 \times 10^3}{60 \text{ g mol}^{-1}} \text{ g}$

$n = 0.05 \text{ mole}$

\therefore The number of moles of acetic acid is 0.05 mole.

$$\text{Mass of solvent (water)} = \text{Density} \times \text{volume}$$

$$= 0.997 \text{ g cm}^{-3} \times 500 \text{ cm}^3 \\ = 498.5 \text{ g}$$

$$\Delta T_f = 1.23 \times 1.86 \text{ }^\circ\text{C kg mol}^{-1} \times 1000 \times 0.05 \\ 498.5$$

$$\Delta T_f = 0.229 \text{ }^\circ\text{C}$$

\therefore The depression in freezing point is 0.229 $^\circ\text{C}$.

In Extract 5.1, the candidate correctly responded to every part of the question. All the work is clearly shown.

2016 PAST PAPERS

8. (a) Pure ethanol, ($\text{C}_2\text{H}_5\text{OH}$) boils at 78.3 $^\circ\text{C}$ and at pressure of 760 mmHg. When 2.51 g of an organic compound M (Mwt = 146 g) is dissolved in 100 g of ethanol, the solution boils at 85.9 $^\circ\text{C}$ and 760 mmHg.

- (i) Explain why the boiling point of ethanol was raised. (5 marks)
- (ii) Calculate the molal boiling point, K_b for ethanol.

(b) A solution was prepared by dissolving 2.40 g of biphenyl ($\text{C}_{12}\text{H}_{10}$) in 75.00 g of benzene. Calculate the boiling point of the solution given that $K_b = 2.53 \text{ }^\circ\text{C}/\text{m}$; $K_f = 5.12 \text{ }^\circ\text{C}/\text{m}$; boiling point of pure benzene = 80.1 $^\circ\text{C}$ and freezing point of pure benzene is 5.5 $^\circ\text{C}$. (5 marks)

8(c)

SolnData Given

$$B.P_1 (\Theta_1) = 78.3^\circ C, \text{ pressure } (P) = 960 \text{ mmHg} \\ = 1 \text{ atm}$$

$$\text{Mass of M (m)} = 2.519$$

$$\text{Molar mass (M}_M\text{)} = 146 \text{ g}$$

$$\text{Mass of solvent ethanol (M}_e\text{)} = 100 \text{ g} = 0.1 \text{ kg}$$

$$B.P_2 (\Theta_2) = 85.9^\circ C, \Delta T = 85.9 - 78.3 = 7.6^\circ C$$

- i) The boiling point of ethanol was raised due to the following reason:
- The solute molecules added lowers the vapour pressure of the solution due to lowering the rate of escaping of ethanol molecules above the surface.
 - The lowering of vapour pressures makes the solution boil at temperature greater than normal boiling point.

8(a) ii) required: $k_b = ?$

But $\Delta T \propto m\delta\text{latity} (m)$.

$$\Delta T = k_b m \rightarrow m = \frac{\Delta T}{k_b}$$

Mass of solution in kg.

$$m = \frac{m}{M_F \times \text{mass of solute}}$$

$$\Delta T = m k_b$$

$$\frac{m}{M_F \times M_V \text{ in kg.}}$$

$$k_b = \frac{\Delta T \times M_F \times M_V \text{ in kg.}}{m}$$

(ii)

$$k_b = \frac{(7.6) \times (4.6 \times 0.1)}{2.51} = 44.2 \text{ K mol}^{-1} \text{ kg.}$$

$$k_b = 44.2 \text{ K mol}^{-1} \text{ kg.}$$

\therefore The initial boiling point $k_b = 44.2 \text{ K mol}^{-1} \text{ kg.}$

8(b) Data Given.

$$\text{mass of Glycerine (m)} = 2.4 \text{ g.}$$

$$\text{Molar mass (M}_F) = (12 \times 12 + 10) = 154.8 \text{ g/mol.}$$

$$\text{mass of solvent + benzene (M}_V) = 75 \text{ g} = 0.075 \text{ kg}$$

$$B.P (B) = ?, k_b = 2.53^\circ\text{C/m}, k_f = 5.12^\circ\text{C}$$

$$\Delta T = \frac{k_b \times m}{M_F \times M_V \text{ in kg.}} = \frac{2.53 \times 2.4}{154 \times 0.075} = 0.526^\circ\text{C}$$

$$\Delta T = 0.526^\circ\text{C}$$

$$B - 80.1 = 0.526^\circ\text{C}$$

8(c) $B = 80.63^\circ\text{C.}$

\therefore The boiling point of solution is 80.63°C

Extract 8.1 shows a response from the candidate who performed well in this question. All workings are correct and clearly shown.

2016 PAST PAPERS

6. (a) Give two differences between osmosis and diffusion. (2 marks)
- (b) When 15 g of glucose ($C_6H_{12}O_6$) was dissolved in 50 g of a certain solvent with a relative molecular mass of 180 g, the freezing point was depressed by 8.0°C . Using these data, calculate the freezing point depression constant, for the solvent. (2 marks)
- (c) An aqueous solution of sugar containing 19.15 g of sugar per dm^3 has osmotic pressure of $136,300 \text{ Nm}^{-2}$ at 20°C . Calculate the relative molecular mass of sugar. (6 marks)

6(a) Differences between osmosis and diffusion	
Osmosis	diffusion
i. Is a movement of solvent molecule from a region of high water potential to the region of low water potential through a selective permeable membrane	i. Is the movement of gas or any substance from a region of high concentration to the region of low concentration
ii. It involves selective permeable membrane	ii. It does not involve permeable membrane
(b) Solution:	
Given that:	
$\text{Mass of solute (M}_s\text{)} = 15\text{g}$	
$\text{mass of solvent (M}_A\text{)} = 50\text{g}$	
$\text{relative molecular mass of solvent (m}_A\text{)} = 180\text{g/mol}$	
$\text{depressed freezing point} = 8.0^{\circ}\text{C}$	
Asked to find freezing point depression constant for solvent.	
From	
$\Delta T_f = \frac{k_f M_B}{m_A m_B} \times 1000$	
$\text{Let } M_{\text{molar mass solute}} = 180\text{g/mol}$	
$8.0^{\circ}\text{C} = \frac{k_f \times 15\text{g}}{180\text{g/mol} \times 50\text{g}} \times 1000$	
$k_f = \frac{8.0^{\circ}\text{C} \times 180\text{g/mol} \times 50\text{g}}{15\text{g} \times 1000}$	
$k_f = 4.8 \text{ }^{\circ}\text{C} \text{ g mol}^{-1}$	
$\therefore \text{freezing Point depression} = 4.8 \text{ }^{\circ}\text{C g mol}^{-1}$	

6 (a) Solution

Given that -

$$\text{mass of solute} = 19.155 \text{ g}$$

$$\text{Volume of solution} = 1 \text{ dm}^3$$

$$\text{Osmotic pressure} = 136,300 \text{ N m}^{-2}$$

$$\text{Temperature } T = 20^\circ\text{C} = 20 + 273 = 293 \text{ K}$$

Asked to find molar mass of sugar.

From

$$\Pi V = nRT$$

$$\Pi = \frac{n \cdot RT}{m \cdot V}$$

$$M_r = \frac{m \cdot R \cdot T}{\Pi V}$$

but volume should be changed into m^3

$$= 10 \text{ dm}^3$$

$$M_r = \frac{19.155 \times 1.8 \cdot 10^{-3} \text{ mol}^{-1} \text{ K}^{-1} \times 293}{136300 \text{ N m}^{-2} \times 10}$$

Let change the pressure given in atmosphere

$$136300 \text{ N m}^{-2} = 1.34517$$

$$= \frac{19.155 \times 1.8 \cdot 10^{-3} \text{ atm mol}^{-1} \text{ K}^{-1} \text{ dm}^3 \times 293 \text{ K}}{1.34517 \text{ atm}}$$

$$= 342.4 \text{ g/mol}$$

$$\therefore \text{Relative molecular mass of sugar} = 342.4 \text{ g/mol}$$

Extract 6.1 shows that the candidate was able to differentiate between osmosis and diffusion and correctly calculated the freezing point depression constant for the solvent and relative molecular mass of sugar.

2015 PAST PAPERS

7. (a) 0.01 M aqueous solution of 92.5% NaCl is dissociated at 18 °C. Calculate the osmotic pressure (π) of this solution at the given temperature. (5 marks)
- (b) When 5.8 g of acetic acid ($\text{CH}_3\text{CO}_2\text{H}$) was dissolved in 90 g of benzene (C_6H_6) the freezing point depression was found to be 3.8 °C. Calculate the degree of association of acetic acid in benzene, given that acetic acid dimerizes in benzene and $K_f = 5.1 \text{ }^\circ\text{C mol}^{-1}\text{kg}^{-1}$. (5 marks)

7.1	Data given: $M = 60 \text{ g/mol}$ of $\text{CH}_3\text{CO}_2\text{H}$ $m_b = 90 \text{ g}$ $K_f = 5.1 \text{ }^\circ\text{C}^{-1}$ $\Delta T = 3.8 \text{ }^\circ\text{C}$ From $\Delta T = K_m \cdot m$ $m = \frac{\Delta T}{K_m}$ $m = \frac{3.8}{5.1}$ Molarity = $3.8/60$
-----	---

Extract 7.1 is a response to part (b) of the question where a candidate presented data and few calculations which were not of any use to give a correct response.

5.0 TWO COMPONENT LIQUID SYSTEMS

2021 PAST PAPERS - 2

2. (a) Write a mathematical expression for distribution law. (2 marks)
- (b) Compound P has a partition coefficient of 4.00 between ethoxyethane and water. Given that 2.0 g of P is obtained in solution, in 50 cm³ of water, calculate the mass of P that can be extracted from the aqueous solution by
 (i) 50 cm³ of ethoxyethane.
 (ii) two successive extractions of 25 cm³ of ethoxyethane each. (8 marks)
- (c) Comment on the variation of the amount extracted in (b) (i) and (ii). (2 marks)
- (d) When 500 cm³ of an aqueous solution containing 4 g of a solute G per litre was shaken with 100 cm³ of pentan-1-ol, 1.5 g of the solute G was extracted. Assuming a molecular state of the solute remains the same in both solvents, calculate:
 (i) The partition coefficient of the solute G between pentan-1-ol and water.
 (ii) Mass of the solute G which will remain in the aqueous solution after a further shaking with 100 cm³ of pentan-1-ol. (8 marks)

Q	① Mathematical expression is :-
*	
K _d	= $\frac{\text{Concentration of solute in the upper layer}}{\text{Concentration of solute in the lower layer}}$
where:	
	K _d = Partition Coefficient
② (i) Solution:	
Given:	
K _d = 4.	
K _d = $\frac{[P \text{ in ethoxyethane}]}{[P \text{ in water}]}$.	
X = 2.0 g.	
V _w = 50 cm ³ .	
X ₁ = ?	
V _E = 50 cm ³ .	
F = ?	
From	
K _d = $\frac{[P \text{ in ethoxyethane}]}{[P \text{ in water}]}$	
K _d = $\frac{\text{mass concentration of P in ethoxyethane}}{\text{mass concentration of P in water}}$	
K _d = $\frac{FV_E}{X - FV_w}$	

Q. (b) (i).

$$Kd = \frac{F/V_e}{25-F/V_w}$$

$$4 = \frac{F/50\text{cm}^3}{25-F/50\text{cm}^3}$$

$$4 = \frac{F}{25-F}$$

$$8g - 4F = F$$

$$5F = 8g$$

$$F = 1.6g$$

The mass of P extracted from aqueous solution by 50cm^3 of ethoxyethane is 1.6 g.

(ii). solution :

From the first extraction.

$$Kd = \frac{F/V_e}{25-F/V_w}$$

$$4 = \frac{F/25\text{cm}^3}{25-F/50\text{cm}^3}$$

$$4 = \frac{F}{25-F} \times \frac{50\text{cm}^3}{25\text{cm}^3}$$

2. (b) (ii). 4

$$q = \frac{2F}{2g - F}$$

$$8g - 4F = 2F$$

$$6F = 8g$$

$$F = 1.33 g.$$

∴ For the first extraction mass of P extracted is 1.33 g.

for the second extraction

$$Kf = \frac{V_1}{m - F_{11}}$$

$$\text{Let } m = 2g - 1.33g = 0.67g.$$

$$q = \frac{F/25\text{cm}^3}{0.67g - F_1}$$

$$q = \frac{F_1}{0.67g - F_1} \times \frac{50\text{cm}^3}{25\text{cm}^3}$$

$$q = \frac{2F_1}{0.67g - F_1}$$

$$2.66g - 4F_1 = 2F_1$$

$$6F_1 = 2.66g$$

2. (b) (ii) $F_1 = 0.45 \text{ g}$.

\therefore Mass of P extracted for the second extraction
is 0.45 g .

$$\text{Total mass extracted } (F_2) = F + F_1$$

$$F_2 = 1.32 \text{ g} + 0.45 \text{ g}$$

$$F_2 = 1.78 \text{ g}$$

\therefore For two successive extractions of 25 cm^3 of ethoxy ethane each, the amount of P extracted is
1.78 g

(c). - The amount extracted in (b) (ii) is higher (1.78 g) than that extracted in (b) (i) which is (1.65 g).

This shows that on dividing the extraction solvent into small volumes and using for many successive extractions will yield much amount of salt extracted compared to using the whole volume for only one extraction. Hence two successive extractions is much efficient than single extraction.

(d) (i) Solution:

From:

since there is 4 g of G in 1 litre .

x of G would present in 800 ml

Q. (Q3).

$$x = \frac{4 \text{ g of Br} \times 500 \text{ cm}^3}{1 \text{ litre}}$$

$$\text{But } 1 \text{ litre} = 1000 \text{ cm}^3$$

$$\therefore x = \frac{4 \text{ g of Br} \times 500 \text{ cm}^3}{1000 \text{ cm}^3}$$

$$x = 2 \text{ g of Br.}$$

\therefore Mass of solute Br present in 500 cm^3 of aqueous solution is 2 g.

From:

$$K_d = \frac{\text{Mass concentration of Br in pentane-1-ol}}{\text{Mass concentration of Br in water}}$$

$$K_d = \frac{1.5 \text{ g}/100 \text{ cm}^3}{\frac{2 \text{ g}-1.5 \text{ g}}{500 \text{ cm}^3}}$$

$$K_d = \frac{1.5 \text{ g}}{2 \text{ g}-1.5 \text{ g}} \times \frac{500 \text{ cm}^3}{100 \text{ cm}^3}$$

$$K_d = 15$$

\therefore Partition coefficient of solute Br between pentane-1-ol and water is 15.

2. (d) (i) solution.

Principle:

$$K_d = \frac{\text{concentration of solute in pethrol-1-oh}}{\text{concentration of solute in water}}$$

$$15 = \frac{F}{10 \text{ cm}^3}$$

$$\frac{m-F}{10 \text{ cm}^3}$$

$$\text{But } m_2 - 2g - 1.5g = 0.5$$

$$15 = \frac{F}{0.5g - F} \times \frac{50 \text{ cm}^3}{10 \text{ cm}^3}$$

$$15 = \frac{5F}{0.5g - F}$$

$$9.5g - 15F = 5F$$

$$20F = 9.5g$$

$$F = 0.375 \text{ g.}$$

$$\text{Total solute extracted } F_1 = 1.5g + 0.375 \text{ g.}$$

$$F_1 = 1.875 \text{ g.}$$

$$\text{Mass of solute & remains MF } 2g - 1.875 \text{ g.}$$

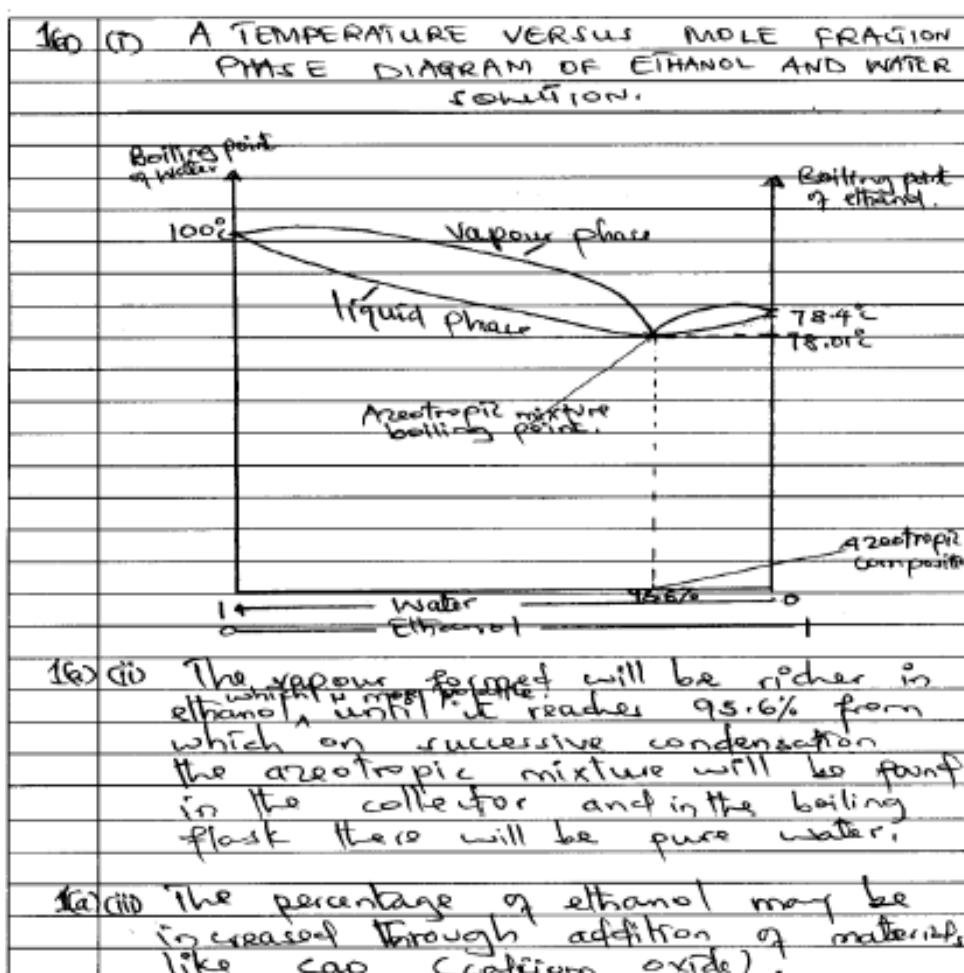
$$m_r = 0.125 \text{ g.}$$

\therefore The mass of solute of which will remain in aqueous layer after shaking is 0.125 g.

Extract 12.1: A sample of correct responses in question 2

2020 PAST PAPERS - 2

1. (a) Ethanol and water form an azeotropic mixture which boils at 78.01°C and contains 95.6% ethanol at standard pressure. If the boiling points of pure water and ethanol are 100°C and 78.4°C , respectively.
- draw and label a temperature versus mole fraction phase-diagram of ethanol and water solution. (4 marks)
 - what happens when a dilute ethanol solution of less than 50% is boiled and condensed several times? (3 marks)
 - how would you increase the percentage of ethanol after obtaining a 95.6% ethanol-water mixture? (3 marks)
- (b) When 500 cm^3 of an aqueous solution containing 4 g of a solute G per litre was shaken with 100 cm^3 of pentan-1-ol, 1.5 g of the solute G was extracted. Assuming the molecular state of the solute remained the same in both solvents, calculate:
- partition coefficient of the solute G between pentan-1-ol and water. (4 marks)
 - mass of the solute G which remained in the aqueous solution after a further shaking with 100 cm^3 of pentan-1-ol. (4 marks)
- (c) Write two practical applications of the partition law. (2 marks)



16

Data given.

$$\text{Volume of aqueous solution (V}_1\text{)} = 500 \text{ cm}^3$$

$$\text{Mass of solute g per litre (M)} = 4 \text{ g/L}$$

$$\text{Volume of pentanol (V}_2\text{)} = 100 \text{ cm}^3$$

$$\text{Mass of solute g extracted} = 1.5 \text{ g}$$

Q Distribution coefficient (k_d) = ?

from

Mass of solute in grams

$$4 \text{ g of solute } \xrightarrow{\quad} 1000 \text{ cm}^3$$

$$x? \leftarrow 500 \text{ cm}^3$$

$$x = \frac{4 \text{ g} \times 500 \text{ cm}^3}{1000 \text{ cm}^3}$$

$$x = 2 \text{ g}$$

 \therefore Mass of solute in gram = 2 g.

Then

$$\text{Distribution coefficient (k}_d\text{)} = \frac{\text{concentration of solute in upper layer}}{\text{concentration of solute in lower layer}}$$

$$k_d = \frac{1.5 \text{ g}}{100 \text{ cm}^3}$$

$$\frac{(2 - 1.5) \text{ g}}{500 \text{ cm}^3}$$

$$k_d = \frac{1.5 \text{ g}}{100 \text{ cm}^3} \times \frac{500 \text{ cm}^3}{10 \cdot 5}$$

$$k_d = 15$$

Q(i) \therefore Partition (Distribution coefficient) of solute G between pentan-1-ol and waterAns. $\therefore k_d$ will be 15.

16 (ii)

Ans

$-X-$	organic layer
$\frac{-X}{100\text{cm}^3}$	
$\frac{0.5-X}{50\text{cm}^3}$	aqueous layer

$k_d = \frac{\text{concentration of solute in upper layer}}{\text{concentration of solute in lower layer}}$

$$k_d = \frac{X \times 50\text{cm}^3}{100\text{cm}^3 \times 0.5 - X}$$

$$\frac{15}{1} = \frac{5X}{0.5 - X}$$

$$15(0.5 - X) = 5X$$

$$7.5 - 15X = 5X$$

$$\frac{7.5}{20} = \frac{20X}{20}$$

$$X = 0.375\text{g}$$

The mass of solute G remained after further shaking with 100cm^3 of pentan-1-ol will be

$$0.5 - 0.375\text{g}$$

$$= 0.125\text{g}$$

\therefore Mass of solute G which will remain on further shaking with 100cm^3 of pentan-1-ol = 0.125g

(b) Two practical applications of partition law are :-

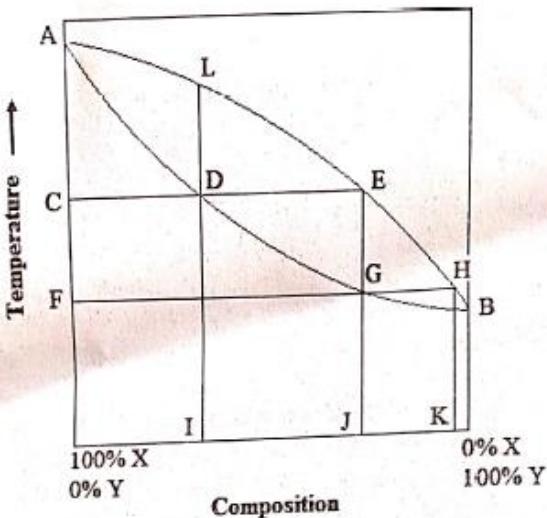
- (i) Separation of the immiscible solvents
- (ii) Extraction of solute from immiscible solvents.

Extract 11.2: A sample of correct responses in question 1

2019 PAST PAPERS

4. (a) (i) State Raoult's law regarding solutions of liquids in liquids. (1 mark)
(ii) Define azeotropic mixture. (1 mark)
(iii) Use a well labeled hand sketch to show the difference between minimum boiling point azeotropic mixture and maximum boiling point azeotropic mixture. (2 marks)
- (b) Briefly explain the meaning of the following phrases:
(i) Freezing point depression.
(ii) Boiling point elevation.
(iii) Van't Hoff's factor-*i*. (3 marks)

(c) Study the following liquid-vapour phase diagram and then answer the questions that follow.



- (i) If a liquid mixture of composition I is heated to temperature C, what will be the composition of the vapour phase? (1 mark)
(ii) If the vapour at E is cooled to temperature F, what will be the composition of the vapour phase? (1 mark)
(iii) What temperature represents the boiling point of composition J? (1 mark)

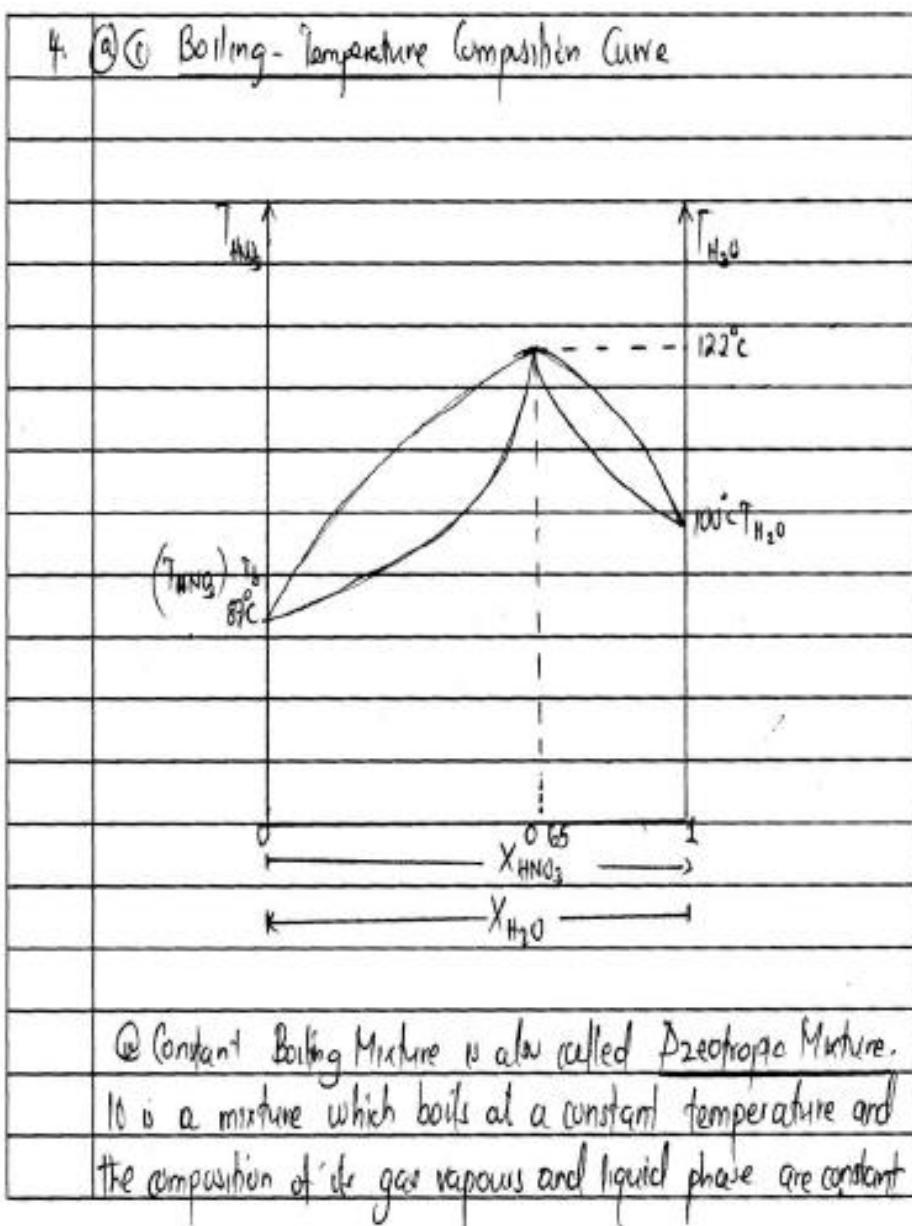
4.	<p>(i) Raoult's law</p> <p>A partial pressure of a liquid in a liquid mixture is the product of the vapour pressure of the pure liquid and the mole fraction present in a solution.</p> <p>Mathematically: $P_A' = X_A P_A$</p> <p>Where here: P_A' = Partial pressure of a liquid A X_A = Mole fraction of a liquid A P_A = Pure vapour pressure of a liquid A</p> <p>(ii) Azeotropic mixture is a mixture of liquids in which the vapour phase composition is equal to the liquid phase composition of the liquids and hence the mixture boils at constant boiling point.</p> <p>(iii)</p> <p>g) Azeotropic mixture having maximum boiling point Nitric Acid and water at 100°C</p>
----	---

q.	iii) (i) A eutectic mixture having minimum boiling point (e.g. water and methanol)
	(ii) Fractional distillation is the effect that occurs when a non-volatile solute dissolved in a liquid and results in the depression of the freezing point of the liquid, the freezing point depression depends on the amount of the solute dissolved (constant proportion)
	(iii) Boiling point elevation is; the relative solute dissolved in a liquid has an effect on the boiling point of the liquid as it hinders the escape of the particles into vapour phase and hence high temperature is needed to boil the liquid.
	(iv) Raoult's law:- i) The extent of decrease in the property (vapour pressure) of a liquid, dissolved from the real pure values of a liquid. Raoult's law:- $\frac{P - P_0}{P_0} = \text{Observed effect / Expected value}$
q.	(i) The composition of the vapour will be at T
	(ii) The composition of the vapour phase will be at T
	(iii) The boiling point of composition is T

Extract 4.1: A sample of correct responses in question 4.

2018 PAST PAPERS

4. Given the information that, nitric acid ($T_b = 87^\circ\text{C}$) and water form a constant boiling mixture of $T_b = 122^\circ\text{C}$ and composition 65% by mass nitric acid:
- Draw the boiling temperature – composition curve for nitric acid and water. (4 marks)
 - State what is meant by a constant boiling point mixture. (1 mark)
 - (i) State Raoult's law. (1 mark)
 - Identify whether the mixture of nitric acid and water shows a positive or a negative deviation from Raoult's law. (1 mark)
 - With reference to Raoult's law, distinguish positive deviation from negative deviation. (2 marks)
 - What interaction between nitric acid and water gives rise to this type of deviation? (1 mark)



4 (b) Raoult's law

"The vapour pressure of the volatile component above the surface of the mixture is directly proportional to its mole fraction in the mixture."

(i) The mixture shows a Negative Deviation from Raoult's law.

This is because it form a constant boiling point mixture with boiling higher than those of its constituents, hence it's a maximum boiling point azeotrope.

(ii) Positive Deviation

Show a higher tendency of forming vapours

There is an expansion in volume during it course.

Heat is evolved during it course

Negative Deviation

Show a low tendency of forming vapours.

It shows a slight contraction in volume.

Heat is absorbed during it course

(iii) Hydrogen Bonding is responsible for holding Nitric acid and water molecules together, hence they show a Negative Deviation from Raoult's law.

In Extract 4.1, the candidate correctly sketched the boiling temperature-composition curve in part (a), stated Raoult's law appropriately and gave appropriate responses to the rest of the items in part (b).

2017 PAST PAPERS

6. (a) (i) Define vapour pressure. (0.5 mark)
 (ii) Using Raoult's law of vapour pressure, show that the lowering of vapour pressure is proportional to the mole fraction of the solute. (2 marks)
- (b) Briefly explain why the solution becomes ideal when it is made more dilute. (2 marks)
- (c) Two liquids A and B form an ideal solution when mixed. At 298 K, the vapour pressure of pure A and B for a mixture of 1 mole of A and 3 moles of B are 32 kPa and 16 kPa, respectively. Calculate;
 (i) the vapour pressure of the mixture. (3 marks)
 (ii) the mole fraction of A in the vapour which is in equilibrium with the mixture. (2.5 marks)

6. (a) i) Vapour pressure;
 → Is the pressure exerted by the volatile component of the substance formed over its surface at a given temperature.

6. (a) ii) let :
 $P_N = \text{partial vapour pressure of solvent}$
 $X_N = \text{mole fraction of solvent}$
 $X_u = \text{mole fraction of solute}$
 $P_u = \text{partial vapour pressure of solute}$
 $P_{sv}^{\circ} \text{ and } P_u^{\circ} = \text{pure vapour pressure of solvent and solute}$
 $P_N = X_N P_{sv}^{\circ}$
 $P_u = X_u P_u^{\circ}$

Form of Dalton's law:

$$P_{\text{soln}} = X_V P^{\circ}_V + X_U P^{\circ}_U$$

but Solute is non-volatile
and hence $P^{\circ}_U = 0$.

$$P_{\text{soln}} = X_V P^{\circ}_V$$

but $X_V + X_U = 1$.

$$X_U X_V = 1 - X_V$$

$$P_{\text{soln}} = P^{\circ}_V - X_U P^{\circ}_V$$

$$X_U P^{\circ}_V = P^{\circ}_V - P_{\text{soln}}$$

but $P^{\circ}_V - P_{\text{soln}} = \text{lowering of vapour pressure}$

$$P^{\circ}_V - P_{\text{soln}} = \Delta P$$

$$X_U P^{\circ}_V = \Delta P$$

but P°_V is constant

$$X_U \propto \Delta P$$

∴ $\Delta P \propto X_U$ hence shown.

where ΔP is lowering of vapour pressure

X_U is mole fraction of solute.

6. (b) Because in dilute solution there is more of Solvent-Solvent force of attraction than solvent-solute force of attraction hence the Solute-Solute force of attraction are also very few thus can be neglected hence the solution behaves as an ideal solution.

> Because the forces in the solution will be explained only by solvent-solvent forces of attraction and neglecting solute-solute forces of attraction.

6. (c) If $N_A = 3$,

$$(i) N_B = 3$$

$$N_T = 4$$

$$X_A = \frac{1}{4} = 0.25$$

$$X_B = \frac{3}{4} = 0.75$$

	$P_{\text{soln}} = X_A P_A^{\circ} + X_B P_B^{\circ}$ $= 0.25 \times 32 \times 10^3 + 0.75 \times 16 \times 10^3$ $\Rightarrow 8000 + 12000$ $= 20000 \text{ Pa}$ $\therefore \text{Vapour pressure of the mixture is } 20000 \text{ Pa}$ $\text{or } 20 \text{ kPa.}$
6. (c) (ii)	$X_A^v = \frac{X_A^l P_A^{\circ}}{P_{\text{soln}}}$

6. (c) (iii)	$X_A^v = \frac{0.25 \times 32 \times 10^3}{20000}$ $= 0.4.$
	$\therefore \text{mole fraction of A in vapour is } 0.4$

In Extract 6.1, the candidate gave the correct definition of vapour pressure and showed the proportionality between the lowering of vapour pressure and the mole fraction of the solute. She/he also explained correctly why the solution becomes ideal when it is made more dilute, and properly performed all the calculations.

2017 PAST PAPERS

7. (a) (i) Briefly explain the principle of solvent extraction. (3 marks)
(ii) Compare and contrast fractional distillation from steam distillation. (3 marks)
- (b) Steam distillation of a mixture of an organic compound B and water at 98 °C and pressure of 101320 Pa yielded a distillate containing 31.6% by volume of B. The vapour pressure of pure water at this temperature is 94260 Pa. The densities of B and water are 0.961 g/cm³ and 1.000 g/cm³, respectively. Calculate the relative molecular mass of B. (4 marks)

7 d) Solvent extraction This is the method of removing solute in a first solvent by introducing another solvent which is immiscible to the first one, and solute is allowed to distribute itself in the mixture, then extracting solute is removed with significant amount of solute, for successive extraction extractive solvent is added again and again and finally solute is removed the first solvent.

- i) - Both fraction distillation and Steam distillation are applied in solution.
- Both involved in separating mixture of two liquids with different boiling point.
- Both affected by concentration differences.

Fraction distillation	Steam distillation.
- Separable solution which is miscible	- Separable solution which is immiscible
- molecular weight of liquid not be higher than that of the water	- Molecular ^{weight} of a liquid should be higher than that of the water.

7 b) data given

Pressure of organic compound B was 101320

Pressure of water was 540260

Percentage by volume of Compound B was 31.6%

Density of compound B was 0.961 g/cm³

Density of water was 1 g/cm³.
from.

$$\text{Volume of Compound B} = \frac{31.6\%}{100\%} \times 100$$

$$\text{Volume of Compound B} = 31.6 \text{ cm}^3.$$

Then

from

$$\text{Volume of solution} = \text{volume of } D + \text{volume of H}_2\text{O}$$

$$100 - 31.6 = \text{volume of H}_2\text{O}$$

$$\therefore \text{volume of H}_2\text{O} = 68.4 \text{ cm}^3.$$

To calculate mass of water and compound B
from

$$\text{Compound B} = \frac{M}{V}$$

$$0.96 \times 31.6 = M$$

$$\text{Mass of Compound B was } 30.3 \text{ g.}$$

$$\text{Thus mass of water} = 68.4 \text{ g}$$

From

$$\frac{P_B}{P_{H_2O}} = \frac{m_B}{m_{H_2O}}$$

but

$$P_T = P_B + P_O$$

$$107200 - 94260 = P_B$$

$$\text{Pressure of B} = 7060 \text{ mmHg}$$

$$\frac{7060}{94260} = \frac{m_B}{m_{H_2O}} \times \frac{M_{H_2O}}{M_B}$$

Extract 7.2 shows a part of good answer from the candidate who was able to explain the principle of solvent extraction. She/he was able to compare and contrasted fractional distillation from steam distillation and correctly performed all the calculations.

2016 PAST PAPERS

7. (a) Give a brief molecular explanation of positive and negative deviations from Raoult's law for non-ideal binary solutions. (2 marks)
- (b) What vapour pressure lowering difference(s), if any, would you expect for 1 M aqueous solutions of (i) CaCl_2 , (ii) KBr and (iii) Na_3PO_4 ? Justify your answer. (3 marks)
- (c) Benzene (C_6H_6) and toluene ($\text{C}_6\text{H}_5\text{CH}_3$) form an ideal solution. At 333 K, the vapour pressure of pure benzene is 53.3 kPa while that of pure toluene is 26.7 kPa. If a solution is prepared by mixing two moles of benzene and three moles of toluene;
- find the partial pressure of each component in the vapour phase in equilibrium with this solution at 333.
 - calculate the total vapour pressure of the solution.
 - explain which substance will be collected from the top of the distillation column, if a mixture of benzene and toluene is distilled. (5 marks)

7	<p>(a) - Positive deviation from Raoult's law occurs when intermolecular forces of attraction of solution becomes less than either of intramolecular forces of attraction in pure components.</p> <p>- Negative deviation from Raoult's law occurs when intramolecular forces of attraction of solution is greater than intramolecular forces of attraction in pure liquids.</p> <p>(b) . The lowering of vapour pressure follows this trend</p> $\text{Na}_3\text{PO}_4 > \text{CaCl}_2 > \text{KBr}$ <p style="text-align: right;">↓</p> <p style="text-align: center;">Decrease in lowering in vapour pressure-</p> <ul style="list-style-type: none"> This difference is due to dependency on lowering in vapour pressure with amount of solute added. Since Na_3PO_4 dissociates to give four mole of ion it lowers vapour pressure of solution much than all other solutes given. Also since CaCl_2 dissociates to give three mole of ions it will lower vapour pressure at high amount than KBr which gives only two ions e.g.
---	---

7 (b) ~~distillation~~

(c) Given

- Vapour pressure of pure benzene, $P_B^{\circ} = 52.3 \text{ kPa}$.
- Vapour pressure of pure toluene, $P_T^{\circ} = 26.7 \text{ kPa}$.
- Number of moles of benzene, $n_B = 2$
- Number of moles of toluene, $n_T = 3$

\Rightarrow From Raoult's law, $P_{\text{soln}} = P_B^{\circ} x_B + P_T^{\circ} x_T$.

$$\text{But } n_T = n_B + n_T = 2 + 3 = 5.$$

$$x_B = \frac{n_B}{n} = \frac{2}{5} = 0.4$$

$$x_T = \frac{n_T}{n} = \frac{3}{5} = 0.6$$

Then, Partial pressure of benzene, $P_B = P_B^{\circ} x_B$.

$$P_B = P_B^{\circ} n_B = 52.3 \text{ kPa} \times 0.4$$

$$\therefore P_B = 21.32 \text{ kPa}$$

Also, Partial pressure of toluene, $P_T = P_T^{\circ} x_T$.

$$P_T = 26.7 \text{ kPa} \times 0.6$$

$$\therefore P_T = 16.02 \text{ kPa}.$$

\therefore Partial pressure of benzene is 21.32 kPa.

Partial pressure of toluene is 16.02 kPa.

\Rightarrow From: $P_{\text{soln}} = P_B + P_T$

$$= 21.32 \text{ kPa} + 16.02 \text{ kPa}.$$

\therefore Total pressure of solution is 37.34 kPa .

7 (c) Benzene will be collected from the top of the distillation flask since it has higher positive vapour pressure compared to toluene.

In Extract 7.1 the candidate properly explained positive and negative deviations from Raoult's law for non-ideal binary solutions and correctly differentiated the vapour pressure lowering differences for 1M solution of the given compounds. The candidate also correctly

calculated the required answers for the items of part (c) and finally concluded that benzene will be collected from the top.

2015 PAST PAPERS

(1 mark)

6. (a) Give any four differences between a positive and a negative non-ideal solutions. (4 marks)
- (b) Equal moles (0.5 moles) of benzene and toluene were mixed to form an ideal solution. Calculate the fraction of benzene and toluene in the second vapour given that, $P^{\circ}_{\text{benz.}} = 95.1 \text{ mmHg}$ and $P^{\circ}_{\text{tol.}} = 28.4 \text{ mmHg}$. (6 marks)

Q	(a) Differences between Positive and negative non-ideal solution
---	--

Positive non-ideal solution	Negative non-ideal solution
(i) It has a tendency of forming high vapour pressure than expected for ideal solution.	It has a tendency of forming vapour pressure than that expected for ideal solution.
(ii) There is expansion in volume during mixing of the pure solvent.	There is contraction in volume of the mixture solution.
(iii) Preparation involves absorption of heat energy.	- It release heat energy in preparation.
(iv) Form azeotropic mixture on distillation with lower boiling point than pure solvents.	- It forms azeotrope mixture & higher boiling point than pure solvents.

(b) Data given:
$n_{\text{tol.}} = 0.5 \text{ mol}$
$n_{\text{benz.}} = 0.5 \text{ mol}$
$P^{\circ}_{\text{benz.}} = 95.1 \text{ mmHg}$
$P^{\circ}_{\text{tol.}} = 28.4 \text{ mmHg}$
From Raoult's law:
$P^{\circ}_{\text{benz.}} = X_{\text{benz.}} \times P^{\circ}_{\text{benz.}}$
For $X_{\text{benz.}} = \frac{0.5}{0.5 + 0.5} = 0.5$

6 (b)

$$P_{benz} = 0.5 \times 95.1 \text{ mmHg}$$

$$P_{benz} = 47.55 \text{ mmHg}$$

$$X_{tot} = 1 - 0.5 = 0.5$$

$$P_{tot} = X_{tot} \times P_{total}$$

$$= 0.5 \times 22.4$$

$$= 11.2 \text{ mmHg}$$

$$P_T = (14.2 + 47.55) \text{ mmHg}$$

$$P_T = 61.75 \text{ mmHg}$$

from?

composition of air

$$X_{benz} = \frac{P_{benz}}{P_T}$$

$$X_{benz} = \frac{47.55}{61.75} = 0.77$$

$$X_{tot} = \frac{P_{tot}}{P_T}$$

$$X_{tot} = \frac{14.2}{61.75} = 0.23$$

air in lungs

$$P'_{benz} = 0.77 \times 95.1$$

$$= 73.28 \text{ mmHg}$$

$$P_{tot} = 0.23 \times 22.4$$

$$= 5.23 \text{ mmHg}$$

$$P_T = 73.28 + 5.23 = 78.51 \text{ mmHg}$$

G	(b)
	P_{benz}
	P
	fraction benzene = $\frac{P_{\text{benz}}}{P_T}$
	$= \frac{73.93}{74.76} = 0.98$
	Fraction toluene = $1 - 0.98 = 0.02$
	\therefore fraction benzene in vap. second vapour = 0.98 and fraction toluene in second vapour = 0.02

The answers in Extract 6.1 indicate that the candidate had sufficient knowledge on Two Component Liquid Systems as he/she presented his/her work correctly and systematically.

2015 PAST PAPERS

2. (a) State the distribution law. (1 mark)
- (b) The concentration of a solute X in water was found to be 8.5 g/dm³ at room temperature. 100 cm³ of this solution was shaken with 50 cm³ of methyl benzene until equilibrium was obtained. The organic layer was separated and found to contain 0.8 g of X.
- Calculate the distribution coefficient of X between methyl benzene and water.
 - What further mass of X would be removed from the aqueous layer if it was shaken with a further 50 cm³ of methyl benzene?
 - Calculate the mass of X extracted if 100 cm³ of methyl benzene was used at once instead of using 50 cm³ twice. Which is the more efficient extraction process? Give reason for your answer. (9 marks)

Ques	Distribution law. "If the solute is dissolved into two immiscible liquids, it will tend to distribute itself in such a way that, the ratio of concentrations of the solute in one liquid to the ratio of concentration of the solute in another liquid is constant and the constant is called partition constant".
(b)	Calculation Illustration.
	<p>A = Initial mass of X y = mass of X in benzene.</p>
	<p>Remember;</p> $\frac{8.5 \text{ g of } X}{A} = \frac{100 \text{ cm}^3}{100 \text{ cm}^3}$ $A = 0.85 \text{ g}$ <p>on separation of the organic layer; 0.85 g of X were found = y.</p>
	<p>Now;</p> <p>(i) Distribution coefficient = $\frac{\text{concentration of } X \text{ in methylbenzene}}{\text{concentration of } X \text{ in water}}$</p> <p>But; $K_d = \frac{y}{A-y} = \frac{0.8}{0.85-0.8} = 16.7 \text{ dm}^3$.</p> <p>$L_w = \frac{A-y}{100 \text{ cm}^3} = \frac{0.85-0.8}{0.1} = 0.5 \text{ dm}^3$.</p> <p>Distribution coefficient = $\frac{L_w}{K_d} = \frac{0.5}{16.7} = 0.03$</p> <p>$\therefore = 32$.</p>

2(b) (i)

$\frac{m}{0.05}$	- methyl benzene
$\frac{m}{0.05-m}$	water
m	total

$$\text{Distribution coefficient} = \frac{C_b}{C_w}$$

$$\text{where; } C_b = \frac{m}{0.05} = \frac{m}{0.05 \text{ dm}^3}$$

$$\text{and } C_w = \frac{m}{0.05-m} = \frac{m}{0.1 \text{ dm}^3}$$

$$\text{Then; } 32 = \frac{m}{0.05}$$

$$\frac{m}{0.05} = \frac{m}{0.05-m}$$

$$\frac{m}{0.05} \times \frac{0.1}{(0.05-m)} = 32$$

$$\frac{0.1m}{0.05(0.05-m)} = 32$$

$$32 \times 0.05(0.05-m) = 0.1m$$

$$1.6(0.05-m) = 0.1m$$

$$0.08 - 1.6m = 0.1m$$

$$\frac{0.08}{1.7} = \frac{m}{0.1}$$

$$m = 0.047 \text{ g}$$

\therefore Further mass removed = 0.047 g.

2(b) (ii)

$\frac{m}{0.05}$	- methyl benzene
$\frac{m}{0.05-m}$	water
m	total

Ans.

$$\text{Distribution coefficient} = 32 = \frac{C_b}{C_w}$$

$$C_b = \frac{m}{0.05} = \frac{m}{0.05 \text{ dm}^3}$$

$$C_w = \frac{A-n}{100\text{cm}^3} = \frac{A-n}{0.1\text{dm}^3}$$

But; $A = 0.85\text{g}$

$$\therefore C_w = \frac{0.85-n}{0.1}$$

Then;

$$\frac{0.85-n}{0.1} = 32$$

$$\frac{0.85-n}{0.85-n} = 32$$

$$\frac{n}{0.85-n} = 32$$

$$32(0.85-n) = n$$

$$27.2 - 32n = n$$

$$\frac{33n}{33} = \frac{27.2}{33}$$

$$n = 0.824\text{ g}$$

\therefore The mass of X removed = 0.824 g .

Now, ^{because} For the first extraction, total mass extracted = $0.8 + 0.824 = 0.847\text{ g}$.

And; For the last single extraction = 0.824 g .

\therefore The more efficient extraction process is the multiple

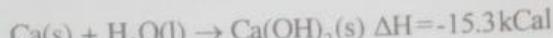
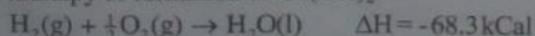
24(iii) extraction as it extract more solute (0.847 g) as compared to the single extraction which extracts less amount of solute (0.824 g)

Response in Extract 2.2 signifies that the candidate was acquainted with the distribution law and the related calculations. The candidate used diagrams to show how the solute X distributes and carried out correctly all calculations involved leading to anticipated conclusion that extraction using 50 cm^3 twice was more efficiency compared to single extraction of using 100 cm^3 .

6.0 ENERGETICS

2021 PAST PAPERS

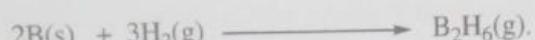
4. (a) Using the following chemical equations and values provided for each, calculate the enthalpy of formation of $\text{Ca}(\text{OH})_2$.



(5 marks)



- (b) Diborane, (B_2H_6) is synthesized in the laboratory according to the equation:



Calculate the heat change for the synthesis of diborane from its elements, using the enthalpies provided in the following table:

S/N	Reaction	$\Delta H \text{ kJ}$
1	$2\text{B}(\text{s}) + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow \text{B}_2\text{O}_3(\text{s})$	- 1273
2	$\text{B}_2\text{H}_6(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow \text{B}_2\text{O}_3(\text{s}) + 3\text{H}_2\text{O}(\text{g})$	- 2035
3	$\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$	- 286
4	$\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$	44

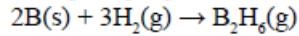
(5 marks)

4	(b) Heat change for the synthesis in eqn (iii) unbalanced.
	$3\text{H}_2(\text{g}) + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow 3\text{H}_2\text{O}(\text{l}) \quad \Delta H = -286$
	Add eqn (iii) with reverse of eqn (iv x3)
	$\begin{cases} 3\text{H}_2(\text{g}) + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow 3\text{H}_2\text{O}(\text{l}) & -286 \\ 1. 3\text{H}_2\text{O}(\text{g}) \rightarrow 3\text{H}_2\text{O}(\text{l}) & +132 \end{cases}$
	$3\text{H}_2(\text{g}) + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow 3\text{H}_2\text{O}(\text{g}) \quad -418 \text{ kJ} \quad (\text{v})$
	Add eqn (v) with eqn (i)
	$\begin{cases} 2\text{B}(\text{s}) + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow \text{B}_2\text{O}_3(\text{s}) & -1273 \text{ kJ} \\ 3\text{H}_2(\text{g}) + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow 3\text{H}_2\text{O}(\text{g}) & -418 \text{ kJ} \end{cases}$
	$2\text{B}(\text{s}) + 3\text{H}_2(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow \text{B}_2\text{O}_3(\text{s}) + 3\text{H}_2\text{O}(\text{g}) = -1691 \text{ kJ}$
	Followed by reverse of eqn (ii)
	$\begin{cases} 2\text{B}(\text{s}) + 3\text{H}_2(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow \text{B}_2\text{O}_3(\text{s}) + 3\text{H}_2\text{O}(\text{g}) & -1691 \text{ kJ} \\ \text{B}_2\text{O}_3(\text{s}) + 3\text{H}_2\text{O}(\text{g}) \rightarrow \text{B}_2\text{H}_6(\text{g}) + 3\text{O}_2(\text{g}) & 2035 \text{ kJ} \end{cases}$
	$2\text{B}(\text{s}) + 3\text{H}_2(\text{g}) \rightarrow \text{B}_2\text{H}_6(\text{g}) \quad 344 \text{ kJ}$
	' . Heat change for synthesis of diborane is 344 kJ

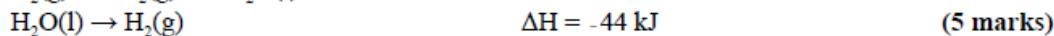
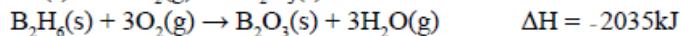
Extract 4.1: A sample of good responses in question 4

2020 PAST PAPERS

4. (a) Diborane, (B_2H_6) is very reactive such that it was once considered as a possible rocket fuel for U.S space programs. The overall equation for the synthesis of diborane is:



Use the following data to calculate the enthalpy change of formation of B_2H_6 from its elements:



- (b) When 100 cm^3 of 1 M KOH and 100 cm^3 of 1 M HCl were mixed in a calorimeter, temperature rose by 6.25 K. Given that the heat capacity of the calorimeter was 95 J/K and specific heat capacity of the solution mixture was 4.2 J/gK, calculate the standard enthalpy of neutralization. Assume that the density of the solution is equal to the density of water. (5 marks)

4(a)	$\begin{array}{c} \text{SOLN} \\ \text{let } \Delta H \\ 2B(s) + \frac{3}{2}O_2(g) \rightarrow B_2O_3(s) \quad \Delta H = -1273 \text{ kJ} \quad (i) \\ B_2H_6(s) + 3O_2(g) \rightarrow B_2O_3(s) + 3H_2O(g) \quad \Delta H = -2035 \text{ kJ} \quad (ii) \\ H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l) \quad \Delta H = -286 \text{ kJ} \quad (iii) \\ H_2O(l) \rightarrow H_2(g) \quad \Delta H = -44 \text{ kJ} \quad (iv) \end{array}$
------	--

	Then
	reverse equation (ii)
B_2O_3	$\xrightarrow{(s)} \xrightarrow{(g)} B_2O_2 \xrightarrow{(s)} -202 \text{ kJ}$
$2B$	$\xrightarrow{(s)} \xrightarrow{(s)} B_2O \xrightarrow{(s)} \Delta H = -127.3 \text{ kJ} \dots \text{(b)}$
$3H_2$	$\xrightarrow{(s)} \xrightarrow{(g)} H_2O \xrightarrow{(s)} \Delta H = 285 \text{ kJ} \dots \text{(c)}$
$2H_2O$	$\xrightarrow{(s)} \xrightarrow{(g)} -2H_2 \xrightarrow{(s)} \Delta H = +44 \text{ kJ} \dots \text{(d)}$
	add equation a+b+c+d
$2B$	$\xrightarrow{(s)} \xrightarrow{(s)} B_2H_6 \xrightarrow{(s)}$
	$\Delta H_f = 36 \text{ kJ}$
	\therefore Heat formation is 36 kJ

4.6	given $\Delta T = 6.25 \text{ K}$
	volume of base, $V_b = 100 \text{ cm}^3$
	moles of base, $M_b = 1 \text{ M KOH}$
	volume of acid, $V_a = 100 \text{ cm}^3$
	moles of acid, $M_a = 1 \text{ M}$
	from reaction
	$KOH + HCl \xrightarrow{(aq) (aq)} KCl + H_2O$
	moles ratio KOH : HCl : H_2O is 1 : 1 : 1
	now
	$n_b = \text{Molarity} \times \text{volume of base}$
	$n_b = 1 \text{ M} \times 100 \times 10^{-3} \text{ dm}^3$
	$n_b = 0.1 \text{ mol}$
	and
	$n_a = 1 \text{ M} \times 100 \times 10^{-3} \text{ dm}^3$
	$n_a = 0.1 \text{ mol}$
	so since
	$n_b : n_a : n_{H_2O} = 0.1 : 0.1$
	$n_{H_2O} = 0.1 \text{ mol}$
	from
	$H = (\text{Heat capacity of calorimeter} + M_f C_f \Delta T) / \text{content}$
	$= ((9.5 \times 84 \times 6.25) + 1 \text{ mol} \times 100 \times 4.23 \times 6.25)$
	$= (783 \text{ J/K} \times 6.25) + 0 \times 100 \times 4.23 \times 6.25$
	$H = -5862.5 \text{ J}$
	$\text{Answer} = \Delta H = -5862.5 \text{ J/mol}$
	Then

4.6	$\Delta H_{\text{neutral}} = -5862.5 \text{ J}$
	$\frac{0.1 \text{ mol}}{-5862.5 \text{ J/mol}}$
	-58.675 kJ/mol

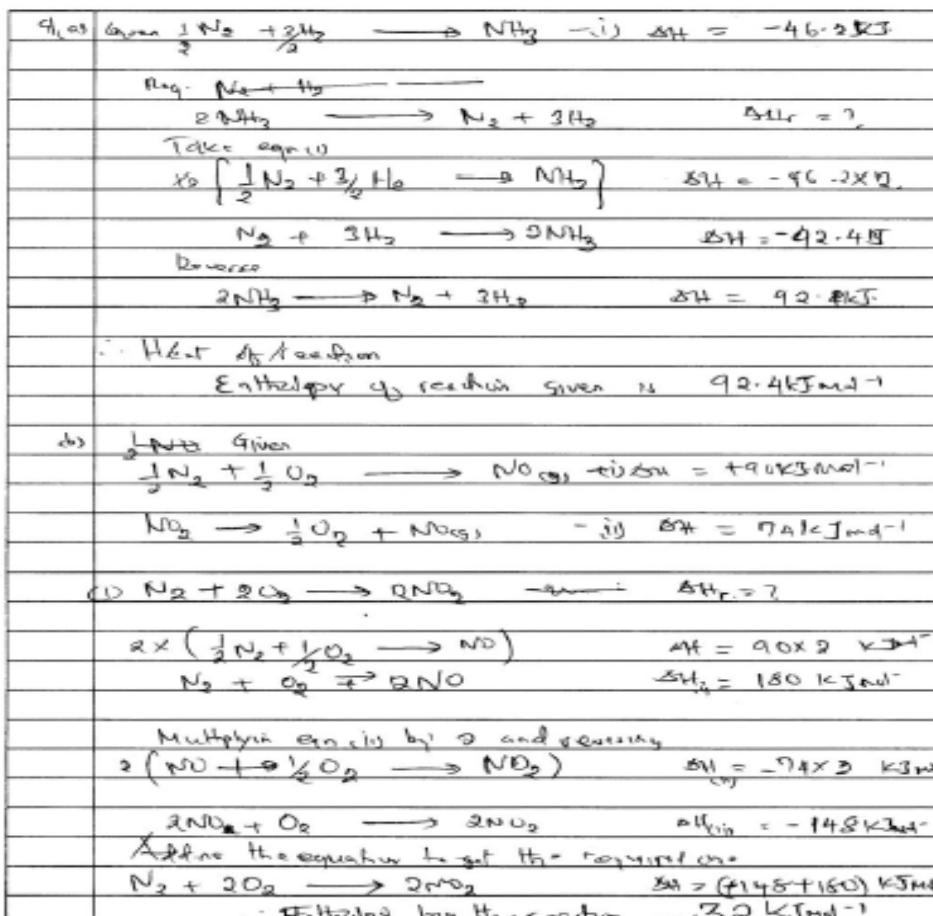
$$\Delta H_{\text{neutralization}} = -58.675 \text{ kJ/mol}$$

Extract 4.1: A sample of good responses in question 4

2019 PAST PAPERS

9. (a) The enthalpy for the formation of ammonia, $\text{NH}_3(\text{g})$, under standard conditions is $-46.2 \text{ kJ mol}^{-1}$. Calculate the enthalpy for the reaction $2\text{NH}_3(\text{g}) \rightarrow \text{N}_2(\text{g}) + 3\text{H}_2(\text{g})$. (1.5 marks)
- (b) Study carefully the following chemical reactions, and then answer the questions that follow:
- $$\frac{1}{2}\text{N}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{NO}(\text{g}) \quad \Delta H^\circ = +90 \text{ kJ mol}^{-1}$$
- $$\text{NO}_2(\text{g}) \rightarrow \frac{1}{2}\text{O}_2(\text{g}) + \text{NO}(\text{g}) \quad \Delta H^\circ = +74 \text{ kJ mol}^{-1}$$
- (i) Calculate the enthalpy for the reaction $\text{N}_2(\text{g}) + 2\text{O}_2 \rightarrow 2\text{NO}_2(\text{g})$. (1.5 marks)
- (ii) Which of the two species $\text{NO}_2(\text{g})$ and $\text{NO}(\text{g})$ is more thermodynamically stable? (1.5 marks)
- (c) At 25°C , the dissociation energies of $\text{H}_2(\text{g})$ and Cl_2 are $+435.4 \text{ kJ mol}^{-1}$ and $+243 \text{ kJ mol}^{-1}$ respectively. The enthalpy of formation of $\text{HCl}(\text{g})$ is $-92.2 \text{ kJ mol}^{-1}$. Calculate the dissociation energy for $\text{HCl}(\text{g})$. (4 marks)
- (d) Use the given average bond enthalpies to calculate the change in enthalpy, ΔH , for the reaction: $\text{C}_3\text{H}_8 + 5\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$.

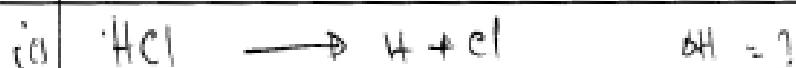
Bond	Enthalpy
C-H	$= 414 \text{ kJ mol}^{-1}$
C-C	$= 347 \text{ kJ mol}^{-1}$
C=O	$= 741 \text{ kJ mol}^{-1}$
H-O	$= 464 \text{ kJ mol}^{-1}$
O=O	$= 464 \text{ kJ mol}^{-1}$
C-O	$= 498 \text{ kJ mol}^{-1}$
O-O	$= 335 \text{ kJ mol}^{-1}$
	$= 138 \text{ kJ mol}^{-1}$



Q(b) (ii) NO₂ is more stably thermally stable than NO₃.

Reason:

Combustion of NO gives off energy of formation of NO₂ is large, this means that the same large amount should be supplied in order to break its bonds.



Given



$$\therefore \Delta H = \sum E_{\text{Product}} - \sum E_{\text{Reactant}}$$

$$= -4$$

$$(121.5 + 217.7) - (-92.2)$$

$$= 431.4 \text{ kJ/mol}^{-1}$$

∴ Dissociation energy of HCl is 431.4 kJ



$$\Delta H_r = \sum \text{BE}_{\text{products}} - \sum \text{BE}_{\text{reactants}}$$

$$\sum \text{BE}_{\text{reactants}} =$$

$$\begin{aligned} \sum \text{BE}_{\text{reactants}} &= \delta(\text{C-H}) + 2(\text{C-C}) \\ &= 2312 + 644 \\ &= 4006 \end{aligned}$$

$$\begin{aligned} \delta x(\text{O=O}) &= 5x \text{ 498} \\ &= 2490 \end{aligned}$$

$$\begin{aligned} \sum \text{BE}_{\text{products}} &= 2490 + 4006 \\ &= 6496 \text{ kJ mol}^{-1} \end{aligned}$$

Products

$$\begin{aligned} \delta(\text{C=O}) &= 6x \text{ 741} \\ &\approx 4446 \text{ kJ mol}^{-1} \end{aligned}$$

$$\begin{aligned} \delta(\text{H-O}) &= 6x \text{ 464} \\ &\approx 2712 \end{aligned}$$

$$\sum \text{BE}_{\text{products}} = 8158 \text{ kJ mol}^{-1}$$

$$\sum \Delta H_r = (6496 - 8158)$$

$$-1662 \text{ kJ mol}^{-1}$$

Extract 9.2: A sample of correct responses in question 9.

2019 PAST PAPERS

10. (a) Define the following phrases as applied in energetics concept in chemistry: (1.5 marks)
- Heat (enthalpy) of formation.
 - Standard enthalpy of formation.
 - Heat (enthalpy) of fusion.
 - Heat (enthalpy) of neutralization.
- (b) (i) State Hess's law of constant heat summation. (2 marks)
- (ii) Given a hypothetical reaction $aA + bB \rightarrow cC + dD$, where A, B, C and D are compounds and a, b, c and d are stoichiometric values, determine an expression for enthalpy change Δ_H° of the reaction. (1 mark)
- (c) The standard heat of combustion of ethanol, $\Delta_c H^\circ = -1386 \text{ kJ mol}^{-1}$. The standard heat of formation of carbon dioxide, $\Delta_f H^\circ(\text{CO}_2) = -393 \text{ kJ mol}^{-1}$, and standard heat of formation of water, $\Delta_f H^\circ(\text{H}_2\text{O}) = -287 \text{ kJ mol}^{-1}$: Calculate the standard heat (enthalpy) of formation of ethanol. (2.5 marks)

- (d) The following data were obtained for Born-Haber cycle formation for one mole of crystalline NaCl.

Step	Heat (Enthalpy)
Sublimation of Na metal to gaseous Na atoms.	$\Delta_{\text{sub}} H^\circ = +107.3 \text{ kJ mol}^{-1}$
Ionization of gaseous Na atoms to Na^+ ions and e^-	$\Delta_i H^\circ = +495.8 \text{ kJ mol}^{-1}$
Formation of Cl^- (g) by addition of e^- to Cl(g)	$\Delta_{\text{eq}} H^\circ = -348.6 \text{ kJ mol}^{-1}$
Formation of NaCl crystals from Na^+ and Na^-	$\Delta_l H^\circ = -787.3 \text{ kJ mol}^{-1}$

In a single step, $\text{Na(s)} + \frac{1}{2}\text{Cl}_2 \rightarrow \text{NaCl}$, it was found that $\Delta_f H^\circ(\text{NaCl, crystal}) = -412.3 \text{ kJ mol}^{-1}$. Calculate heat (enthalpy) of dissociation of one mole of Cl_2 gas. (2.5 marks)

- 10(a) (i) Heat of formation is the enthalpy change when one mole of substance is formed.
- 10(b) (ii) Standard enthalpy of formation is the enthalpy change when one mole of the substance is formed under the standard conditions.
- 10(c) (iii) Heat of fusion is the enthalpy change when a solid substance is melted to liquid at its melting temperature.
- 10(d) (iv) Heat of neutralization is the enthalpy change when one mole of H^+ ions react with one mole of OH^- to form one mole of water at the standard conditions.

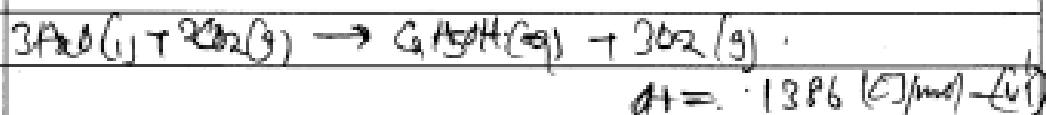
10(b) (i) Hess's law of constant heat summation states that "the heat of reaction of the chemical reaction is independent in the manner in which it is brought about"

10(b) (ii)



$$\Delta H^\circ = (c \Delta H_C + d \Delta H_D) - (a \Delta H_A + b \Delta H_B)$$

10(c) The required equation is,



on adding (ii), (v) and (vi)

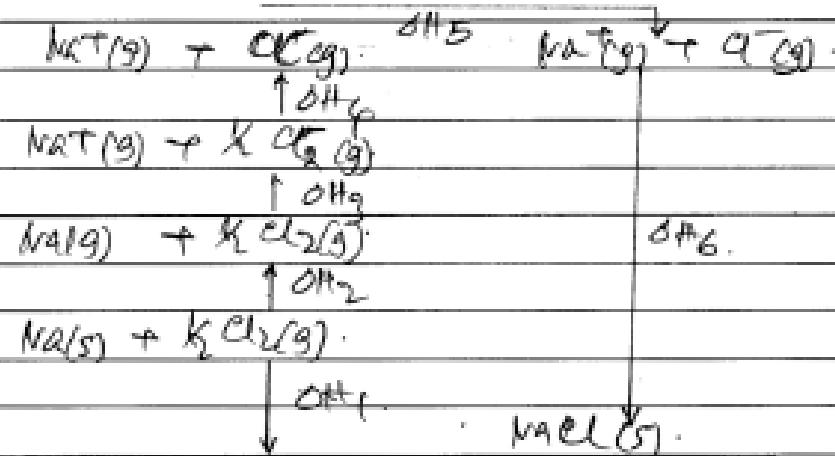


$$(b)(c) \quad \Delta H = [(270 - 393) + (3 \times -287) + 1386] \text{ kJ/mol}$$

$$\Delta H = -261 \text{ kJ/mol.}$$

(d)

consider the Born-Haber cycle
below:



$$\Delta H_f = \Delta H_2 + \Delta H_3 + \Delta H_5 + \Delta H_6.$$

$$\Delta H_f = \Delta H_f - (\Delta H_1 + \Delta H_2 + \Delta H_5 + \Delta H_6).$$

$$\Delta H_f = -412.3 - (107.9 + 495.8 - 748.6 - 787.3)$$

$$\Delta H_f = 120.5 \text{ kJ/mol.}$$

$$\begin{aligned}
 \text{Dissociation energy} &= (120.5 \times 2) \text{ kJ/mol} \\
 &= 241 \text{ kJ/mol.}
 \end{aligned}$$

Extract 10.1: A sample of correct responses in question 10.

2018 PAST PAPERS

6. (a) Briefly give the meaning of the following phrases as used in chemical energetics:
- (i) Heat of solution.
 - (ii) Spontaneous reaction.
 - (iii) Enthalpy change.
 - (iv) Heat of sublimation.
 - (v) Endothermic reaction.
- (2.5 marks)
- (b) During chemical reactions, bonds are broken (reactants) and formed (products), and the overall process may be exothermic or endothermic. Compare bond strengths in reactants and products if the overall reaction is
- (i) exothermic
 - (ii) endothermic.
- (1 mark)
- (c) State the types of enthalpies in each of the following equations:
- (i) $\text{KOH(aq)} + \text{HCl(aq)} \rightarrow \text{KCl(aq)} + \text{H}_2\text{O(l)}$ $\Delta H^\circ = -57 \text{ kJ mol}^{-1}$
 - (ii) $\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O(l)}$ $\Delta H^\circ = -286 \text{ kJ mol}^{-1}$
 - (iii) $\frac{1}{2}\text{H}_2(\text{g}) + \frac{1}{2}\text{Cl}_2(\text{g}) + (\text{aq}) \rightarrow \text{HCl(aq)}$ $\Delta H^\circ = -164 \text{ kJ mol}^{-1}$
 - (iv) $\text{Cl(g)} + \text{e}^- \rightarrow \text{Cl}^-(\text{g})$ $\Delta H^\circ = -347 \text{ kJ mol}^{-1}$
- (2 marks)
- (d) Two liquids, trichloromethane (CHCl_3) and ethoxyethane ($\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$), form intermolecular hydrogen bonds when mixed. In a certain experiment, 0.05 moles of trichloromethane and 0.3 moles of ethoxyethane were weighed into the same calorimeter. When the temperature of both liquids had equalized, the liquids were mixed. The temperature increase of 5.4°C was recorded upon mixing. Assume that the heat capacity of the calorimeter is negligible, while heat capacities of trichloromethane and ethoxyethane are $0.98 \text{ J g}^{-1} \text{ K}^{-1}$ and $2.28 \text{ J g}^{-1} \text{ K}^{-1}$, respectively. Calculate:
- (i) Heat change in this experiment.
 - (ii) Enthalpy change of mixing one mole of trichloromethane with excess ethoxyethane.
Show your work clearly including manipulations of units. [Atomic masses: C = 12, H = 1, O = 16, Cl = 35.5]
- (4.5 marks)

6	<p>(i) Heat of solution: Is the heat change when one mole of solute dissolved into a specific amount of solvent at a given conditions of temperature and pressure.</p> <p>(ii) Spontaneous reaction: Is the reaction which occurs itself without requiring energy to initiate the reaction.</p> <p>(iii) Enthalpy change: Is the energy released or absorbed when a certain chemical reaction takes place.</p> <p>(iv) Heat of sublimation: Is heat change when one mole of a substance in its solid state converted into its corresponding gaseous state under a given conditions of temperature and pressure.</p> <p>(v) Endothermic reaction: Is the type of reaction which absorb energy from the surrounding for it to proceed forward or to reverse take place.</p>
---	---

Extract 6.2 shows that the candidate correctly defined the terms heat of solution, spontaneous reaction, enthalpy change, heat of sublimation and endothermic reaction.

2017 PAST PAPERS

9. (a) Study carefully the information in the following table and then answer the questions that follow.

Process	ΔH_{298K}° (kJ mol ⁻¹)
$\text{Na(s)} \rightarrow \text{Na(g)}$	+108
$\frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{Cl(g)}$	+121
$\text{Na(g)} \rightarrow \text{Na}^+(\text{g}) + \text{e}^-$	+496
$\text{Cl(g)} + \text{e}^- \rightarrow \text{Cl}^-(\text{g})$	-349
$\text{NaCl(s)} \rightarrow \text{Na}^+(\text{g}) + \text{Cl}^-(\text{g})$	+787
$\text{NaCl(s)} + \text{H}_2\text{O(l)} \rightarrow \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$	+4.0

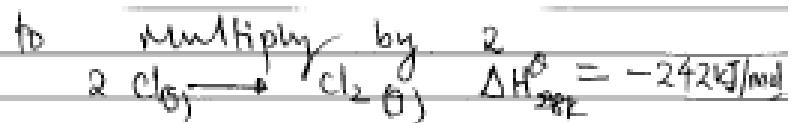
- (i) Calculate the enthalpy change for the process $2\text{Cl(g)} \rightarrow \text{Cl}_2(\text{g})$.
- (ii) Calculate the standard molar enthalpy change for the process:
 $\text{Na(s)} + \frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{Na}^+(\text{g}) + \text{Cl}^-(\text{g})$. (1 mark)
- (iii) Compare the different between enthalpy change for the processes: $\text{NaCl(s)} \rightarrow \text{Na}^+(\text{g}) + \text{Cl}^-(\text{g})$ and $\text{NaCl(s)} + \text{H}_2\text{O(l)} \rightarrow \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$, and then comment on the differences. (1.5 marks)
(0.5 mark)

(b) Magnesium will displace copper from copper (II) sulphate solution according to the equation:
 $\text{CuSO}_4(\text{aq}) + \text{Mg(s)} \rightarrow \text{Cu(s)} + \text{MgSO}_4(\text{aq})$.

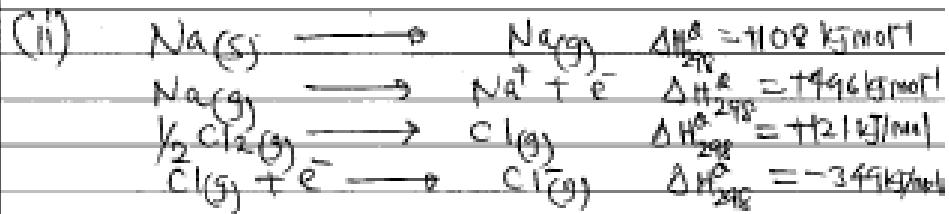
When an excess of magnesium was added to 100 cm³ of 0.1 mol dm⁻³ copper(II) sulphate, the temperature increased by 46.3 °C. It is known that density and specific heat capacity of the solution are 1.0 g cm⁻³ and 4.18 J g⁻¹ °C⁻¹, respectively. Calculate:

- (i) The molar enthalpy change for the reaction. (4 marks)
- (ii) Minimum quantity of magnesium required. (2 marks)
- (iii) The change in temperature if only 0.8 g magnesium was added. (1 mark)

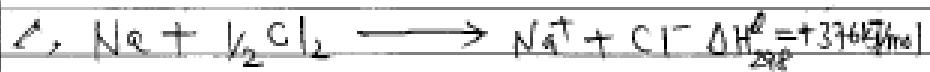
q	(a)	(i)	from data given
			$\frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{Cl(g)} \Delta H_{298K}^\circ = +121 \text{ kJ/mol}$
			To reverse this equation $\text{Cl} \rightarrow \frac{1}{2}\text{Cl}_2 \Delta H_{298K}^\circ = -121 \text{ kJ/mol}$



\therefore enthalpy for process $2\text{Cl}_{(\text{l})} \rightarrow \text{Cl}_2(\text{g})$ is
 -242 kJ/mol .



to add the equations above



(iii) More heat is given out in forming $\text{Na}^+(\text{aq})$ and $\text{Cl}^-(\text{aq})$ as compared to formation of $\text{Na}^+(\text{g})$ and $\text{Cl}^-(\text{g})$ because $\text{Na}^+(\text{g})$ and $\text{Cl}^-(\text{g})$ hydrated in water which is exothermic reaction.

9 (b) (i) Mass of solution (m) =
 density \times Volume

$$= 1 \text{ g/cm}^3 \times 100 \text{ cm}^3 \\ = 100 \text{ g}$$

Enthalpy change $\Delta H = -MC\Delta T$

where C = Specific capacity of
 solution = $4.18 \text{ J/g}^\circ\text{C}$.

ΔT = Increase in temperature
 of solution

$$= 46.3$$

$$\text{So } \Delta H = -100 \times 4.18 \times 46.3 \\ = -19353.4 \text{ J}$$

$$\begin{aligned}
 \text{Molar heat change} &= \frac{\Delta H}{\text{(number of moles of CuSO}_4)} \\
 &= -19353.4 \\
 &\quad \text{Molarity} \times \text{Volume} \\
 &= -19353.4 \\
 &\quad 0.1 \times \frac{100}{1000} \\
 &= -19353.4 \text{ J/mol} \\
 &= -1935.34 \text{ kJ/mol} \\
 \therefore \text{molar heat of reaction is} \\
 &-1935.34 \text{ kJ/mol.}
 \end{aligned}$$

(ii) from balance equation given,
 Number of moles of Magnesium
 = Number of moles of Copper(II)
 Sulphate

$$\begin{aligned}
 \text{Number of moles of CuSO}_4 &= \frac{100 \times 0.1}{100} \\
 &= 0.01 \text{ mole.} \\
 \text{Mass of Magnesium} &= \text{mole} \times \text{Molar mass} \\
 &= 0.01 \times 24 \\
 &= 0.24 \text{ g.} \\
 \therefore \text{Minimum quantity of magnesium required is } &0.24 \text{ g.}
 \end{aligned}$$

In Extract 9.2 the candidate correctly calculated the enthalpy change and gave the differences between the enthalpy changes. The appropriate approaches were used in calculating the molar enthalpy change, minimum quantity of magnesium and the change in temperature of magnesium.

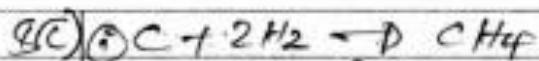
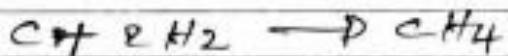
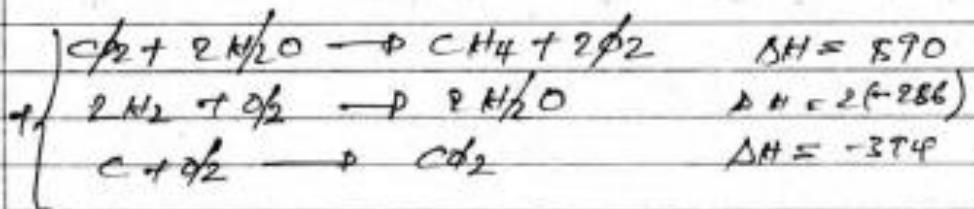
2017 PAST PAPERS

8. (a) Define the following:
- (i) Standard enthalpy change of neutralization.
 - (ii) Heat of solution.
 - (iii) Bond energy.
 - (iv) Standard enthalpy change of combustion.
- (2 marks)
- (b) Differentiate between:
- (i) Lattice energy and energy of reaction.
 - (ii) Standard molar enthalpy change of dissolution and heat of combustion.
- (2 marks)
- (c) Given the standard enthalpy change of combustion of hydrogen, $\Delta H^\circ = -286 \text{ kJ/mol}$; carbon, $\Delta H^\circ = -394 \text{ kJ/mol}$; methane, $\Delta H^\circ = -890 \text{ kJ/mol}$; Ethane, $\Delta H^\circ = -1390 \text{ kJ/mol}$ and heat of formation of $\text{CH}_3\text{CH}_2\text{OH}$ is -276 kJ/mol , calculate in kJ/mol the enthalpy change;
- (i) of formation of methane. (1.5 marks)
 - (ii) of formation of ethene. (1.5 marks)
 - (iii) for the reaction $\text{CH}_2=\text{CH}_2(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightarrow \text{CH}_3\text{CH}_2\text{OH}(\text{g})$ (1.5 marks)
 - (iv) of combustion of 4.48 dm^3 of ethane. (1.5 marks)

<u>Q@) (i) Standard enthalpy change of Neutralization</u>
is heat evolved when an alkali solution provide one mole of OH^- to reaction with acidic solution provide one mole of H^+ to form one mole of water under standard conditions of temperature and pressure
<u>(ii) Heat of solution</u> is the heat change when one mole of a solute dissolved in a solvent to forms a solution at a given conditions

	(iii) Bond energy is the heat required to break a bond from which a compound is formed at a given condition
	(iv), Standard enthalpy change of combustion is the heat evolved when one mole of substance is completely burnt in oxygen under standard conditions of temperature and pressure.
(b)	(i) Lattice energy is the heat evolved when a one mole of lattice compound is formed from its corresponding gaseous ions. While Energy of reaction is the heat change when one mole of compound is grown from its corresponding gaseous atom at their normal physical state.
	(ii) Standard molar enthalpy change ^{of solution} is the heat change when a one mole of substance is dissolve in a solvent under standard conditions lattice Heat of combustion is the heat evolved when a one mole of a substance is completely burnt in oxygen at a given condition
(c)	Given $H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l) \Delta H^\circ = -286 \text{ kJ/mol}$ $C(s) + O_2(g) \rightarrow CO_2(g) \Delta H^\circ = -394 \text{ kJ/mol}$ $CH_4(g) + 2O_2 \rightarrow CO_2 + 2H_2O \Delta H^\circ = -870 \text{ kJ/mol}$ $C_2H_6 + \frac{7}{2} O_2 \rightarrow 2CO_2 + 3H_2O \Delta H^\circ = -1270 \text{ kJ/mol}$

(2) Formation of Methane

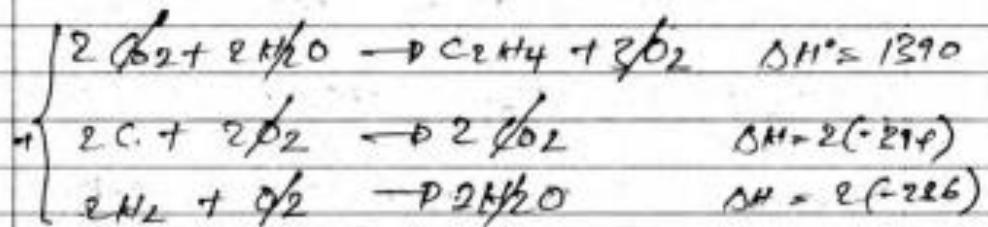


$$\Delta H^\circ = (890 + 2(-286) + (-394)) \text{ kJ mol}^{-1}$$

$$\Delta H^\circ = -76 \text{ kJ mol}^{-1}$$

Heat of formation of Methane = -76 kJ mol^{-1}

(3) Heat of formation of Ethene

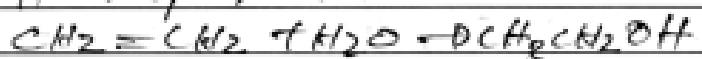


$$\Delta H^\circ = 1390 + 2(-394) + 2(-286)$$

$$\Delta H^\circ = 30 \text{ kJ mol}^{-1}$$

Heat of formation of Ethene = 30 kJ mol^{-1}

8(c) (iii) Heat of Reaction



$$\Delta H^\circ = \sum \Delta H_{\text{rxn}} - \sum \Delta H_{\text{products}}$$

$$\Delta H^\circ = \Delta H_{\text{catalyzed}}^\circ - (\Delta H_{\text{combustion}}^\circ + \Delta H_{H_2O}^\circ)$$

$$\Delta H^\circ = -296 - (80 + (-286))$$

$$\Delta H^\circ = -20 \text{ kJ mol}^{-1}$$

$$\text{Heat of reaction} = -20 \text{ kJ mol}^{-1}$$

(iv) Combustion of 44.0 g dm⁻³ Ethane



$$\text{Number of moles} = \frac{44.0 \text{ g dm}^{-3}}{22.4 \text{ dm}^3 \text{ mol}^{-1}} = 0.2 \text{ mol}$$

$$\text{1 mole} \rightarrow \phi = 1390 \text{ kJ mol}^{-1}$$

$$0.2 \text{ mol} \rightarrow \phi ?$$

$$\therefore -278 \text{ kJ mol}^{-1}$$

$$\text{Heat of combustion} = -278 \text{ kJ mol}^{-1}$$

In Extract 8.1 the candidate presented correct answers to all the items in the question. The candidate managed to score full marks.

2016 PAST PAPERS

10. (a) State the following:
 (i) Heat of reaction
 (ii) Exothermic reaction
 (iii) Endothermic reaction. (3 marks)
- (b) 1.5 g of ammonium nitrate (NH_4NO_3) was added to 35.0 g of water in a plastic beaker and stirred until the salt dissolved. The temperature of the solution dropped from 22.7 °C to 19.4 °C. Based on the given information respond to the following questions:
 (i) Is the process endothermic or exothermic? Explain.
 (ii) Calculate the heat of solution of NH_4NO_3 in kJ/mol., given that specific heat capacity of water = 4.184 J/g°C. (7 marks)

10a)	i) Heat of reaction is the heat change when the certain stoichiometric of reactants has completely reacted.
	ii) Exothermic reaction is the reaction which proceeds with the evolution of heat to the surrounding.
	iii) Endothermic reaction is the reaction which proceeds with the absorption of heat from the surrounding.
b)	Given: $M_r = 1.5 \text{ g}$. $M_w = 35.0 \text{ g}$. $T_1 = 22.7^\circ\text{C}$. $T_2 = 19.4^\circ\text{C}$. $T_2 - T_1 = -3.3^\circ\text{C}$.
	i) The process is endothermic. This is because the decrease in temperature shows that the process proceeds with absorption of heat.
	ii) Heat of Solution: $C = 4.184 \text{ J/g}^\circ\text{C}$. <u>Sohm</u>
	$H = -(mc\Delta T)$.
	$m = \rho V$.

$$100 \text{ g} M = 35.0 \text{ g}$$

$$H = -(35 \times 4.184 \times (-3.3))$$

$$H = -(-483.252)$$

$$H = 483.252 \text{ J}$$

Required heat of solution of NH_4NO_3 in KJ/mol .

$$\text{NH}_4\text{NO}_3 = (14+4)+(14+32) \text{ g/mol} + 16 \text{ g/mol}$$

$$= 64 \text{ g/mol} + 16 \text{ g/mol}$$

$$\text{NH}_4\text{NO}_3 = 80 \text{ g/mol}$$

$$n(\text{NH}_4\text{NO}_3) = \frac{M}{m} = \frac{1.5 \text{ g}}{80 \text{ g/mol}}$$

$$n(\text{NH}_4\text{NO}_3) = 0.01875 \text{ moles}$$

$$\Delta H = \frac{H}{n} = \frac{483.252 \text{ J}}{0.01875 \text{ mole}}$$

$$\Delta H = 25,773.4 \text{ J/mol!}$$

$$\Delta H = 25.77 \text{ kJ/mol!}$$

The heat of solution of NH_4NO_3
is given by = 25.77 kJ/mol!

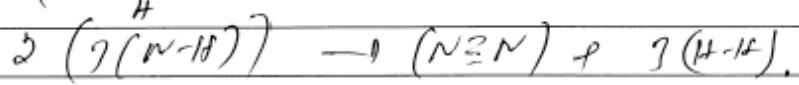
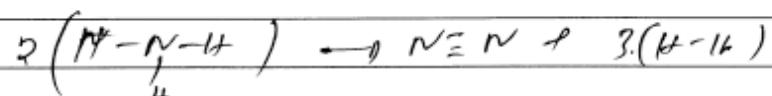
In Extract 10.1, the candidate wrote correct definitions and formulae with all the symbols. Eventually, the candidate managed to do the related calculations correctly.

2015 PAST PAPERS

8. (a) State Hess's law of constant heat summation. (1 mark)
- (b) (i) Give the difference between the standard bond dissociation energy and the standard heat of formation of a substance.
- (ii) Calculate the enthalpy change for the reaction $2\text{NH}_{3(\text{g})} \rightarrow \text{N}_{2(\text{g})} + 3\text{H}_{2(\text{g})}$ given that: $E(\text{N-H}) = 388 \text{ kJ mol}^{-1}$; $E(\text{N=N}) = 944 \text{ kJ mol}^{-1}$ and $E(\text{H-H}) = 436 \text{ kJ mol}^{-1}$.

Q:	<p>(a) Hess's law of constant heat of summation (state first) "The total heat change of the reaction is independent of the path or way which happens by the reaction."</p> <p>(b) (i) The standard heat of few dissociation energy is the energy required to break one mole of an molecule to its gaseous state</p> <p>(b) (ii) The standard heat of the dissociation energy is the energy required to break the one mole of a molecule to its corresponding gaseous atom under standard temperature and pressure for example $\text{H}_2\text{Cl}_2 \xrightarrow{\Delta T} 2\text{Cl}_{(\text{g})}$, while. The standard heat of formation of the substance is the energy change when the one mole of the compound is formed from its pure element under standard condition of temperature and pressure, for example $\text{C} + \text{P} + \text{O}_2 \rightarrow \text{CO}_2$.</p>
----	---

Q11 From the reaction



Therefore in the reactant side the heat of absorption will be.

$$\sum \text{B.E.}(\text{reaction}) = 2[3(988)] = 2328 \text{ kJ mol}^{-1}$$

Q In the product side.

$$\sum \text{B.E.} = 944 + (436)3.$$

$$= 2252.$$

$$\Delta H_r^\circ = \sum \text{B.E.}(\text{reactant}) - \sum \text{B.E.}(\text{product})$$

$$2328 - 2252 = 76 \text{ kJ mol}^{-1}$$

∴ The enthalpy of the reaction is +76 kJ mol⁻¹.

Extract 8.1 shows a response from the candidate who performed well in this question. All workings are well organized and the responses are precisely presented.

7.0 PERIODIC CLASSIFICATION

2021 PAST PAPERS - 2

4. (a) State the reason(s) for the following facts:
- (i) Although Na^+ , Mg^{2+} and Al^{3+} ions have the same electronic configuration, they have different radii.
 - (ii) At ordinary temperature, phosphorous pentachloride (PCl_5) is a white solid with unexpected high melting point.
 - (iii) Sodium chloride (NaCl) and unhydrous aluminium chloride (AlCl_3) are both chlorides of metals of period (III). Molten sodium chloride can be electrolysed while molten unhydrous aluminium chloride can not.
 - (iv) The first ionization energy increases from left to right across a period but the first ionization energy of magnesium is larger than that of aluminium.
 - (v) Lithium and potassium are metals of group (I). In aqueous solution, lithium is a poor conductor of electricity while potassium is a good conductor.
 - (vi) Boiling point of water (H_2O) is higher than that of hydrogen sulphide (H_2S). All are hydrides of group (IV) elements. (11 marks)

- (b) (i) Which factors are used to classify elements in the periodic system of elements?
(ii) Account for the fact that the third period of the periodic system of elements has only eight elements and not eighteen as expected. (3 marks)

- (c) Ammonia, NH_3 and phosphene, PH_3 are hydrides of the first two elements in group VA. Some physical properties of ammonia and phosphene are given in the following table:

Compound	Boiling point (°C)	Solubility in water (Mol/dm ³)
Ammonia, NH_3	-33	31.1
Phosphene, PH_3	-88	8.88×10^{-4}

- (i) Suggest one reason for the difference in boiling temperature.
(ii) Why ammonia is more soluble in water than phosphene? Give a reason. (2 marks)
- (d) Why do elements exhibit diagonal relations? Briefly explain by giving two examples. (4 marks)

Q4 Q2. i) By considering table below

element	number of electron	proton
Na ⁺	10	11
Mg ²⁺	10	12
Al ³⁺	10	13

Since all three element has same number of electron hence same electronic configuration but due to different nuclear attractive force exerted by the proton toward electron atomic radius decreases thus aluminium has smallest size followed by magnesium and then sodium because their progressive decrease in nuclear attractive force from aluminium to sodium.

ii) At ordinary temperature Pcs exist in the ionic form of $[Pc14]^{+}$ where its chlorine atom are strongly held by attractive force in a crystal lattice and thus due to the stronger bond it is less led to higher melting point of Pcs and exist as white solid.

iii) Since sodium chloride is more ionic thus its good conductor of heat and electricity which do in turn used electrolysis means can be electrolysed but AlCl₃ due to smaller size of aluminium mean higher polarising power hence aluminium chloride to exist as covalent compound hence poor conductor of heat and electricity which in turn can not be electrolysed.

Q4(a), iv). By considering electron configuration of magnesium and aluminium.



1s	1s	2s	2p	3s
1v	1v			1v



1s	1s	2s	2p	3s	3p
1v	1v			1v	1v

> First ionization energy of magnesium is large because magnesium possessed stable electronic configuration thus extra energy is required to unpaired electron but Aluminium possessed the only one unpaired electron.

Ans:

> The distance of outer orbital from nucleus thus magnesium valence electron is at 3s-orbital mean near the nucleus but Aluminium valence orbital is at 3p-orbital far from nucleus.

lastly:

> Aluminium experiences stronger screening effect than the magnesium atom.

Q4(a), v). lithium is very smaller in size as compared with potassium and thus in the aqueous solution lithium is highly hydrated due to stronger nuclear attractive which attract lone pair of water and thus its atoms become heavy as the result of lower mobility which intern lithium becomes poor conductor but the potassium is not hydrated due to larger size hence good conductor of electricity.

0497 vi). Oxygen atom in water posses lone pair thus water has greater ability of doing forming hydrogen bonding between its molecules thus due to hydrogen bonding boiling point of water is so higher.

But-

H_2S its sulphur atom posses no any lone pair as the result thus it can cause lower boiling point due to small strength of its bond.

0498 i) Ammonia (NH_3) has larger boiling point than phosphine because nitrogen atom has lone pair hence it can form hydrogen bonding between its molecules.

ii) Ammonia is more soluble in water because as it can form hydrogen bond between NH_3 and H_2O thus due to hydrogen bonding solubility of ammonia in water do increase. But phosphine since phosphorus has no lone pair thus it can not form hydrogen bonding with water hence lower solubility.

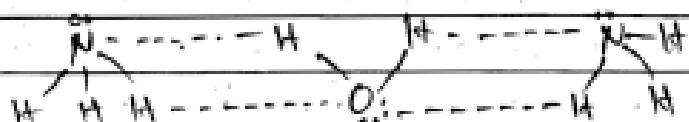


Illustration of hydrogen bonding between water and ammonia.

04(d)	<p>Elements do exhibit diagonal relationship because of the following reasons:</p> <ul style="list-style-type: none"> i) Posses same polarizing power ii) Same atomic radius and the nuclear attractive force iii) Same electronegativity. <p>Examples are:</p> <p>1st: Beryllium and Aluminium experience diagonal relationship like</p> <ul style="list-style-type: none"> > Both they can form complex > Both undergo association in the aqueous solution (Alcl₃ and Becl₂) > Both posses amphoteric oxide and hydroxide. <p>2nd: Lithium and magnesium experiencing diagonal relationship like.</p> <ul style="list-style-type: none"> > Both can react with nitrogen to form nitride > Both posses unstable carbonate and bicarbonate which decompose on heating.
04(b)	<p>1) Atomic number is the factor which play role in arrangement of element in periodic table</p> <p>2) Also physical and chemical properties play role in classification of elements</p> <p>iii) This is because during arrangement electron are filled in the shells and thus period 2 element has three shells thus all of its eighteen electron can be filled in the three shells.</p>

Extract 14.1: A sample of correct responses in question 4

2020 PAST PAPERS - 2

4. (a) Describe four characteristics of *s*-block elements. (4 marks)
- (b) (i) What do you understand by the word electronegativity?
(ii) Explain three factors that affect the size of electronegativity. (6 marks)
- (c) Briefly, explain how hydrides of period 2 react with water, acids and bases. Support your answers with reaction equations. (10 marks)

04	a) i. They have large atomic size.
	ii. They have low electronegativity due to large atomic size.
	iii. They have high metallic character compared to other blocks.
	iv. They have large electron affinity due to the larger atomic size.
b) i. Electronegativity is an ability of atom to attract electrons toward it self.	
	ii) a) Atomic size. Increasing atomic size cause to decreasing in electronegativity due to the decreasing in nuclear attractive force.
	. b) Effective nuclear charge Increasing in effective nuclear charge cause to increasing of electronegativity.

40.	<p>Element of period three are Li Be B C N O F</p> <p>The hydrides are LiH BeH₂ BH₃ CH₄ NH₃ H₂O HF</p> <p>Prot acids are a) NH₃ H₂O HF</p> <p>The NH₃ is (NH₃)</p> <p>Reactions with water (NH₃)</p> <p>With NH₃ When NH₃ react with water it will form ammonia solution (NH₄OH) which is basic in nature. It can turn red litmus paper blue $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4\text{OH}$</p> <p>Reaction between NH₃ and acid. When NH₃ treated with strong acid it will result to salt and water $\text{HCl} \text{ NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl} + \text{H}_2\text{O}$</p> <p>Reaction of NH₃ with base Because NH₃ is base it has no reaction with other bases $\text{NH}_3 + \text{NaOH} \rightarrow \text{No reaction}$</p>
41.	<p>(i) in H₂O Water is amphoteric in nature since it can act as a base or an acid.</p> <p>Reaction of H₂O and Acid When H₂O is treated with strong acid it will act as a base $\text{HCl} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^-$</p> <p>Reaction of water and Base when H₂O reacting with strong bases it will act as the acid $\text{NaOH} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{CO}_3^{2-}$</p> <p>Reaction between H₂O and H₂O Because it is the same compound there is no reaction between $\text{H}_2\text{O} + \text{H}_2\text{O} \rightarrow \text{No reaction}$</p> <p>(ii) HF HF is an acid in nature, when heat & with strong base it will form salt and water $\text{HF} + \text{NaOH} \rightarrow \text{NaF} + \text{H}_2\text{O}$</p>

4c	ii) HF Reaction with acids When it treated with acids, HF has no significant reaction ie $\text{HF} + \text{HCl} \longleftrightarrow \text{No reaction}$
	Reaction with water When HF is treated with water, it will produce hydronium ion and fluoride ion. ie $\text{HF} + \text{H}_2\text{O} \longleftrightarrow \text{H}_3\text{O}^+ + \text{F}^-$

Extract 14.2: A sample of correct responses in question 4

2019 PAST PAPERS - 2

4. (a) (i) Define isoelectronic species.
(ii) Name a species that will be isoelectronic with each of the following species; F^- , and Mg^{2+} . (3 marks)
- (b) Among the elements of the second period, Li to Ne, identify the one(s)
(i) with the highest first ionization energy.
(ii) with the highest electronegativity.
(iii) with the largest atomic radius.
(iv) that is most reactive non metal.
(v) that is the most reactive metal. (5 marks)
Give reason for your answer in each case.
- (c) Write a chemical equation representing the following;
(i) In moist air copper corrodes to produce a greenish layer on the surface.
(ii) Chlorination of calcium hydroxide produces a bleaching powder.
(iii) Adding concentrated H_2SO_4 in sugar produces a dense brownish black mass.
(iv) Action of phosphorus on concentrated HNO_3 .
(v) Oxidation of hydrogen peroxide with potassium permanganate in acidic medium.
(vi) Action of zinc on dilute nitric acid. (6 marks)
- (d) Element A burns in nitrogen to give an ionic compound B. B reacts with water to give C. C reacts with CO_2 to give D. Also C gives a milky colouration on bubbling with CO_2 . Excess bubbling of C gives a clear solution E. Use chemical equations to identify A, B, C, D and E. (6 marks)

t (a) Iso-electronic species are the ions of different elements having the same number of electrons.

(ii)

Is-electronic with F^- is Ne with 10 electrons.

Is-electronic with Mg^{2+} is Na^+ with 10 electrons.

(b)

(i) Neon, Ne

- This is because it is a noble gas with full-filled electron shells that are more stable. It is also small in size.

(ii) Fluorine, F

This is because it is smaller in size with high electron density.

(iii) Lithium, Li

This is because it has less effective nuclear attractive force to contract the shells.

(iv) Fluorine, F

- This is because it is most electronegative element and it is a strongest oxidizing agent.

(v) Lithium, Li

- This is due to its highest reducing power with lowest ionisation energy compared to other elements in a period.

4	(c)
(i)	$\text{Cu} + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{Cu CO}_3$ greenish layer.
(ii)	$2\text{Cl}_2 + 2\text{Ca(OH)}_2 \rightarrow \text{Ca(ClO)}_2 + \text{CaCl}_2 + 2\text{H}_2\text{O}$ ↓ bleaching powder
(iii)	$\text{C}_2\text{H}_5\text{O}_2 + \text{H}_2\text{O}_2 \xrightarrow{\text{conc.}} \text{CH}_3\text{COOH} + \text{H}_2\text{O}$ black mass
(iv)	$\text{P}_2 + 4\text{HNO}_3 \rightarrow \text{H}_3\text{PO}_4 + 2\text{NO}_2 + \text{H}_2\text{O}$
(v)	$2\text{KMnO}_4 + 3\text{H}_2\text{O}_2 + 5\text{H}_2\text{O} \rightarrow 5\text{O}_2 + 2\text{MnO}_2 + \text{K}_2\text{SO}_4 + 8\text{H}_2\text{O}$
(vi)	$\text{Zn} + 2\text{HNO}_3 \rightarrow \text{Zn(NO}_3)_2 + \text{H}_2$

4	<p>(d)</p> <p>since - C gives a milky elevation with CO₂ then C must be Ca(OH)₂ and D must be CaCO₃.</p> <p>- On excess CO₂, E = Ca(HCO₃)₂</p> <p>∴ Element A = Calcium and R is Calcium nitride, Ca₃N₂.</p> <p>E. A = Ca R = Ca₃N₂ C = Ca(OH)₂</p> <p>B = CaCO₃ E = Ca(HCO₃)₂</p> <p>Equations:</p> $\text{Ca}_3\text{N}_2(s) \rightarrow \text{Ca}_3\text{N}_2(s)$ $\text{Ca}_3\text{N}_2(s) + 6\text{H}_2\text{O}(l) \rightarrow 3\text{Ca(OH)}_2(s) + 2\text{NH}_3(g)$ $\text{Ca(OH)}_2(s) + \text{CO}_2(g) \rightarrow \text{CaCO}_3(s) + \text{H}_2\text{O}(l)$ $\text{Ca(OH)}_2(s) + 2\text{CO}_2(g) \rightarrow \text{Ca(HCO}_3)_2(s)$
---	--

Extract 18.2: A sample of correct responses in question 4.

2018 PAST PAPERS - 2

5. (a) Why hydrogen element was placed in group I in the modern periodic table? **(2 marks)**
- (b) Account for the following:
 (i) The cationic size of an element is smaller than its atomic size.
 (ii) Group I elements are called alkaline metals.
 (iii) Group II elements melt at higher temperatures than group I elements.
 (iv) Some compounds are said to be polarized. **(6 marks)**
- (c) Briefly explain the following facts:
 (i) Every first member of the group in the periodic table behaves anomalously from other members.
 (ii) Some elements in the periodic table show diagonal relationships.
 (iii) Some elements are called d-block elements.
 (iv) The compounds of Sc³⁺ are colourless. **(6 marks)**
- (d) The valency shell electronic configuration of element X is represented as 6s²6p³.
 (i) Give the block, group and period of element X in the periodic table.
 (ii) Give the possible oxidation state of element X.
 (iii) Give the formula of the oxide of X. **(6 marks)**

5	<p>a) Hydrogen is placed in group I because</p> <p>i/ it fills its outermost electron in the s-orbital hence it is a s-block element like other alkali metals found in group I</p> <p>ii/ In modern periodic table elements are arranged in order of increasing their atomic number since hydrogen has smallest atomic number of 1 It deserve the first place in the modern periodic table and that is group I.</p>
b)	<p>i/ - This is because formation of cation results loss of electron but number of protons remain constant. This cause the remaining electrons to experience greater nuclear attractive force leading to decrease in its size and sometimes loss of electron may be accompanied with loss of shells.</p> <p>ii/ Group I metals are called alkaline metals because when they dissolve in water they form alkaline solutions</p> $2\text{Na}(s) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{NaOH} + \text{H}_2$
iii/	<p>This is because group II elements have 2 electrons in their outer most shell which they can donate during metallic bond formation causing their metallic bond to be stronger than group I elements which contribute only one electron in metallic bond formation. Hence group II elements melt at higher temperatures than group I elements.</p>
iv/	<p>Soem This is because their net dipole moments do not cancel thus having partial positive charge and partial negative charges in their constituent atoms.</p>

5	<p>i) This is because the first members of group 3 has following features</p> <ul style="list-style-type: none"> → Smallest cationic or ionic size → Highest electropositivity or electronegativity → Highest cationic or ionic charge due to small size
	<p>ii) This because elements showing diagonal relationships have</p> <ul style="list-style-type: none"> → Comparable atomic or ionic size → Have same or comparable polarizing powers. → Comparable ionic charges.
	<p>iii) This is because they fill their outermost electron (valence electrons) in the d-orbitals.</p>
	<p>iv) This is because the compounds of Sc^{2+} have no or any d-orbital with unpaired electron required for d-d promotions to form coloured compounds. i.e. their d-orbitals are empty hence colourless.</p>
	<p>d). i) - Block of element X is \rightarrow P-block ii) - group of element X is \rightarrow group V - period of element X is \rightarrow period 6</p>

5	<p>d) i) Possible oxidation states of element X $\rightarrow X^4$, $\rightarrow X^{2+}$ or X^{5+}</p>
	<p>ii) Oxide of element X $\rightarrow X_2\text{O}_3$</p>

In Extract 19.1, the candidate applied correctly the concept of modern periodic law to attempt part (a), (b) and (c). He/she managed to give the oxidation states of element X and its oxide correctly.

2017 PAST PAPERS - 2

5. (a) (i) State the periodic law. (1 mark)
- (ii) What is the advantage of arranging elements in the periodic table on the basis of atomic numbers rather than atomic masses? (1 mark)
- (iii) Give three (3) diagonal similarities between Be and Al. (3 marks)
- (b) Basic characters of elements in the modern periodic table always increase down the group. Justify this statement by considering the oxides of group V elements. (5 marks)
- Page 3 of 7
- (c) Explain the following:
- (i) Silicon has a higher melting point than it is expected.
 - (ii) Graphite is used as a lubricant as well as a cell electrode but not diamond.
 - (iii) The first ionization energy of boron is lower than that of beryllium although boron is towards the right across period 2 in the periodic table. (6 marks)
- (d) A researcher decided to place a newly discovered element at the bottom of group (VII). What would be the expected physical and chemical properties of the new element? Give your answers based on
- (i) the state of the element at room temperature and pressure.
 - (ii) redox properties of the element.
 - (iii) atomicity.
 - (iv) reaction with alkali. (4 marks)

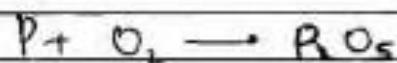
5	Periodic law states that the properties of elements in the periodic table are functions of their atomic numbers.
a)	It helps to remove the doubts which arise for the case of isotopes since atoms of the same element can have different atomic masses though they have the same atomic number. Hence by using atomic numbers the doubts are cleared for such elements.
b)	Both Aluminium and Beryllium can form complex compounds e.g. $\text{Be}(\text{OH})_4^-$ and $\text{Al}(\text{OH})_4^-$.

	5 (a) Both beryllium and Aluminium form amphoteric oxides example Al_2O_3 and BeO
	(b) Both Aluminium and Beryllium form chlorides which are unstable in their molecular mass. Aluminium chloride dimerises while Beryllium chloride polymerises
	(c) Both form hydroxides which are amphoteric and decompose on heating
5 (b)	By considering the group five elements including nitrogen and phosphorus in the top part of Group Nitrogen reacts with oxygen to form oxides such as Nitrogen dioxide and nitrogen monoxide in limited supply of oxygen
	$\text{N}_2 + \text{O}_2 \rightarrow \text{NO}_2$
	$\text{N}_2 + \text{O}_2 \rightarrow \text{NO}$

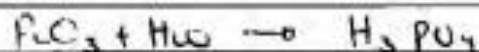
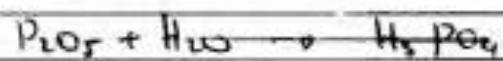
These dissolve in water to form strongly acidic solutions hence showing acidic character.



5. Phosphorus just below nitrogen in the group react with water oxygen to form oxide like phosphorus pentoxide and phosphorus trioxide.



These dissolve in water to form less solution with less acidity compared to those of nitrogen e.g.



\nwarrow
weaker acid

These show an ^{decrease} in acidity character and increase in basic character down the group.

c)	<p>These is because Nitrogen forms the giant molecular structure in which several atoms of nitrogen are closely held together and hence making it to have giant structure and higher boiling points.</p>
5.	<p>Graphite is made up of carbon atoms lying in plate like structure with weak bonds between them hence they can easily slide over one another and hence giving it its slippery nature.</p> <p>(i) which makes it as a lubricant - graphite conducts electricity due to having free electrons in its structure hence can be used as a cell electrode whereas diamond is formed by strong bonds between carbon atoms and hence having a very hard structure and very high melting and boiling points.</p>

(c) This is because boron has an unpaired electron in its $2p$ orbital which is easily removed as it is not so close to the nucleus. Removing the electron is unstable due to fact that the outermost orbital (the $2s$ orbital) is a duplet filled with 2 electrons and it is stable. hence a large amount of Ionization energy is required to remove than in boron.

(d) (i) The expected state of the new element at room temperature and pressure is solid state. This is due to its large molecular mass which would make it to have large amount of Van der waals force and hence it will be solid in nature.

Extract 19.2 shows a sample response of a candidate who managed to perform question 5 correctly.

2016 PAST PAPERS - 2

5. Study a portion of periodic table indicated below and answer questions in part (a) and (b).

s - block			p - block					
GROUP	I	II	III	IV	V	VI	VII	VIII
Period 1	M							
Period 2								
Period 3	G							
Period 4	H						J	

- (a) (i) Identify with reason the block in which elements A, C, D and E are to be found if their electronic configurations are as follows:
 A: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$
 C: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$
 D: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5$
 E: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2$.
- (ii) Write the molecular formula of a compound formed when D combines with E. (5 marks)
- (b) (i) Justify that, the first ionization energy of J is larger than that of G although both are found in the same period.
 (ii) Account for the increase of metallic nature from M to H. (4 marks)
- (c) Briefly explain each of the following trends:
 (i) Some members in the periodic table are said to be related diagonally.
 (ii) Fluorine is more reactive than other members of the halogen group. (4 marks)
- (d) Describe how hydrides of the elements in period 3 react with water.

5 (a)	
(i)	A : s-block. reason:- valence electrons enter the s-orbitals ($5s^1$). - It can't be d-block since it doesn't have $ns^{1-2}(n-1)d^{1-10}$ structure
(ii)	C : d-block. reason:- its valence electronic configuration is $4s^2 3d^8$ which corresponds to general formula $ns^{1-2}(n-1)d^{1-10}$ of d-block elements - its d-orbital is partially filled unlike the rest.
(iii)	D : p-block. reason:- valence electrons enter the p-block with all other lower orbitals filled +
(iv)	E : s-block. reason - valence electrons are in its $5s$ orbital - other lower orbitals are all filled. - It can't be transition d-block since it doesn't have $ns^{1-2}(n-1)d^{1-10}$ configuration.

5 (a)	
(i.)	D has most probable ion : D^{-1} E most probable ion : E^{2+} .
	Now: $2D^{-1} + E^{2+} \rightarrow ED_2$
	Molecular formula : ED_2
5 (b)	
(i.)	T has got more protons than G, with the two having the same number of shells. As a result, T has got a higher and electronegativity than G. Due to higher electronegativity, T has got higher ability to hold on to its valence electrons hence higher ionization energy is needed to remove valence electrons from T than from G.
(ii.)	from M to H, number of shells increases. Increase in number of shells does increases screening effect which reduces ability of nucleus to hold on to its valence electrons. As a result, from M to H, there is an increased tendency to loose electrons which accounts for highly metallic increase in metallic nature from M to H.
5 (c)	
(i.)	The first member of a group has got similar properties with second member of next group in terms of its their chemistry and physical properties. This is due to similar ionization energy, similar atomic and ionic radius and similar electronegativity. Eg. Li and Mg, Be and Al have diagonal relationship.

5 (c)	
(ii)	All of all the halogens, fluorine is the smallest making it have a high charge density and highest electronegativity.
5 (d)	Being the most electronegative halogen, it has the highest ability to oxidise other molecules. Hence, fluorine is the most reactive halogen.
	Hydrides of period 3 are as follows.
	- NaH , MgH_2 , AlH_3 , SiH_4 , SPH_3 , H_2S , HCl .
	- Hydrogen being noble gas doesn't form hydride.
	→ NaH , MgH_2 react with water to form basic solution.
	$\text{NaH} + \text{H}_2\text{O} \longrightarrow \text{NaOH} + \text{H}_2$
	$\text{MgH}_2 + \text{H}_2\text{O} \longrightarrow \text{Mg(OH)}_2 + \text{H}_2$
	→ Aluminium hydride forms amphoteric hydroxide
	$\text{AlH}_3 + \text{H}_2\text{O} \longrightarrow \text{Al(OH)}_3 + \text{H}_2$
	→ SiH_4 and PH_3 being highly covalent show no reaction with water.
	$\text{SiH}_4 + \text{H}_2\text{O} \longrightarrow$ no reaction
	$\text{PH}_3 + \text{H}_2\text{O} \longrightarrow$ no rxn.

5 (e)	- H_2S and HCl dissociate in water to form acidic solution.
	$\text{H}_2\text{S} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{HS}^-$: weak acid.
	$\text{HCl} + \text{H}_2\text{O} \longrightarrow \text{H}_3\text{O}^+ + \text{Cl}^-$: strong acid

In Extract 19.1, the candidate was able to answer all parts of the question.

2015 PAST PAPERS - 2

7. (a) What is the basic difference between Mendeleev's periodic law and the Modern periodic law? (1 m)
- (b) A neutral atom of a certain element has 17 electrons.
(i) Write its ground state electronic configuration.
(ii) Classify the element into s, p, d or f block.
(iii) Determine whether it is diamagnetic or paramagnetic.
(iv) What is the principal oxidation number of the element? (4 m)

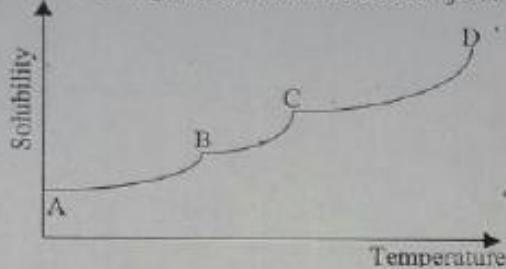
(c) Study the following hypothetical elements placed in various groups and periods of part of the periodic table and then answer the questions that follow.

GROUP/PERIOD	I	II	III	IV	V	VI	VII	O
2	A	B	C	D	E	F	G	H
3	I	J	K	L	M	N	O	P

Giving reason(s) identify:

- (i) an element which is most likely to have the highest electron affinity.
(ii) an element which is likely to have the highest electronegativity.
(iii) an element which is likely to have least first ionization energy.
(iv) a pair of elements which is likely to form the strongest electrovalent bond.
(v) two elements which are likely to have strongest reducing properties.
(vi) two elements which form neither negative nor positive ions. (6 marks)

- (d) (i) Define the term deliquescence and explain what makes a hydrated salt to deliquesce.
(ii) The following sketch shows the solubility curve of calcium chloride in water:



Explain the discontinuities in the solubility curve. (3 marks)

- (iii) Briefly explain at least three hazards associated with the useful applications of sulphur and lead or their compounds. (6 marks)

7(b) Mendeleev arranged elements in a periodic table in order of increasing atomic mass while in the modern periodic law elements are arranged in a periodic table in order of increasing atomic number.

Tb(i)	1s ²	2s ²	2p ⁶	3s ²	3p ⁶	4s ²	3d ⁶	4p ¹
-------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------

7b(ii) The element is in p-block

7b(iii) The element is paramagnetic because it has one unpaired electron in its valency shell

7b(iv) The oxidation number of the element is -1.

7c(i) G

Reason:

- It has a small size that results into great nuclear charge that increases its electron affinity.
- Has only one electron to fulfill its valency orbital hence has greater affinity for electrons.

7c(ii) G

Reason:

It has small atomic size which result into strong nuclear effective charge hence increase the tendency of electrons towards its self.

7c(iii) I

Reasons:

- It has large atomic size which decrease the effective nuclear charge to attract electrons hence much electrons may be lost.

7c(iv) I and G

- This is because I has large atomic size hence can easily lose electrons and G has smallest size hence has high affinity for electrons.
- The difference in electronegativity between the two elements is so great that prevents the formation of strong electrostatic bond.

7c(v) A and I

This is because of their large size which reduce the effective nuclear charge hence can easily lose electrons and reduce other substances into (chemical reagents).

7c(vi) H and F

This is because their valence shell is full of electrons hence cannot gain and form negative ions or lose electrons and form positive ions.

7d.	<u>Hazards of sulphur and its compound</u>
	1. Hydrogen sulphide gas is a very poisonous gas that affect respiratory system of organisms.
	2. Presence of too much Sulphate (SO_4^{2-}) in the soil causes loss of income due to decrease of soil pH hence not suitable for plant growth.
	3. SO_2 (Sulphur dioxide) is one of the greenhouse gases that cause global warming.
	<u>Useful applications of sulphur and its compound</u>
	1. H ₂ S (hydrogen sulphide gas) is very useful in qualitative analysis in the laboratory.
	2. Sulphur is used in vulcanization of natural rubber.
7d.	<u>Hazards of lead and its compounds</u>
	1. Lead metal is a poison hence it is not to be taken in human's body.
	2. Lead is one of the cause of air and water pollution.
	<u>Useful applications of lead and its compound</u>
	1. It is used in car batteries (Pb)
	2. It is used in water pipes
	3. Make different instruments used for construction.

In Extract 7.1, the candidate presented correctly the difference between Mendeleev's periodic law and modern periodic law. She/he wrote correctly the electronic configuration of the given elements and managed to classify them. Likewise, he/she was able to explain the uses of sulphur and lead or their compounds.

8.0 SELECTED COMPOUNDS OF METALS

2021 PAST PAPERS

6. (a) When dilute hydrochloric acid is added to a yellow solution of potassium chromate, an orange solution of dichromate is produced. Briefly, explain what would be observed as a result of:
- adding more hydrochloric acid.
 - adding dilute sodium hydroxide solution.
 - adding anhydrous calcium chloride.
- (6 marks)
- (b) Briefly explain the following:
- Hydrogen gas is evolved when magnesium is introduced into a beaker containing aqueous solution of ammonium chloride.
 - AlCl_3 reacts chemically with water while NaCl does not.
- (4 marks)

<p>(i) If more hydrochloric acid is added the forward reaction will be favoured hence the the colour of the solution will be more orange to show the presence of dichromate</p>	
<p>(ii) If adding dil. sodium hydroxide solution the backward reaction will be favoured hence the yellow colouration will be observed</p>	
<p>(iii) Anhydrous calcium chloride the reaction will be proceed in forward due to increase of chloride solution hence fewer orange colouration.</p>	

<p>(b) (i) Hydrogen gas will evolve since the reaction of NH_4^+ (ammonium) and magnesium, magnesium tends to replace the hydrogen^{Chlorine} as follows:</p> $\text{NH}_4\text{Cl}_{(\text{s})} + \text{Mg}_{(\text{s})} \rightarrow \text{MgCl}_{(\text{s})} + \text{NH}_3 + \text{H}_2\text{O}_{(\text{l})}$	
<p>(ii) AlCl_3 can react with water due to presence of unfilled orbitals but sodium chloride is stable and have no unfilled orbital.</p> $\text{AlCl}_3 + \text{H}_2\text{O} \rightarrow \text{Al(OH)}_3 + \text{HCl}$ $\text{NaCl} + \text{H}_2\text{O} \rightarrow \text{No reaction}$	

Extract 6.2: A sample of appropriate responses in question 6

2020 PAST PAPERS

1. (a) By using chemical equations, describe the following:
 - (i) Amphoteric oxides.
 - (ii) Basic oxides.(4 marks)

- (b) With the aid of chemical equation(s), explain how you can prepare soluble chlorides. (4 marks)

- (c) A student suggested a methodology to prepare aluminium trichloride (AlCl_3) by following the steps (i) – (iv) as follows:
 - (i) Add sodium hydroxide solution to aluminium sulphate solution.
 - (ii) Filter off the precipitate.
 - (iii) Convert the hydroxide into a chloride by adding hydrochloric acid.
 - (iv) Evaporate the solution to leave crystals of AlCl_3 .

Could this process work? Justify. (2 marks)

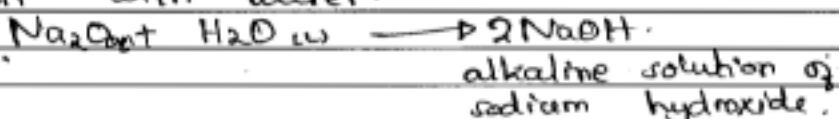
<p>1(a) (i) <u>Amphoteric oxides</u>: These are oxides which react with both acids and bases. Examples of Amphoteric oxides are Al_2O_3, zinc oxide (ZnO) and lead oxide (PbO).</p> <p>Reactions with acids:</p> $\text{Al}_2\text{O}_3 + 6\text{HCl}_{(\text{aq})} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2\text{O}$ <p>Reaction with bases:</p> $\text{Al}_2\text{O}_3 + 2\text{NaOH} \rightarrow 2\text{NaAlO}_2 + \text{H}_2\text{O}$ <p style="text-align: center;">sodium aluminate.</p>

(ii) Basic oxides : These are metallic oxides that react with acids to form salt and water only and when dissolved in water form alkaline solution.
For example ; sodium oxide (Na_2O).

Reaction with acid.

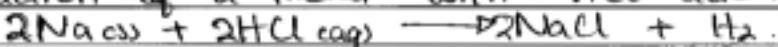


Reaction with water.

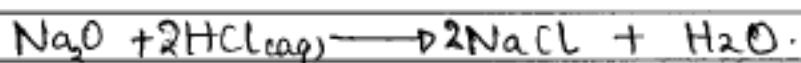


(b) Soluble chlorides include sodium and potassium chloride.

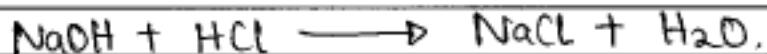
* Reaction of a metal with HCl acid.



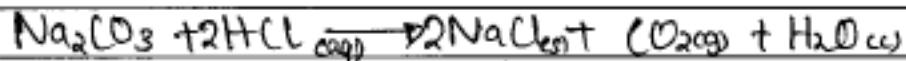
db) * Reaction of metal oxide with HCl acid.



* Reaction of metal hydroxide with HCl acid.



* Reaction of carbonates with HCl acid.



Extract 1.1: A sample of good responses in question 1

2019 PAST PAPERS – 2

5. (a) With the aid of chemical equation, show how the following oxides can be prepared;
- Calcium oxide (Direct method).
 - Magnesium oxide (Direct method).
 - Copper oxide (Indirect method).
 - Zinc oxide (Indirect method).
- (8 marks)
- (b) With the aid of chemical equation, show how the following carbonates can be prepared;
- Sodium carbonate.
 - Magnesium carbonate.
 - Zinc carbonate.
- (6 marks)
- (c) State three uses of metal oxides.
- (6 marks)

Qn 5.	<p>(i) Burning calcium in presence of air -</p> <p>- consider a chemical reaction.</p> $2\text{Ca} + \text{O}_2 \longrightarrow 2\text{CaO}$ <p>Balanced chemical reaction will be.</p> $2\text{Ca(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{CaO(s)}$ <p>(ii). Burning of magnesium in presence of oxygen -</p> <p>air -</p> <p>- consider the reaction below:-</p>
5.	<p>(i) (ii) $2\text{Mg(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{MgO(s)}$</p> <p>(iii). Decomposition of copper carbonate by heating -</p> <p>chemical equation will be.</p> $\text{CuCO}_3\text{(s)} \xrightarrow{\Delta} \text{CuO} + \text{CO}_2\text{(g)}$ <p>(iv) - Decomposition of zinc carbonate by using heat -</p> <p>- consider a chemical reaction below:</p> $\text{ZnCO}_3\text{(s)} \xrightarrow{\Delta} \text{ZnO} + \text{CO}_2\text{(g)}$ <p>5. (b) - (i) - Reaction between sodium borate salt with concentrated sodium hydroxide -</p> <p>reaction</p> $\text{B}_2\text{O}_3\text{(s)} + 2\text{NaOH}\text{(aq)} \rightarrow \text{Na}_2\text{B}_4\text{O}_7\text{(aq)} + \text{H}_2\text{O(l)}$ <p>(ii) - The reaction between magnesium chloride and sodium carbonate -</p> <p>i.e.</p> $\text{MgCl}_2\text{(aq)} + \text{Na}_2\text{CO}_3\text{(aq)} \rightarrow \text{MgCO}_3\text{(s)} + 2\text{NaCl}\text{(aq)}$

5.	<p>(e) Uses of metal oxides</p> <ul style="list-style-type: none"> - metal oxides such as CaO are used as lining materials used to control coil audits. - metal oxides are used as medicines to treat digestion problems in the alimentary canal by neutralizing excess acids. - metal oxides such as CaO and MgO are used in manufacture of building materials such as lime as well as extraction of metals from their ores.
----	--

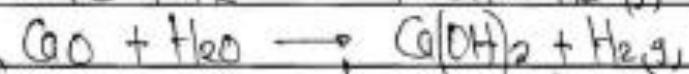
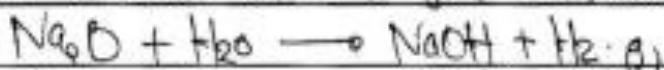
Extract 19.2: A sample of correct responses in question 5.

2018 PAST PAPERS – 2

7. (a) (i) Classify the following oxides as amphoteric, basic or acidic: Al_2O_3 , Na_2O , ZnO and CaO . (2 marks)
- (ii) Using five examples, briefly explain the uses of sulphates of selected metals in different fields. (5 marks)
- (b) Explain these facts with suitable equations:
- (i) The aqueous solution of iron (III) chloride is acidic.
 - (ii) Gaseous iron (III) chloride at low temperature exists as a dimer and is a covalent compound.
 - (iii) Red hot iron decomposes steam reversibly.
 - (iv) The aqueous solution of sodium hydrogen carbonate is alkaline. (4 marks)
- (c) Why iron (III) carbonate does not exist? (3 marks)
- (d) With suitable examples, describe the chemistry of zinc oxide (ZnO). (6 marks)

7@^① Oxides: Al_2O_3 , Na_2O , ZnO and CaO .

Na_2O and CaO are basic oxides since when dissolved in water tends to give alkaline solutions.

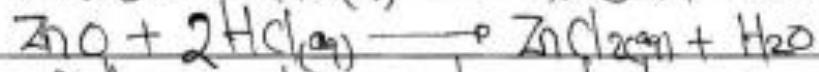
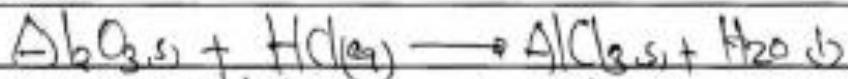


Therefore are called basic oxides since gives alkaline solution when dissolved in water.

- Al_2O_3 and ZnO are amphoteric oxides.

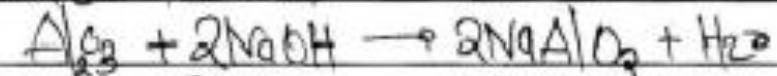
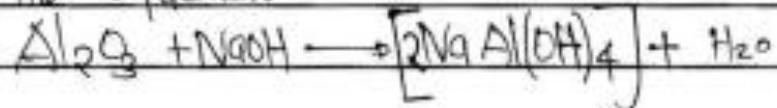
This imply that they have both basic and acidic characteristics.

- As base: they reacts with acids to gives salt and water. Consider the equation below as base.



- As acid: they reacts with base to form complex of tetrahydroxozincium(III).

Consider the equations.

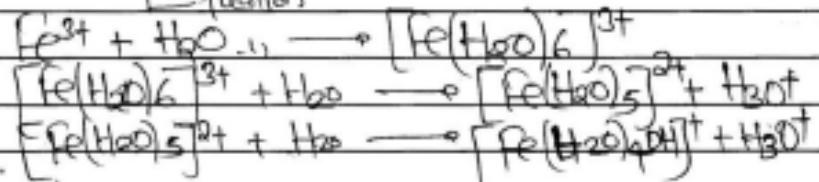


The two complexes are soluble.

- 7@ (i) The following are the uses of sulphates
- They are used as fertilizers in agricultural activities. Example $(\text{NH}_4)_2\text{SO}_4$ help supply nutrients.
 - Sulphates are used in the laboratories in the qualitative analysis of salts. Example Cs_2SO_4 .
 - Sulphates also are used in formation of permanent hardness of water. Example MgSO_4 .
 - Used in production of Nylon.

(ii) (a) the aqueous solution of Iron (III) chloride is acidic because in aqueous solution they undergoes hydrolysis leads to the formation of Hydroxium ions (H_3O^+) which cause the acidic nature.

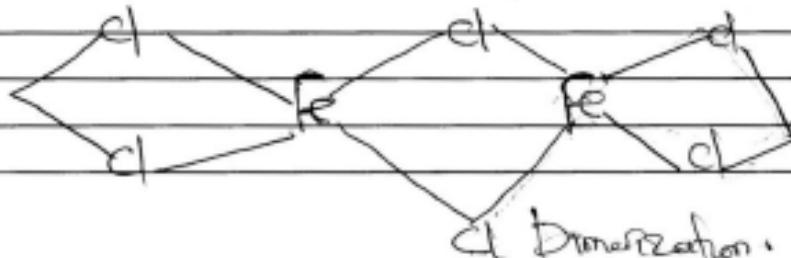
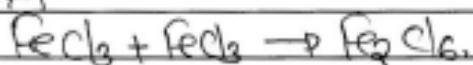
Equation:



Therefore formation of hydroxium ions (H_3O^+) cause the acidic nature.

(ii) Iron (III) chloride at gaseous state undergoes dimerization to form dimer and its molecular mass become twice than expected.

A



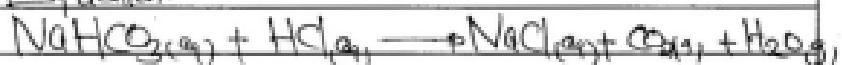
7(b) (iii) Hot iron decomposes steam irreversibly. Because iron can not be attacked by cold water but only decomposes steam (water vapour) reversibly.

7(b) Equation:



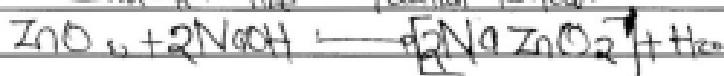
(iv) Aqueous solution of sodium hydrogen carbonate is alkaline because of presence of hydrogen carbonate ions (HCO_3^-) which gives alkalinity as characteristic and therefore can react with HCl to form salt, carbon dioxide and water as neutralization reaction.

Equation:



(v) Iron (III) carbonate does not exist because - Iron have no enough room to accommodate three (3) lone pairs of carbonate. This is because iron ion (Fe^{3+}) is smaller in size and therefore cannot form such compound.

(vi) Zinc oxide (ZnO) is the amphoteric oxide. This indicates that it has both basic and acidic characteristics. As acid can react with base to form complex. Consider the equation below.



Also, As base it can react with acid to form salt and water. This reaction called neutralization reaction. Consider the equation.



Also ZnO can react with other compounds.

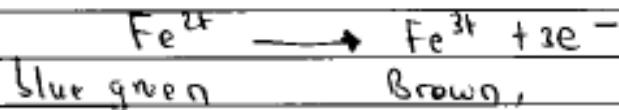
Extract 21.2 shows a response whereby the candidate classified correctly the oxides of metals given, gave three correct uses of metal sulfates with examples. In other parts of the question the candidate responded correctly and included appropriate chemical equations.

2017 PAST PAPERS – 2

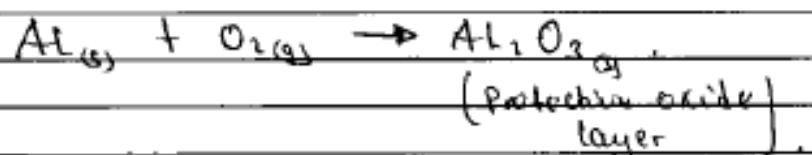
7. (a) With reference to the elements of period III of the periodic table, give the formula of the oxide with the following properties:
- The most basic oxide.
 - The amphoteric oxide.
- (2 marks)
- (b) Briefly explain the action of water on chlorides of period III elements. (6 marks)
- (c) Give reasons to support the following:
- When salts of iron are exposed in air they turn from blue green colour to brown.
 - Concentrated nitric acid renders aluminium passive.
 - Zinc and tin are used to protect iron from rusting.
- (6 marks)
- (d) With the help of chemical equations, state the physical changes that will be observed and their inference in each of the following experiments:
- Sodium oxalate solution is added into potassium permanganate solution in acidic medium.
 - A hydrogen sulphide solution is added into potassium dichromate solution.
- Page 4 of 7 (6 marks)

(a)(i)	The most basic oxide is sodium oxide
7.	(Na ₂ O)
(ii)	The amphoteric oxide is Aluminium oxide (Al ₂ O ₃).
(b)	The chlorides of period III elements includes - Sodium Chloride (NaCl) - Magnesium Chloride (MgCl ₂) - Aluminium Chloride (AlCl ₃) - Silicon tetrachloride (SiCl ₄) - Phosphorus Penta and trichloride (PCl ₃ and PCl ₅)
	Action of water on the above chlorides
	$\text{NaCl} + \text{H}_2\text{O} \rightarrow \text{NaOH} + \text{HCl}$ It forms the neutral solution
	$\text{MgCl}_2 + 2\text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2 + 2\text{HCl}$ It forms neutral solution.
	$\text{AlCl}_3 + \text{H}_2\text{O} \rightarrow \text{Al(OH)}_3 + \text{HCl}$ It forms acidic solution due to HCl formation.
	$\text{SiCl}_4 + \text{H}_2\text{O} \rightarrow \text{Si(OH)}_4 + \text{HCl}$ Also it forms acidic solution.
	$\text{PCl}_3 + \text{H}_2\text{O} \rightarrow \text{P(OH)}_3 + \text{HCl}$ Acidic solution.
	$\text{PCl}_5 + \text{H}_2\text{O} \rightarrow \text{No reaction.}$

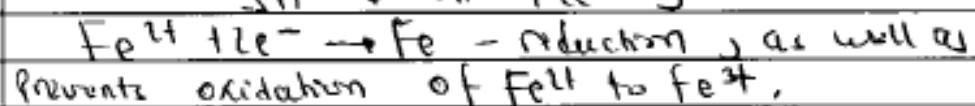
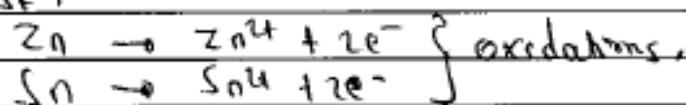
(c)(i) When salts of iron are exposed in air the turn
 7. from blue green colour to brown this is due
 to the formation of iron III ion since when salt
 of iron is exposed in air get oxidized to iron
 (III) that is brown.



(ii) Concentrated nitric acid renders aluminium passive
 since aluminium is being oxidized by air to
 form a protective oxide layer of aluminium that
 prevent the oxidation of nitric acid.



(iii) Zinc and tin are used to protect iron from
 rusting since Zinc and tin have more negative
 electrode potential of -0.76V and -0.44V
 respectively while the electrode potential of iron is
 -0.44V , so Zn and Sn get oxidized faster than
 iron as well as forms the protective layer above
 iron surface from being oxidized by air moisture
 to form rust.



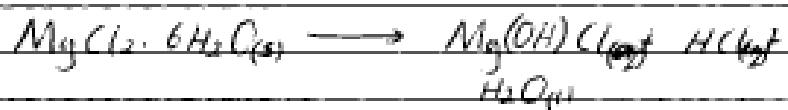
(d)(i)	Sodium oxalate solution is added into per ⁺
7.	sodium permanganate solution in acidic medium tend to decolorises purple colour of potassium permanganate to formation of Mn ²⁺ (colourless)
	$2\text{MnO}_4^- + 5\text{C}_2\text{O}_4^{2-} + 16\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 10\text{CO}_2 + 8\text{H}_2\text{O}$
	↓ ↑
	Purple Colourless.
(ii)	When hydrogen sulphide solution is added into potassium dichromate solution, the orange colour of dichromate will disappear and the green colour of Cr ³⁺ will appear
	$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$
	↓ ↑
	Orange Green.

Extract 21.1 shows a response of a candidate who performed well.
The candidate gave correct explanations to each item, supporting them with the formula or reaction equation.

2016 PAST PAPERS – 2

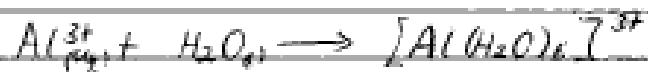
6. (a) Briefly explain the following observations. Support your explanation with equation(s) where applicable.
- Anhydrous magnesium chloride cannot be prepared by heating the hydrated crystals of MgCl₂.6H₂O.
 - Most metal carbonates are prepared by precipitation method but aluminium carbonate has never been prepared by this method.
 - Aqueous aluminium nitrate turns blue litmus red.
 - Zinc oxide is amphoteric.
 - Lead (II) chloride is soluble in concentrated hydrochloric acid.
 - Addition of ammonia solution to aqueous copper (II) sulphate gives a pale blue precipitate initially and deep blue solution when more ammonia is used. **(13 marks)**
- (b) Write the chemical formulae of three oxides of lead and give their uses. **(4 marks)**
- (c) Give two important uses of lead and two hazards of lead in life. **(3 marks)**

6. (a) (i) This is because the hydrated crystals of $MgCl_2 \cdot 6H_2O$ undergo hydrolysis leading to the formation of basic hydroxide of magnesium.



(ii) This is due to the high polarising power of Al^{3+} due to its small size and high charge, hence polarises more the CO_3^{2-} . Thus Alumina carbonate has never been prepared by precipitation method.

(iii) This is due to the high hydration energy of Al^{3+} in water, leading to the production of H_3O^+ ions that make solution acidic hence turn blue litmus red.



6. (iv) Zinc oxide is amphoteric because it reacts with both basic and acidic solutions.

Reaction with basic solution:



Reaction with acid solution:



(v) This is due to the formation of soluble complex salt compound, $[\text{Pb}(\text{Cl}_4)]^{2-}$



(vi) Ammonia solution consists consists of NH_4^+ and OH^- . OH^- reacts with a Cu^{2+} from CuCl_4 to give Cu(OH)_2 which on further addition of ammonia solution gives $[\text{Cu}(\text{NH}_3)_2(\text{OH})_2]^{+}$ which is deep blue.



Extract 20.2 shows part (a) of the candidate's response whereby he/she managed to give the correct explanation and chemical formula for most items except item (ii) and one equation of item (iv).

9.0 ALIPHATIC HYDROCARBONS

2021 PAST PAPERS

7. (a) (i) What are the two properties that makes organic compounds suitable source of fuel? (2 marks)
- (ii) Compressed natural gas methane, (CH_4) is a fossil fuel found in large quantities in our country, Tanzania. Due to its several advantages, compressed natural gas is considered the most promising vehicles' fuel and thus it should be promoted as the main fuel in our country. State four benefits offered by the compressed natural gas over conventional fuel like gasoline and diesel. (4 marks)
- (b) Suggest suitable chemical test to distinguish between the following compounds:
(i) Butane and 1-butene.
(ii) Propyne and propene.
(iii) Pent-1-yne and pent-2-yne.
(iv) Propane and 1-bromo propane. (4 marks)

7a	
i)	<u>Properties of fuel</u>
v)	<u>The Organic Compounds have a very high energy Value. This means that the combustion of the compound yields a reasonable amount of energy.</u>
v)	<u>Organic Compounds are easily stored, transported about and they are affordable since they are available in plenty.</u>
v)	<u>Benefits offered by Compressed natural gas.</u>
v)	<u>It is environment friendly fuel and doesn't pollute the environment as compared to other fuels like diesel.</u>
v)	<u>Natural gas has a very high energy value as compared to the other conventional fuels like diesel.</u>
v)	<u>Natural gas is easily stored and transported as compared to diesel and gasoline that are hard to transport.</u>
v)	<u>Natural gas is affordable as compared to other conventional fuels that are very expensive.</u>

7b:

ii) Butane and 1-Butene.

By using Brunnard's reagent, 1-Butene reacts with Brunnard's reagent and decolorizes it but Butane does not react with Brunnard's reagent.



iii) Propyne and propene.

By reacting with Ammonical Silver nitrate solution. Propyne forms white precipitates with Ammonical Silver nitrate but propene does not react with Ammonical Silver nitrate.

iv) Pent-1-yne from pent-2-yne.

By reacting with Ammonical Silver nitrate. Pent-1-yne forms precipitates since it has a terminal methyl group but alkyne group but Pent-2-yne does not form precipitates since it lacks a terminal alkyne group.

7b	
iv	Propane and 1-bromo propane.
	By reacting with Sodium Cyanide, 1-bromo propane forms a fuel smelling substance and called alkyl nitrile while propane does not react.
	$\text{CH}_3\text{CH}_2\text{CH}_2\text{Br} + \text{NaCN} \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{C}\equiv\text{N} + \text{NaBr}$ (fuel Smelling).
	$\text{CH}_3\text{CH}_2\text{CH}_3 + \text{NaCN} \rightarrow$ No Reaction.

Extract 7.2: A sample of correct responses in question 7

2020 PAST PAPERS

3. (a) (i) Name two major natural sources of organic compounds. (1 mark)
(ii) Briefly, explain three properties of carbon element that makes it able to form a large number of compounds. (3 marks)
- (b) A form six student gave the following names for various substituted aliphatic hydrocarbons:
(i) 2-methyl-3-bromobutane,
(ii) 3,3-dimethyl-2chlorobutane,
(iii) 4-chloro-3-bromo-2-pentene,
(iv) 2-methyl-4-butyne.
The names indicate the formulae of the substituted aliphatic hydrocarbons but do not strictly obey IUPAC rules. Draw the structure suggested by the incorrect names and assign the correct name for each compound. (4 marks)
- (c) Explain each of the following observations:
(i) Methylpropane has a lower boiling point than butane although both have the same molecular mass.
(ii) Ignition sources such as smoking are not allowed at petrol stations. (2 marks)

3 (a) (i) Coal

(ii) Petroleum.

(I) (i) Catenation

- Carbon has ability to form long linked chain of carbon-carbon bonds hence it form large number of compounds

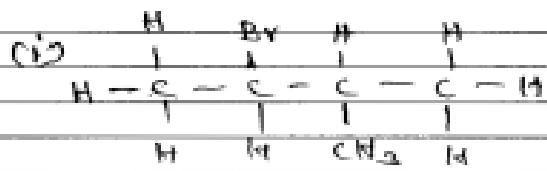
(II) Ability to undergo different types of hybridization

- Carbon can undergo sp^3 , sp^2 and sp types of hybridization hence large number of compounds are formed

(III) Ability to form multiple bonds between its atoms

- Carbon-carbon bonds can be single, double or triple hence a lot of variety of compounds

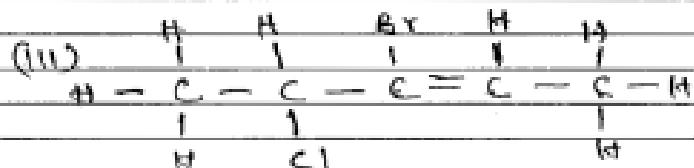
3 b)



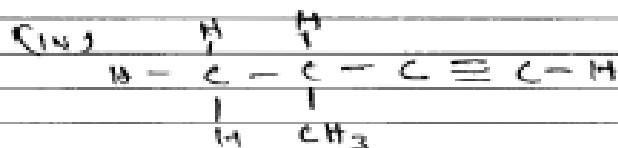
Name: 2-bromo-3-methylbutane.



Name: 2-chloro-3,3-dimethylbutane.



Name: 3-bromo-4-chloropent-1-ene



Name: 3-methylbut-1-yne.

3 c)

(i) This is due to branched structure in methylpropane which provides large surface area and poor packing which lead to poor compactness of its constituents hence it has low boiling point than unbranched butane.

(ii) This because pentane has no organic solvent with volatile and flammable characteristics hence it catch fire easily when it is in vapour form.

Extract 3.1: A sample of correct responses in question 3

2019 PAST PAPERS

13. (a) Write all the isomers of C_5H_{12} . (1.5 marks)
- (b) Draw the structural formulae of the following organic compounds:
 (i) 2,2-dimethylpropane.
 (ii) 4-methylpent-2-yne. (1 mark)
- (c) Name the following compounds:
 (i) $CH_3CH=CHCH_3$,
 (ii) $CH_3C=CCH_2CH_3$. (1 mark)
- (d) Ozonolysis of a hydrocarbon **R** (C_5H_{10}) in the presence of zinc dust gives compounds **S** (C_2H_3O) and **T** (C_3H_5O). While compound **S** gives negative iodoform test, compound **T** responds positively to iodoform test.
 (i) Give the structures of the compounds **R**, **S** and **T**. (1.5 marks)
 (ii) Write all reaction equations that took place during the whole process. (3 marks)

Page 8 of 9

- (e) Using equations, briefly explain how you can differentiate $CH_3C\equiv CH$ from $CH_3C\equiv CCH_3$. (2 marks)

13(a)	Isomers of C_5H_{12}
i)	$ \begin{array}{c} H \quad H \quad CH_3 \\ \quad \quad \\ H-C - C - C - CH_3 \\ \quad \quad \\ H \quad H \quad H \end{array} $
ii)	$ \begin{array}{c} H \quad CH_3 \\ \quad \\ H-C - C - CH_3 \\ \quad \\ H \quad CH_3 \end{array} $
iii)	$ \begin{array}{c} H \quad H \quad CH_3 \\ \quad \quad \\ H-C - C - C - CH_3 \\ \quad \quad \\ H \quad CH_3 \quad H \end{array} $
iv)	$CH_3 - CH_2 - CH_2 - CH_2 - CH_3$

13(b)	i) 2,2-Dimethylpropane.
	$ \begin{array}{c} H \quad CH_3 \quad H \\ \quad \quad \\ H-C - C - C - H \\ \quad \quad \\ H \quad CH_3 \quad H \end{array} $
	ii) 4-Methylpent-2-yne.
	$ \begin{array}{c} H \quad H \quad H \\ \quad \quad \\ H-C - C \equiv C - C - H \\ \quad \quad \\ H \quad CH_3 \quad H \end{array} $
13(c)	i) But-2-one.
	ii) Pent-2-yne
13(d)	By using CuI $CH_3C\equiv CH + CuI \longrightarrow CH_3C\equiv CCu + HCl$ \hookrightarrow Brügel's red ppt.
	$CH_3C\equiv CH + CuI \longrightarrow$ No reaction

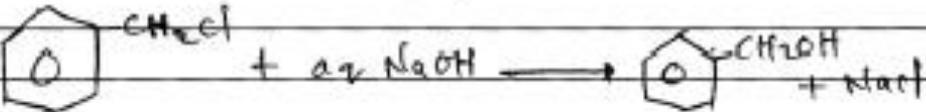
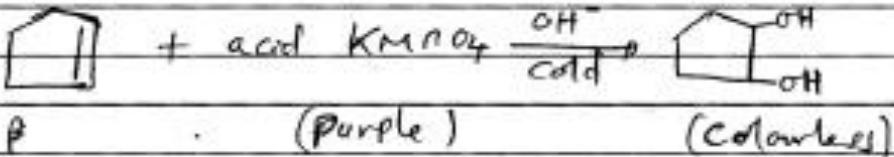
12c)	$\text{R}_2\text{N}^+ (\text{NH}_3)_2^+ \text{OH}^-$
	$\text{CH}_3\text{C}\equiv\text{CH} + \text{Ag}^+(\text{NH}_3)_2^+ \rightarrow \text{CH}_3\text{C}\equiv\text{C}\text{Ag}$ (silver-white ppt.)
	$\text{CH}_3\text{C}\equiv\text{CCH}_3 + \text{Ag}^+(\text{NH}_3)_2^+ \rightarrow \text{No reaction}$
13d)	Compound 5 is $\begin{array}{c} \text{H}_2\text{C}=\text{C}-\text{CH}_2-\text{CH}_3 \\ \\ \text{CH}_3 \end{array}$ $\text{H}_2\text{C}=\text{C}-\text{CH}_2-\text{CH}_3 + \text{O}_2 \xrightarrow{\Delta} \text{H}_2\text{C}\overset{\delta}{\text{C}}\text{H} + \text{CH}_2=\text{CHCO}_2$ Compound 5 is $\text{H}-\overset{\delta}{\text{C}}-\text{H}$ and Compound 7 is $\text{CH}_2=\overset{\delta}{\text{C}}-\text{CH}_3$. Then, $\text{CH}_2=\overset{\delta}{\text{C}}-\text{CH}_3 + \text{I}_2 \xrightarrow{\text{NaOH}} \text{CH}_2\text{COONa} + \text{CHI}_2 + \text{NaI} + \text{H}_2\text{O}$ $\text{H}-\overset{\delta}{\text{C}}-\text{CH}_3 + \text{I}_2 \xrightarrow{\text{NaOH}} \text{No reaction.}$

Extract 13.1: A sample of correct responses in question 13.

2019 PAST PAPERS

11. (a) Suggest suitable tests to distinguish the following pairs of compounds:
- (i) Chlorobenzene and (chloromethyl)benzene. (1 mark)
 - (ii) Cyclopentene and pent-2-yne. (0.5 mark)
 - (iii) Chloroform and carbon tetrachloride. (0.5 mark)
- (b) (i) State and illustrate the type of hybridization at the functional group carbons in alkenes and alkynes. (1.5 marks)
- (ii) Arrange the compounds (ethane, ethene, ethyne and benzene) in order of increasing acidic strength, i.e., starting with less acidic. (0.5 mark)
- (iii) Use sp^3 , sp^2 or sp hybridized orbitals to differentiate sigma (σ)-bond and pie (π)-bond. (1 mark)
- (c) You are provided with the hydrocarbons represented by the following molecular formulae:
- | | |
|--|---|
| $\text{H}_3\text{C}-\overset{\text{H}}{\underset{\text{H}}{\text{C}}}=\text{CH}_3$ | $\text{H}_2\text{C}=\overset{\text{H}}{\underset{\text{H}}{\text{C}}}\text{CH}_3$ |
| 1 | 2 |
- (i) Give systematic names for the hydrocarbons. (1 mark)
 - (ii) State how each hydrocarbon reacts with hydrogen bromide and give the corresponding systematic names for the products. (1 mark)

- (d) Propene reacts with hydrogen bromide following Markovnikov's rule to give a substance A.
 When substance A is heated in the presence of potassium hydroxide, an alcohol B is formed.
- (i) Deduce the chemical structures of substances A and B. (1 mark)
- (ii) By referring to the reaction of substance A with potassium hydroxide under stated condition, illustrate the meaning of the terms "base" and "nucleophile". (2 marks)

<p>11. a) Suitable chemical test between</p> <p>i) chlorobenzene and (chloromethyl)benzene → using aq NaOH, chloromethylbenzene reacts with aqueous NaOH to give benzene alcohol and sodium chloride. The NaCl reacts with AgNO₃ to give white precipitate while chlorobenzene can not precipitate.</p>

$\text{NaCl} + \text{AgNO}_3 \rightarrow \text{AgCl} + \text{NaNO}_3$ (white precipitate)
<p>ii) Cyclopentene and pent-2-yne → cyclopentene decolorizes acidified cold KMnO₄ from purple to colourless while pent-2-yne can not decolorize.</p>

<p>iii) Chloroform and Carbon tetrachloride.</p> <p>→ chloroform reacts with primary amine under alc KOH to give an offensive smelling Isocyanide while carbon tetrachloride can not do so.</p>
$\text{CHCl}_3 + \text{R}-\text{NH}_2 + 3\text{KOH} \rightarrow \text{R}-\overset{\oplus}{\text{N}}\equiv\text{C}$ (offensive smell) $+ 3\text{KCl} + 3\text{H}_2\text{O}$

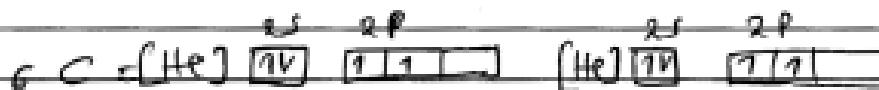
11(b) i) Hybridization of alkene is sp^2 hybridized

Hybridization of Alkyne is sp hybridized

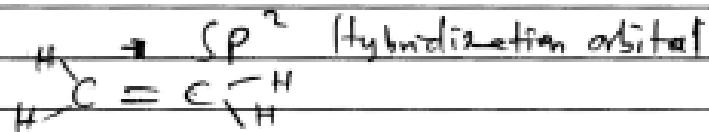
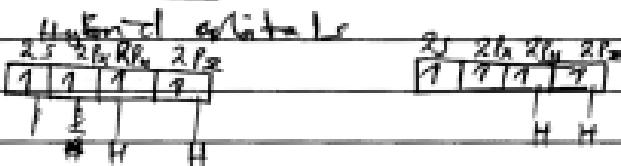
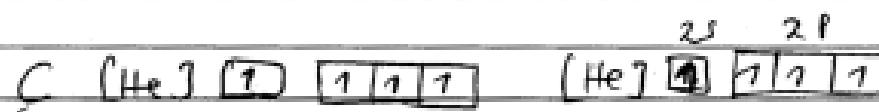
Illustration

Alkene example $\text{CH}_2 = \text{CH}_2$

C at ground state

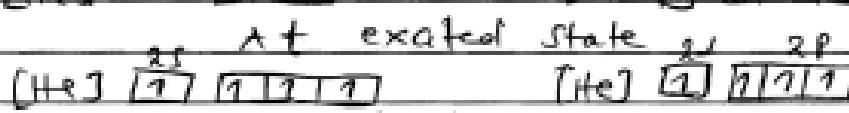


C at excited state



Alkyne example $\text{H}-\text{C}\equiv\text{C}-\text{H}$

C at ground state



Hybridized orbital



iii) i) \rightarrow SP Hybridization orbital



ii) In order of increasing acidic strength

Ethane < ethene < benzene < ethyne

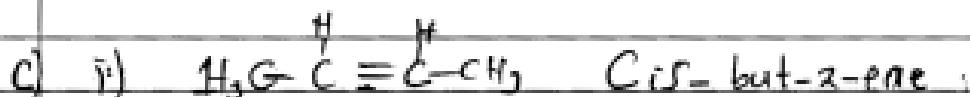
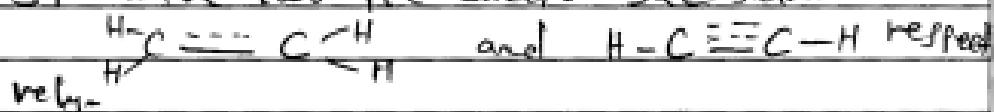
iii) Sigma bond(s) and Pi bond(s)

Sigma bond is the bond which is formed due to end to end overlapping example is than in SP^2 hybridized orbital such as



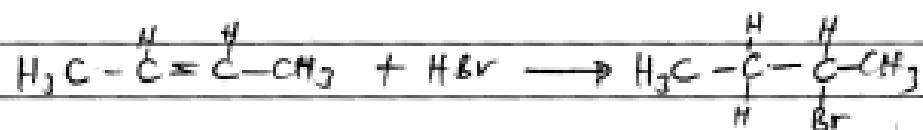
while

Pi bond is the bond which is formed due to side way overlapping. example is that formed in SP^2 have one pi bond and in SP have two pi bond. See below



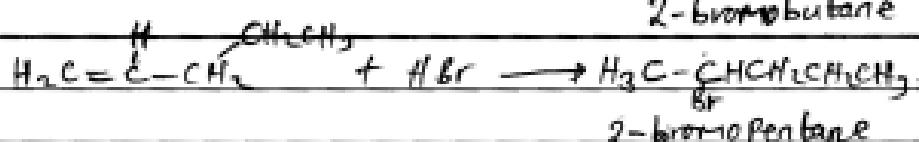
Pent-1-ene .

ii) Reaction with HBr



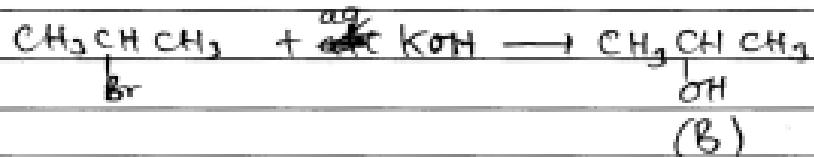
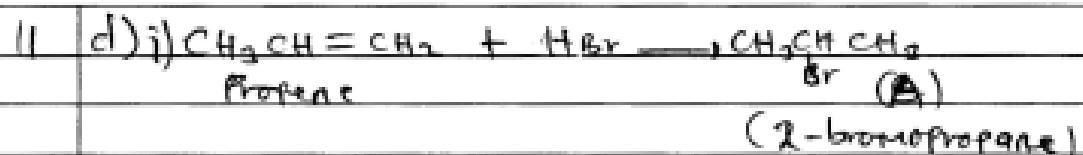
$\underset{Br}{|}$

2-bromobutane



$\underset{Br}{|}$

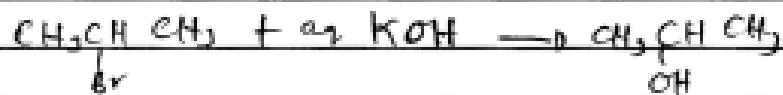
2-bromopentane



(Propan-2-ol)

iii) Base is the any substance that contain Hydroxyl ion and it is able to donate a free Hydroxyl ion

Nucleophile - Is the compound or atom that contain negatively charged particle its electron dense



\rightarrow KOH is a base

\rightarrow OH is a nucleophile

Extract 11.2: A sample of good responses in question 11.

2018 PAST PAPERS

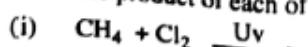
11. (a) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ has a boiling point of -1°C while $\text{CH}_3\underset{\text{CH}_3}{\text{CH}}\text{CH}_3$ has a boiling point of -12°C .

Briefly explain this observation.

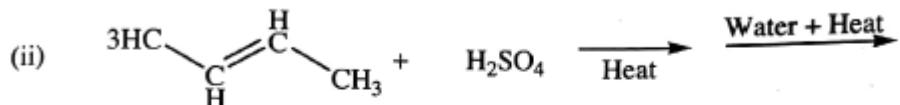
(1 mark)

- (b) (i) With one example, state the meaning of "Friedel-Crafts acylation". (1 mark)
- (ii) With the aid of illustration, show the reaction mechanism between benzene and nitric acid in presence of sulfuric acid. (4 marks)
- (iii) 1,3-dimethylbenzene is oxidized by potassium dichromate(VI) solution. Draw the chemical structure of the product of the reaction. (1.5 marks)

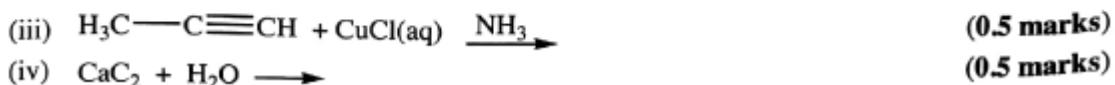
(c) Write the product of each of the following reactions:



(0.5 mark)



(1 mark)



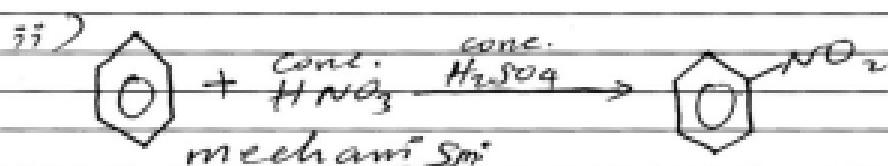
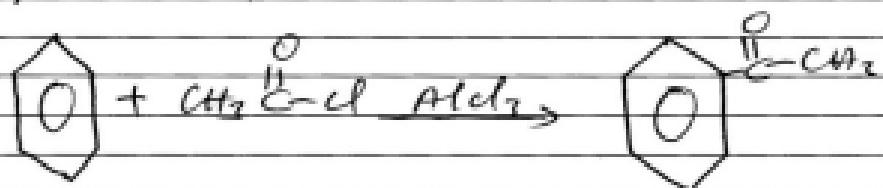
(0.5 marks)



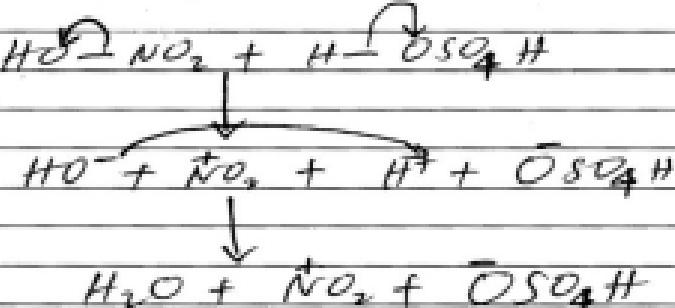
(0.5 marks)

II: (a) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ has high boiling point because it has large surface area as compared to CH_3CHCH_3 . From van der waal's, the large surface area increases the boiling point.

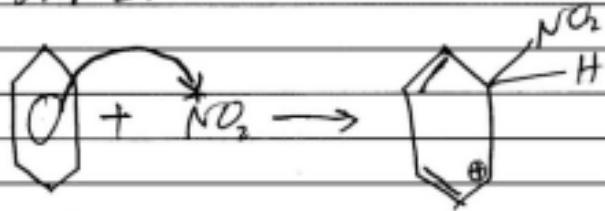
(b) i) Friedel-Crafts acylation is the reaction between benzene and an acyl compound - under presence of AlCl_3 . Example:



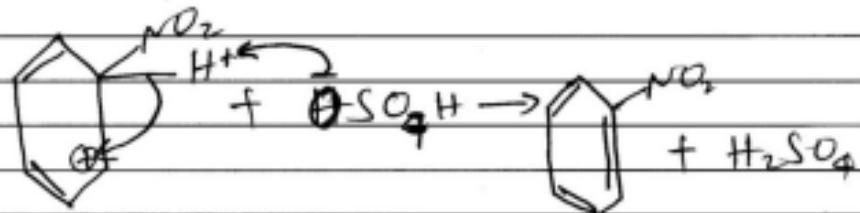
Step 1:



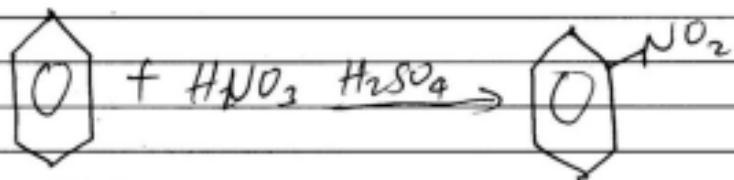
11: (b) iii) Step 2:



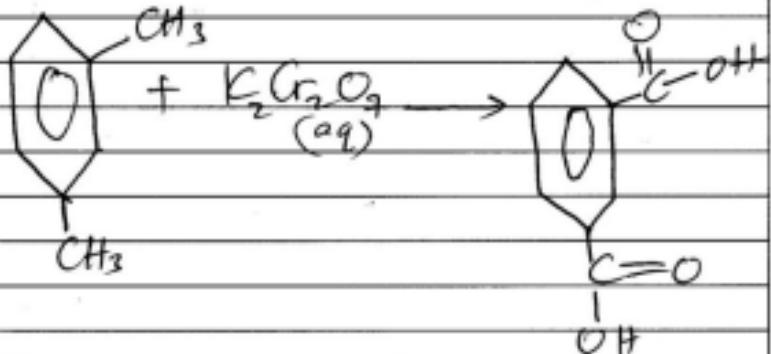
Step 3:



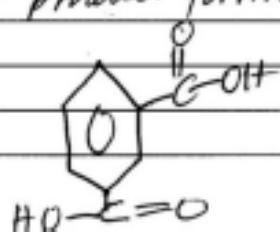
→ overall reaction

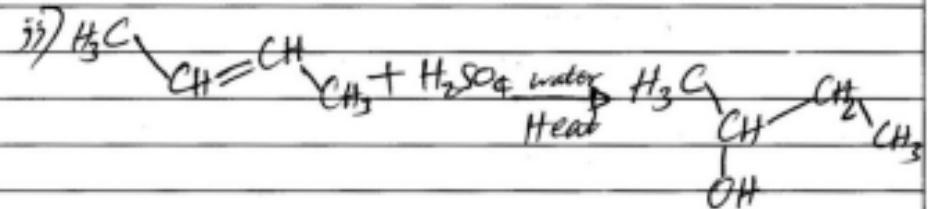
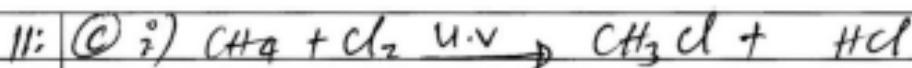


iii)

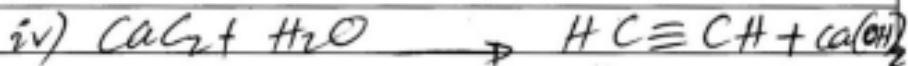
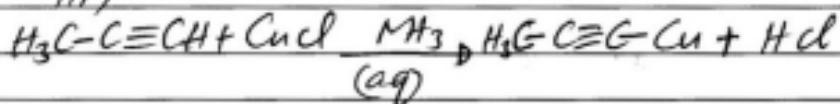


∴ The product formed is:





iii)



In Extract 11.1 the candidate gave correct explanations and products as well as plausible reaction mechanism depending on the demand of each item.

2017 PAST PAPERS

11. (a) Using one appropriate example in each case, briefly explain the meaning of the following terms:
- (i) Homologous series.
 - (ii) Functional group.
 - (iii) Unsaturated hydrocarbon.
 - (iv) Alkyl group. (4 marks)
- (b) Write the formula of the following alkyl groups:
- (i) Methyl group.
 - (ii) Butyl group.
 - (iii) Ethyl group.
 - (iv) Propyl. (2 marks)
- (c) Complete the following reactions:
- (i) $\text{CaC}_2(s) + 2\text{H}_2\text{O(l)} \xrightarrow{\text{cold}}$
 - (ii) $\text{CH}_3\text{CH}_2\text{OH} \xrightarrow[\text{Heat}]{\text{Conc. H}_2\text{SO}_4}$
 - (iii) $\text{CH}_3\text{CH}_2\text{Cl} + \text{KOH} \xrightarrow[\text{Heat}]{\text{Alcohol}}$
 - (iv) $\text{CH}_3\text{CH}=\text{CH}_2 + \text{H}_2\text{O} \xrightarrow{\text{H}^+}$ (4 marks)

11. a) i) Homologous series; Is a family of organic compounds which contains the same functional group characteristics.
Example: Alkene contain double bond.

ii) Functional group; Is a group of atoms which contains the chemical properties of a compound.
Example: OH-group in alcohol and double bond in alkene.

iii) Unsaturated hydrocarbon; It refers to the hydrocarbons which possesses double or triple or π -bonds by its hydrocarbon character between carbon to carbon atoms.
Example: Alkyne and Alkene are unsaturated hydrocarbon

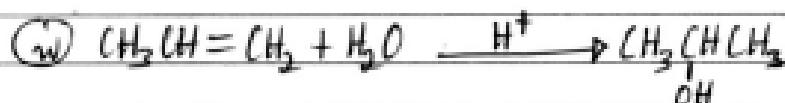
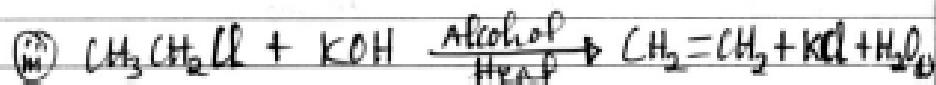
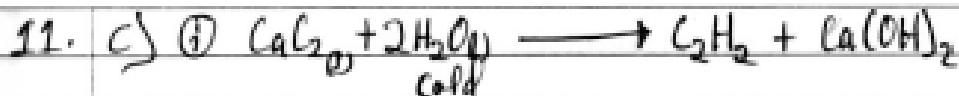
iv) Alkyl group; Is the group of alkane which are formed after the loss of one hydrogen atoms in the compound. Example Ethyl (CH_3CH_2-)
- It is given by $\text{C}_n\text{H}_{2n+1}$

b) i) CH_3 - A methyl group

ii) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ - A butyl group

iii) CH_3CH_2 - Ethyl group

iv) $\text{CH}_3\text{CH}_2\text{CH}_2$ - Propyl group



In Extract 11.1, the candidate managed to explain the meaning of the organic terms and wrote the formula of the functional groups as demanded by the question. She/he also completed correctly, the organic reactions provided.

2016 PAST PAPERS

11. (a) Briefly explain the following terms and give an example of family of organic compounds in each case:

- (i) hydrocarbon
- (ii) saturated hydrocarbon
- (iii) unsaturated hydrocarbon.

(3 marks)

(b) 10 cm^3 of a gaseous hydrocarbon Q required 45 cm^3 of oxygen for complete combustion. Q reacts with 1 mole of bromine gas to form a brominated compound of relative molecular mass of 166 which contains 79.2% bromine.

- (i) Determine the molecular formula of Q.
- (ii) Give the structural formula of Q.

(7 marks)

11	(a) (i) Hydrocarbon is the organic compound formed by Hydrogen and Carbon only. For example Methane $\rightarrow \text{CH}_4$ (methane)
	(ii) Saturated hydrocarbon is the type of hydrocarbon which consists of single bond between carbon atoms (C-C). Example. Ethane $\rightarrow \text{H}_3\text{C}-\text{CH}_3$.
	(iii) Unsaturated hydrocarbon is the type of hydrocarbon which consists of multiple bonds between carbon atoms. Example. Alkenes contain double bonds $\text{H}_2\text{C}=\text{CH}_2$. Alkynes contain triple bonds $\text{H}\text{C}\equiv\text{CH}$.

11	(b) Solution Data given. Volume of hydrocarbon Q = 10 cm ³ Volume of Oxygen = 45 cm ³ . Molecular mass of brominated compound = 200.02. Percentage of Bromine = 79.2% Moles of Bromine = 1 mole.
	Reaction of Q with 1 mole of bromine indicates that the hydrocarbon Q is alkene.
	Reaction: $\text{C}_n\text{H}_{2n} + \text{Br}_2(\text{g}) \xrightarrow{\text{light}} \text{C}_n\text{H}_{2n}\text{Br}_2$
	But Br_2 has 79.2% Molecular mass of $\text{Br}_2 = \frac{79.2}{100} \times 200.02 = 158.42$.
	Molecular mass of Q = $200.02 - 158.42 = 41.6$ Then $\text{C}_n\text{H}_{2n} = 41.6 \approx 42$. $12n + 2n = 42$. $14n = 42$ $n = 3$. C_3H_6

	(i) Therefore the molecular formula of Q is <u>C_3H_6</u> .
	(ii) The structural formula of Q is $\text{CH}_2-\text{CH}=\text{CH}_2$ or $\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{C}=\text{C}-\text{H} \\ \\ \text{H} \end{array}$.

In Extract 8.2, the candidate explained correctly the terms hydrocarbon, saturated hydrocarbon and unsaturated hydrocarbon, and gave correct examples in each case. The candidate also correctly calculated the molecular formula and presented well the structural formula of hydrocarbon Q.

2016 PAST PAPERS

- (a) Define the following:
• (i) isomers
• (ii) isomerism. (2 marks)
- (b) Write the structural formulae of the following:
(i) 3-methyl-1 pentene
(ii) 2-methyl-2-pentene
(iii) 2,2-dimethyl pentane
(iv) 4-methyl pent-2-yne. (4 marks)
- (c) Identify a simple chemical test that can be used to distinguish between the following compounds.
• (i) 1-butyne and 2-butyne
• (ii) Butane and butene. (4 marks)

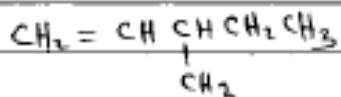
12a) To define

i) Isomers : Are organic compounds which have the same molecular formula but different structural formula.

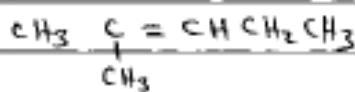
ii) Isomerism : Is the tendency of organic compounds to have the same molecular formula but different structural formula.

b) Structural formulae of the named compounds are as follows

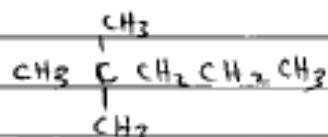
i) 3-methyl - 1-pentene.



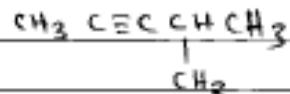
ii) 2-methyl - 2-pentene.



iii) 2, 2-dimethyl pentane.



iv) 4-methyl pent - 2-yne.



12c)	Distinguishing Tests for
i)	$\text{CH}_3\text{CH}_2\text{C}\equiv\text{C}-\text{H}$ and $\text{CH}_3\text{C}\equiv\text{CCH}_3$
	$\Rightarrow \text{CH}_3\text{CH}_2\text{C}\equiv\text{C}-\text{H}$ has acidic terminal hydrogen and hence it will react with Tollen's reagent to form white ppt while $\text{CH}_3\text{C}\equiv\text{CCH}_3$ has no reaction with Tollen's reagent.
	$\text{CH}_3\text{CH}_2\text{C}\equiv\text{C}-\text{H} + [\text{Ag}(\text{NH}_3)_2]^+\text{NO}_3^- \rightarrow \text{CH}_3\text{CH}_2\text{C}\equiv\text{C}\text{Ag} + 2\text{NH}_3$ (white ppt) + HNO_3
	$\text{CH}_3\text{C}\equiv\text{CCH}_3 + [\text{Ag}(\text{NH}_3)_2]^+\text{NO}_3^- \rightarrow \text{No reaction.}$
ii)	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ and $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$ $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ is saturated and hence it can't decolorise bromine while $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$ is unsaturated if decolorizes bromine as per;
	$\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2 + \text{Br}_2 \xrightarrow{\text{CCl}_4}$ $\text{CH}_3\text{CH}_2\text{CH}(\text{Br})\text{CH}_3$ (Brown) or (colorless)
	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 + \text{Br}_2 \xrightarrow{\text{CCl}_4} \text{No reaction.}$

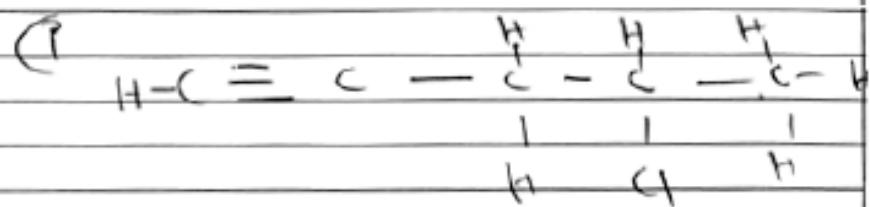
In Extract 12.1, the candidate gave the correct definition of isomers and isomerism. Structural formula of the given organic compounds was correctly written. The candidate also presented correct chemical tests that could be used to distinguish the given organic compounds.

2015 PAST PAPERS

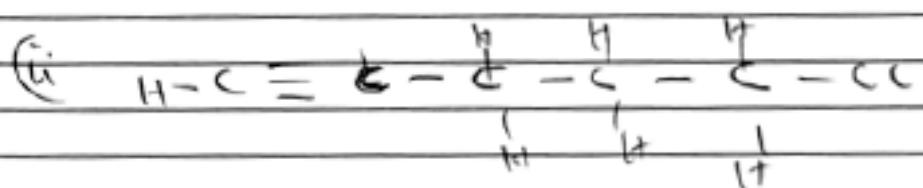
14. (a) Write the open structures of five isomers of the compound $\text{C}_5\text{H}_7\text{Cl}$ and their corresponding IUPAC names. (5 marks)
- (b) Arrange the following compounds in the order of increasing acidity and give reason(s) for your arrangement: $\text{O}_2\text{N}-\text{C}=\text{CH}_2$; $\text{CH}_3-\text{C}(\text{CH}_3)-\text{CH}_2$; $\text{Cl}-\text{C}(\text{CH}_3)-\text{CH}_2$; $(\text{CH}_3)_2-\text{C}\equiv\text{CH}_2$. (2 marks)
- (c) Suggest suitable tests to distinguish the following compounds:
- (i) Propyne and propene.
 - (ii) 2-methylpent-2-ene and 3-methylpent-2-ene.
 - (iii) But-2-yne and butane. (3 marks)

Ques
14
ca

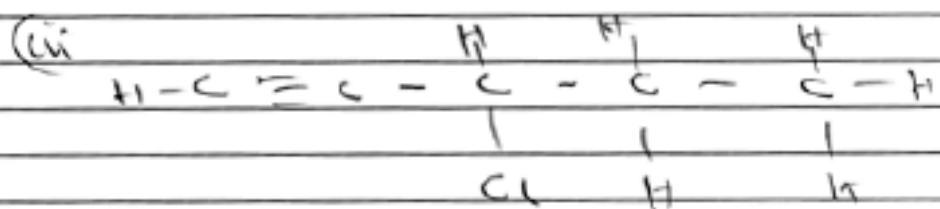
given CH_7Cl ; The isomers are;



Name = 4-Chloro-1-pentyne.



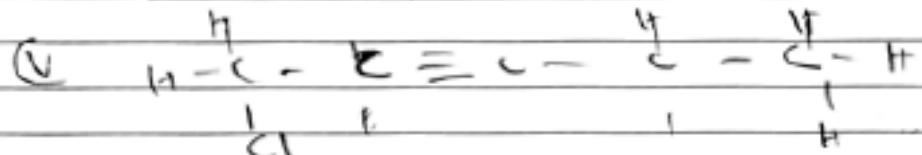
Name = 5-Chloro-1-pentyne.



Name = 3-Chloro-1-pentyne.

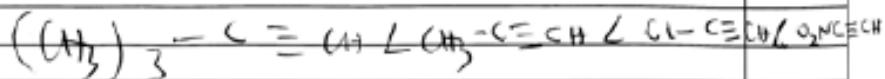


Name = 4-Chloro-2-pentyne.



Name = 1-Chloro-2-pentyne

14(b) Arrangement :-



\rightarrow

Increasing acidity.

Reason :-

The acidic strength increases with the negative inductive effect and the $-$ resonance which deactivates (removes or attracts) electrons from the functional group ($\text{C} = \text{C}^-$). Thus making it polar and H^+ more positive.

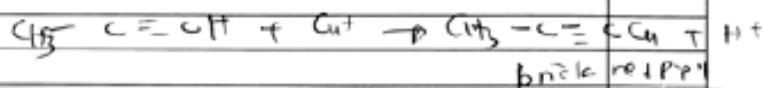
$\Rightarrow \text{NO}_2^-$ being having $-$ negative resonance and negative inductive effect due to electronegative O, and N make the molecule more acidic followed by Cl^- which gives negative inductive effect.

\Rightarrow But $(\text{CH}_3)_3\text{C}^-$ and CH_2^- are alkyl groups which provides +ve inductive effect. Thus making the $-\text{C} = \text{C}-\text{H}$ bond less polar hence less acidic.

14 (Chemical Tests)

(i) Propyne and propene.

Test \Rightarrow Reaction with CuCl in which propyne forms brick red precipitate but propene does not.



14 (ii)

2-methylpent-2-one and 3-methylpent-2-one

Test \Rightarrow Oxidation with conc. KMnO_4/H^+

2-methylpent-2-one gives acetic acid which can be tested on oxidation while 3-methylpent-2-one gives propionic acid.

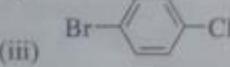
	(iii) But - 2 - yne and Butane.	
14e	Test \Rightarrow Baeyer test (Reaction with conc $KMnO_4$)	
	But - 2 - yne decolorizes the purple colour of $KMnO_4$ to colourless in acidic medium but Butane does not	
	$C_4H_2 + KMnO_4 \xrightarrow{\text{conc. } H_2SO_4} C_4H_2CO_4H$	
	But - 2 - yne + $C_4H_10 \xrightarrow{\text{No Reaction}}$	

In Extract 14.1 the candidate gave open structures with their names in part (a). In the same way, he/she managed to arrange the given compounds in the order of increasing acidity with reasons. Furthermore, he/she managed to distinguish the given compounds in part (c).

10.0 AROMATIC HYDROCARBONS

2021 PAST PAPERS

9. (a) Write the IUPAC name of the following organic compounds:

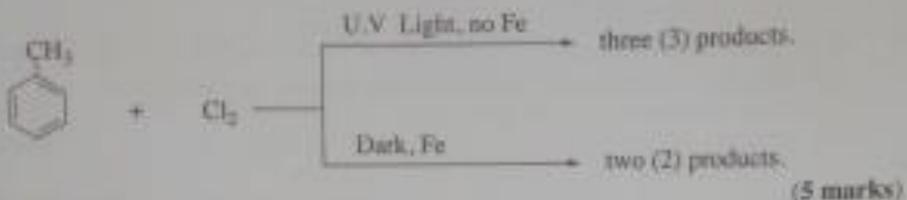
- (i) CCl_3CH_3
- (ii) $\text{CHCl}_2\text{CCl}_2\text{CHCl}_2$
- (iii) 
- (iv) $\text{CCl}_3\text{CH}_2\text{CCl}_3$

Page 4 of 6

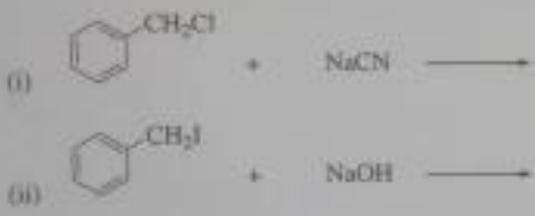
(2 marks)

- (b) With the aid of a chemical equation (no reaction mechanisms is needed), give a reason for the position occupied by bromide atom when bromine reacts with:
(i) phenol. (1 mark)
(ii) benzene carbaldehyde. (1 mark)

- (c) Write the structures and the names of five products in the following reaction:

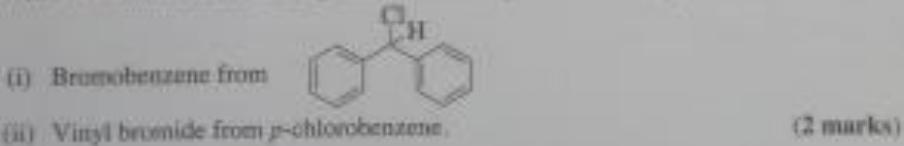


- (d) Write the product of each of the following nucleophilic substitution reactions:



(2 marks)

- (e) Write a chemical test to distinguish the following chemical compounds.



- (f) Using chemical equations, show step-wise conversion of 2-phenol into each of the following organic compounds:



Q

i)

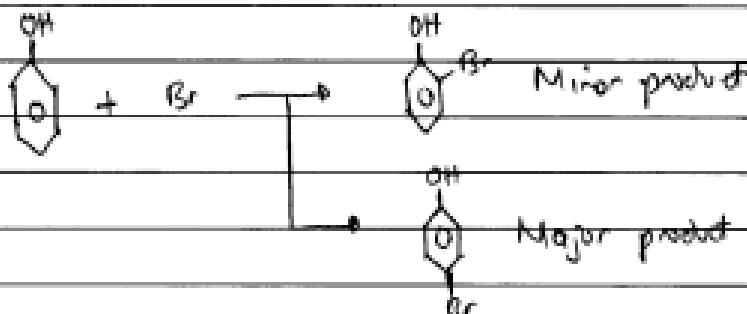
i) 1,1,1 - trichloroethane

ii) 1,1,2,2,2,2 - hexachloropropane

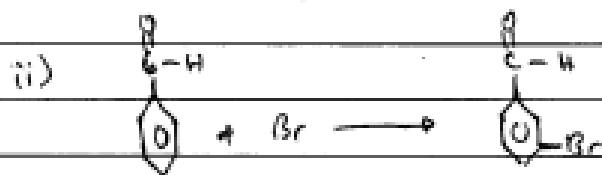
iii) 1-bromo - 4-chlorobenzene

iv) 1,1,1,2,2,2 - hexachloropropane

Q i)



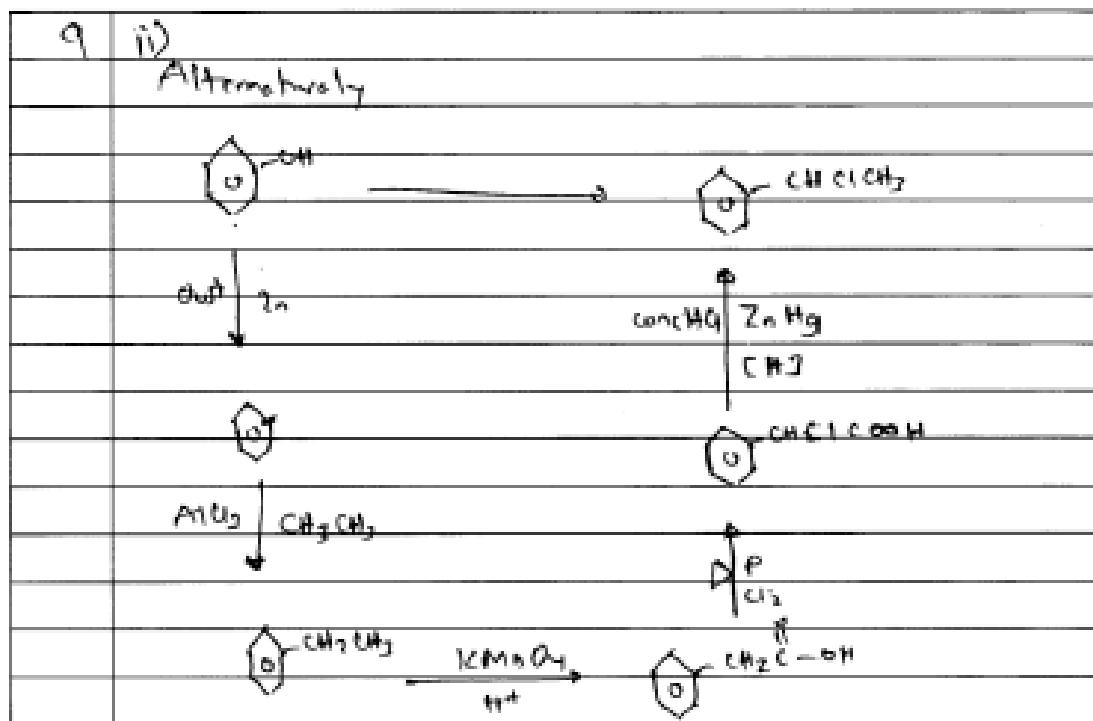
As -OH is an activator it will direct bromide atom to ortho or para position



As -CHO is a deactivator it will direct the coming bromide atom to meta position

q	c)	
		Names of products
		* Under $\text{U.V. light, } \text{FeCl}_3$
		CH_3Cl
		Benzyl chloride / 1-chloro-1-phenylmethane
		CH_2Cl_2
		1,1-dichloro-1-phenylmethane
		CCl_4
		1,1,1-trichloro-1-phenylmethane
		* Under Dark, Fe
		CH_3
		$\text{C}_6\text{H}_5\text{Cl}$
		2-Chloro-1-methylbenzene
		C_6H_5
		4-Chloro-1-methylbenzene.

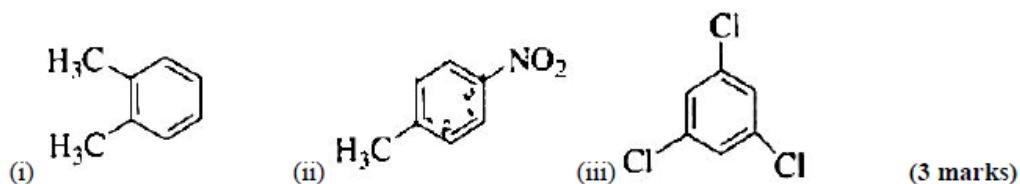
q	d)	
	i)	$\text{C}_6\text{H}_5\text{Cl} + \text{NaOH} \longrightarrow \text{C}_6\text{H}_5\text{ONa} + \text{H}_2\text{O}$
	ii)	$\text{C}_6\text{H}_5\text{Cl} + \text{NaOH} \longrightarrow \text{C}_6\text{H}_5\text{OH} + \text{NaCl}$



Extract 9.1: A sample of appropriate responses in question 9

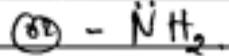
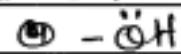
2020 PAST PAPERS

- Why benzene though highly unsaturated, it does not undergo addition reactions? Briefly explain. (4 marks)
- Name two examples in each of the following chemical groups:
 - Ortho-para* directors.
 - Meta* directors.
(2 marks)
- Why *ortho-para* directing groups are called activating groups and *meta*-directing groups are called deactivating groups? Briefly explain. (4 marks)
- Determine the structural formulae of the following compounds:
 - 1,3,5-trimethylbenzene.
 - (1-methylethyl)benzene.
(2 marks)
- Give the IUPAC names of the following aromatic compounds:

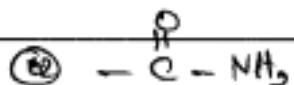
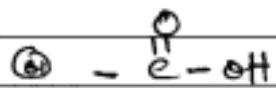


10 a) Benzene according to resonant structure consists of π -bonded electrons which are in resonance. The bond electron pairs are not localized. Due to delocalization of electrons caused by resonance addition reaction can not take place. This is because large extra energy is required to break the resonance and then break the π -bonded electron so as addition can take place.
 - This is only attained at high temperature and pressure which are normally not reached hence addition reaction become impossible.

b) i) Ortho para - directors includes



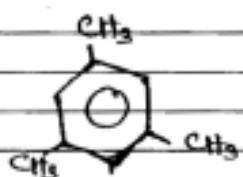
ii) Meta directors includes



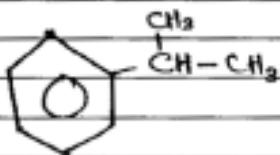
10 c) Ortho-para directing groups are called activating groups because they tend to supply electron to the benzene ring due to mesomerism. This increases the electron density at the benzene ring and hence it becomes reactive to an incoming electrophile at ortho and para positions.

Meta directors are called deactivating groups because they tend to withdraw electron from the benzene ring. This reduces the electron density at the benzene ring and hence it becomes less reactive towards an incoming electrophile. It directs it at meta position.

d)



e)



c) i) 1,2-dimethylbenzene

ii) 4-nitroanisole

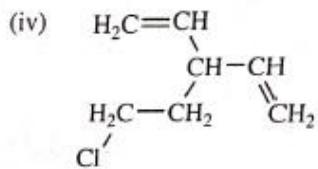
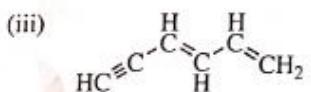
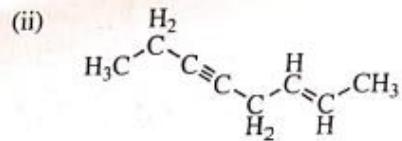
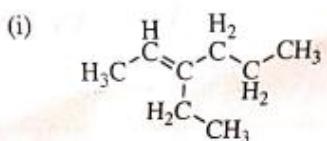
iii) 1,3,5-trichlorobenzene

Extract 10.1: A sample of correct responses in question 10

2019 PAST PAPERS

12. (a) (i) Define the term isomerism. **(0.5 mark)**
(ii) Pentane has three isomers. Draw their chemical structures and provide their corresponding IUPAC names. **(1.5 marks)**

(b) Give the IUPAC names of the following organic compounds:



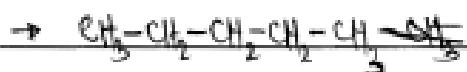
(2 marks)

(c) Compound A is known to be aromatic and contains 66.4% carbon, 5.5% hydrogen and 28.1% chlorine by mass. The vapour density of pure A was found to be 63.

- (i) Find the empirical formula of compound A. **(1 mark)**
(ii) Find the relative molecular formula of compound A. **(1 mark)**
(iii) Give the chemical structures of the four isomers of compound A and their corresponding IUPAC names. **(2 marks)**
(iv) Which of the isomers of compound A will react with dilute KOH. Briefly explain your answer. **(2 marks)**

12 (a) Isomerism Is the occurrence of two or more organic compounds with the same molecular formula but different structural arrangement.

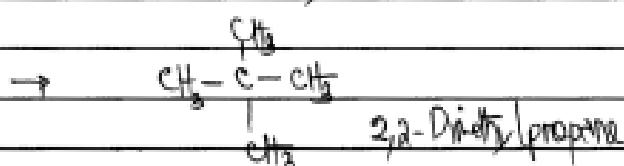
(i) Given,



n-Pentane



2-Methylbutane



(b) (i) 3-Ethylhex-2-ene

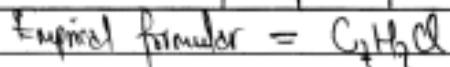
(ii) Octa-2-en-5-yne

(iii) hexa-1,3-dien-5-yne.

(iv) 3-(2-chloromethyl)-penta-1,4-diene

12 (c)

Element	C	H	Cl
Percents by weight	66.4	5.5	28.1
	12	1	35.5
Divide by smallest number	5.5	5.5	0.79
	0.79	0.79	0.79
Simpliest form	6.9	6.9	1
	7	7	1



(i) Vapour density = Molecular weight

a.

$$\text{Molecular weight} = 9 \times \text{V.D}$$

$$= 2 \times 63$$

$$= 126 \text{ g/mol}$$

Then, (Empirical formula)_n = Molecular weight

$$(C_7H_7Cl)_n = 126$$

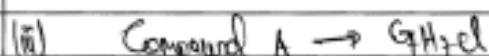
$$126 \cdot 5n = 126$$

$$n = 126 / 126 \cdot 5$$

$$= 0.9$$

$$\approx 1$$

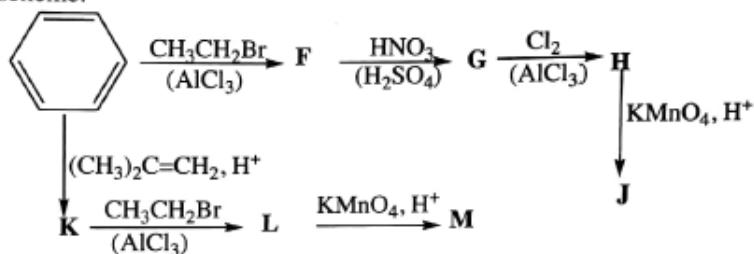
∴ Molecular formula of compound A is C_7H_7Cl .



Extract 12.1: A sample of good responses in question 12.

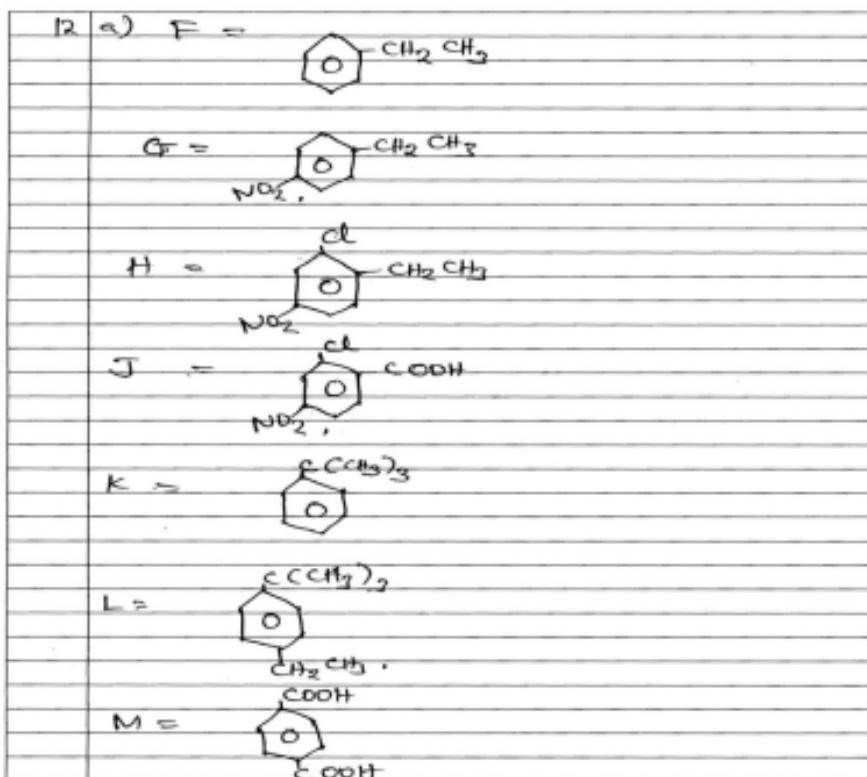
2018 PAST PAPERS

12. (a) Give the structural formula of aromatic compounds F to M which are formed in the following reactions scheme: (6 marks)



(b) What is the product for the chlorination of benzene and methylbenzene in the presence of:

- (i) a halogen carrier catalyst (2 marks)
- (ii) ultra-violet light. (2 marks)



Extract 12.1 shows that the candidates gave correct products F, G, H, J, K, L and M by drawing the structures.

2017 PAST PAPERS

14. (a) State Markovnikoff's rule.

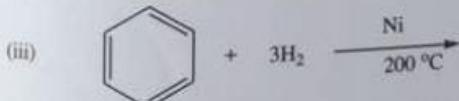
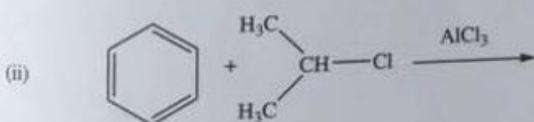
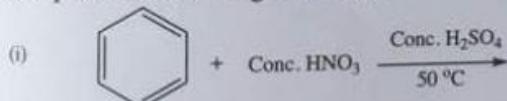
(1 mark)

(b) By indicating whether the reaction will involve side chain, aromatic ring or both, write chemical equations showing the reaction between phenylethene (styrene) and:

- (i) Br₂.
- (ii) H₂, (Pt) at 25°C.
- (iii) H₂, (Pt) at 200 °C.

(3 marks)

(c) Complete the following reactions:



(3 marks)

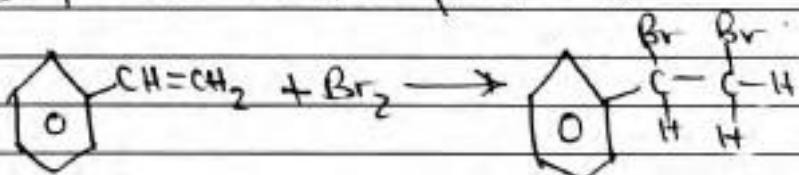
(d) Arrange the following set of compounds in order of decreasing relative reactivity to an electrophile E⁺:

- (i) chlorobenzene, 2,4-dinitrobenzene, 4-nitrochlorobenzene.
- (ii) methylbenzene, 4-nitromethylbenzene, 2,4-dinitromethylbenzene.

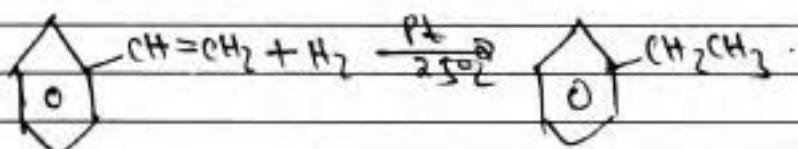
(3 marks)

14. c) Markovnikoff's rule states that "when an electrophile is added to the unsaturated compounds, tend to combine with the carbon atom having greater number of hydrogen atoms first".

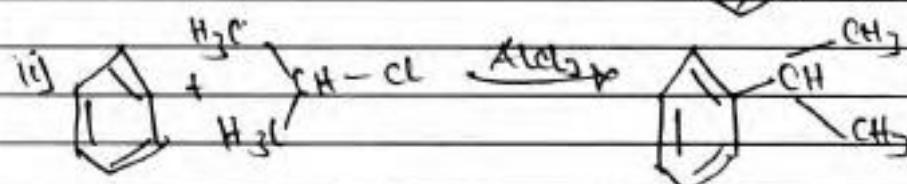
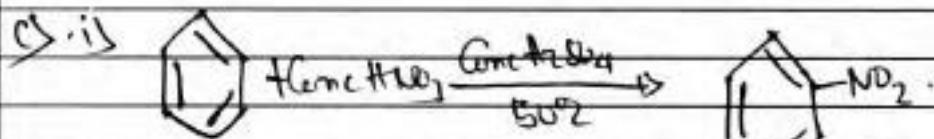
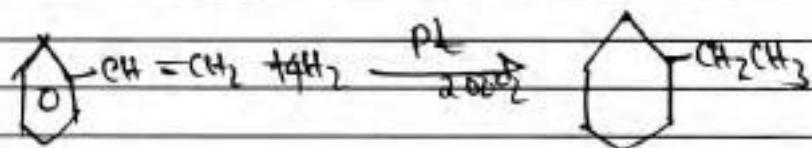
b) i) Reaction will take place to side chain

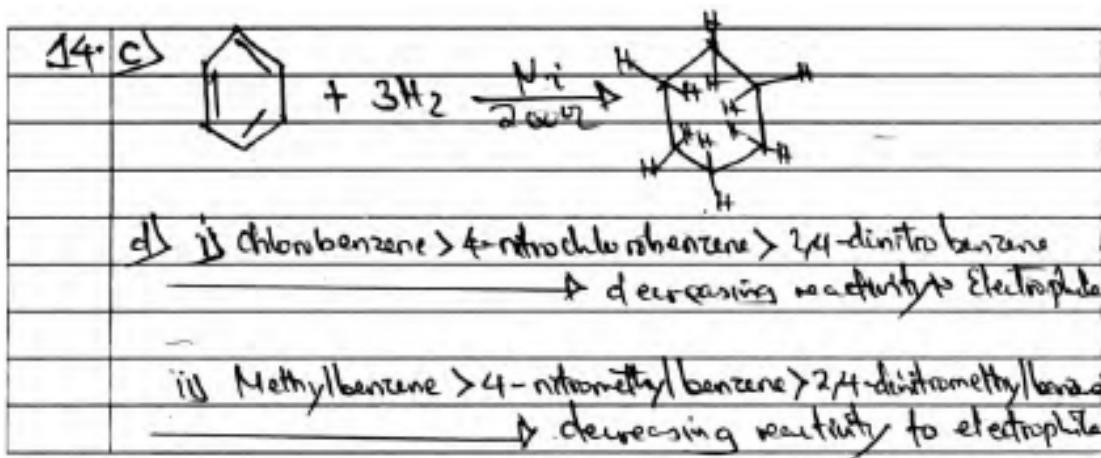


ii) Reaction will take place to side chain



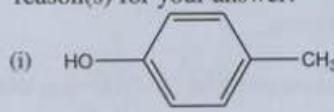
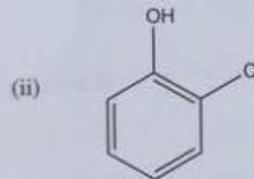
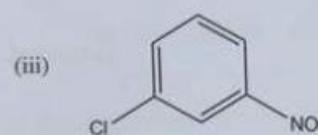
iii) Reaction will take place at both side chain and aromatic ring.





Extract 14.1 is a sample of a good answer in which the candidate presented correctly the Markovnikoff's rule and the position at which the reaction will take place in phenylethene, when reacted with the given reagents. He/she also completed the given reactions and arranged the given compounds in order of decreasing reactivity as demanded by the question.

2017 PAST PAPERS

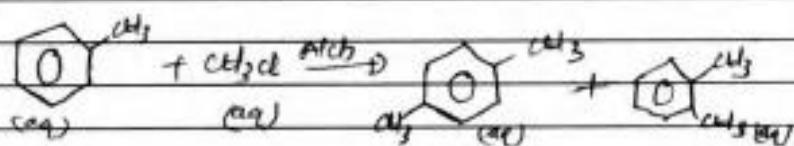
12. (a) Define the following terms:
 (i) Resonance energy.
 (ii) Aromatic compound. (2 marks)
- (b) Briefly explain why methyl benzene (toluene) is more reactive than benzene. (1 mark)
- (c) Write equations to show what will happen when methyl benzene is
 (i) treated with chloromethane (CH_3Cl) in presence of aluminium chloride (AlCl_3).
 (ii) treated with chlorine in presence of ultraviolet (uv) light.
 (iii) refluxed with potassium manganate (VII) (KMnO_4) in the presence of an acid.
 (iv) burnt in excess oxygen. (4 marks)
- (d) Indicate in the following aromatic compounds, which substituent group entered first. Give reason(s) for your answer.
- (i) 
- (ii) 
- (iii) 

12Q (i) Resonance energy is the energy required to stop the resonance in benzene ring, that is delocalisation of

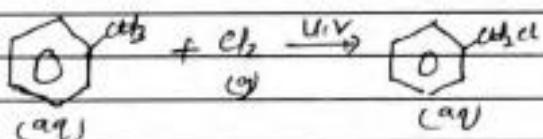
(ii) Aromatic compound is an organic compound which contain benzene ring, which gives sweet smell.

(b) This is because methyl group in toluene is activator hence activate a benzene ring toward incoming electrophile by increasing electron density which make toluene more reactive.

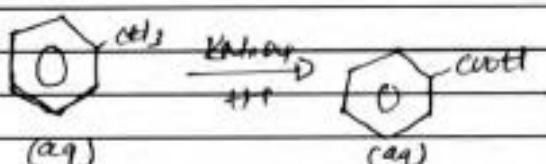
(c) (i)



(ii).



(iii).



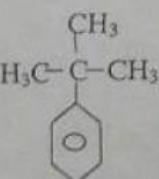
Extract 12.1 is a part of the answer in which the candidate was able to define the terms resonance energy and aromatic compound and explained correctly why methyl benzene (toluene) is more reactive than benzene. She/he correctly wrote the equations and their products in part (c) of the question.

2016 PAST PAPERS

i. (a) Briefly explain the following:

- (i) The C-C bonds are all equal and intermediate in length between a single and a double bond in benzene.
- (ii) Dry ether is necessary in the preparation and use of the Grignard reagent. (7 marks)

(b) The chlorination of methyl benzene and 1,1-dimethylethyl benzene yield the following isomers:

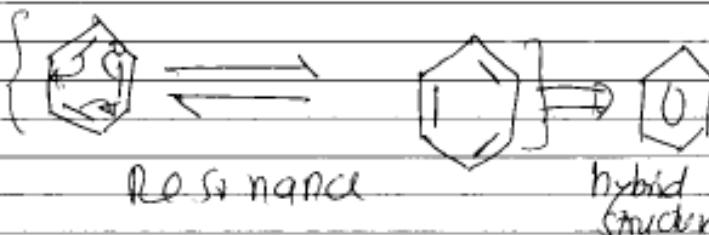
	2	3	4
	60%	0.5%	39.5%
	22%	8%	70%

Study the isomers and then explain the observed different product ratio. (3 marks)

14.1a) C-C in bond all equal and intermediate in length between single and double bond

14.1a) i) This is due to delocalization of the lone pairs in the benzene make the electron charge density around the C-C bond to be of equal length.

- i.e. Delocalization lead to spread of the charge density to all C-C single bond and also C=C double bond thus making to have same length.
This can be show by resonance below



ii) Dry ether is necessary in preparation of dry ether Grignard Reagent

Grignard reagent is prepared by reaction between alkyl halide and magnesium in presence of dry ether

ie $R\text{Mg} + Cl \rightarrow$ ether $R\text{Mg}$

If the ether must be dry in preparation to prevent the hydrolysis of the Grignard reagent to form the alkene. Thus we may employ dry ether to get the required reagent.

Now in the use of Grignard reagent, dry ether must be present to prevent the hydrolysis of Grignard reagent.

14 (b)

In methylbenzene the isomer of 2 is 60% because the ortho methyl is ortho-para director, but the higher yield in ortho is due to small in size of methyl group thus less steric hindrance.

In 1-methyl 1,1-dimethyl ethylbenzene in the ortho carbon there is large steric hindrance thus due to large nature of alky group hence lower yield in isomer (2) Thus it prefer to attack in para carbon which is isomer 4 thus higher yield.

In both case methylbenzene and 1,1-dimethyl benzylbenzene the meta carbon which is isomer 3 is less deactivated thus give lower yield in both cases.

In Extract 14.2 the candidate gave the correct explanation on the delocalization of 6π electrons around the benzene ring. In the same way, he/she appropriately explained the ratio of the product based on the concept of ortho-para director and steric hindrance.

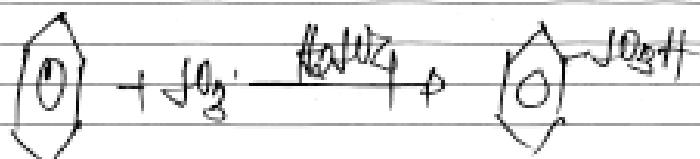
2015 PAST PAPERS

12. Give the mechanism for the following:

(a) Sulphonation of benzene.

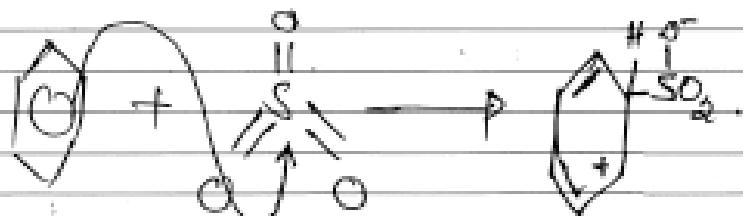
(b) Chlorination of benzene.

12 (a) Sulphonation of benzene
Reaction

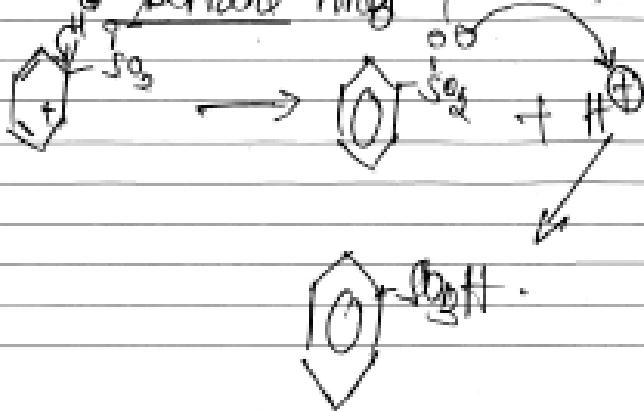


use by H_2SO_4 as a medium
Mechanism

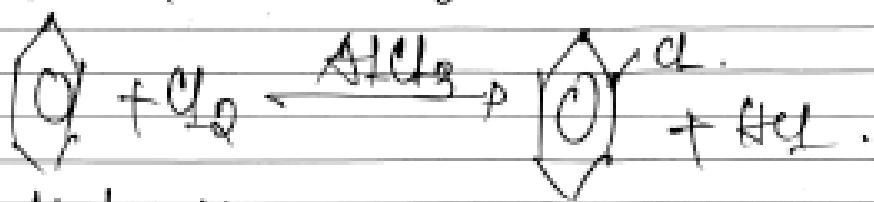
① Formation of intermediate
(Benzonium ion)



② Production of hydrogen ion and
benzene ring

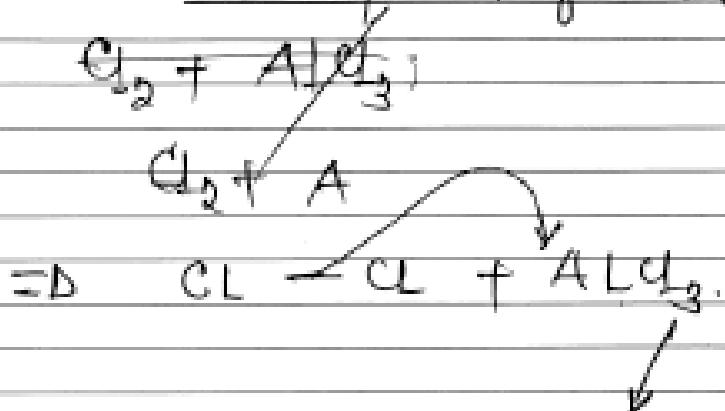


12 ⑥ chlorination of benzene.

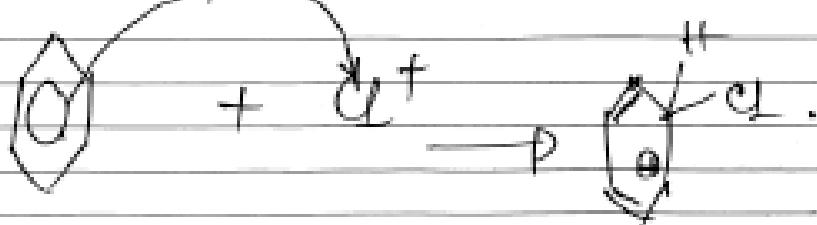


Mechanism

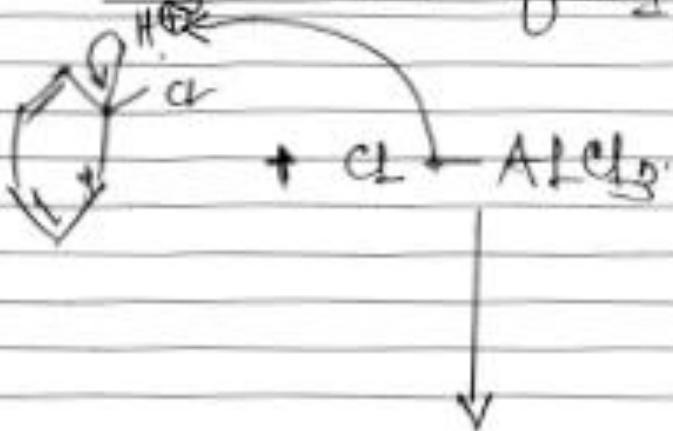
① formation of electrophile.



② formation of carbonium ion.



12(b) (ii) formation of product and regeneration of catalyst



(O) Cl^- + HCl
and catalyst AlCl_3 is
regenerated

Extract 12.2 is a sample of a well presented answer. The candidate showed correctly mechanisms for both sulphonation and chlorination of benzene.

2015 PAST PAPERS

11. (a) Briefly explain each of the following as applied in organic reactions:
- (i) Positive inductive effect.
 - (ii) Negative inductive effect.
 - (iii) Mesomeric effect.
 - (iv) Steric factors. (4 marks)
- (b) Explain each of the following observations:
- (i) Addition reactions in benzene need high energy.
 - (ii) Nucleophilic substitution reactions in benzene are not possible.
 - (iii) Methyl group when attached to benzene ring direct another incoming group to ortho or para position.
 - (iv) Nitro group when attached to benzene ring direct another incoming group to meta position.

II a) i) Positive inductive effect - Is the ability of electrons an element to conduct electrons towards itself.

ii) Negative inductive effect - Is the ability of an element to reject or withdraw electrons ^{away} from itself.

iii) Mesomeric effect - Is the effect that occurs in chemical reactions.

iv) Steric factors - These are factors afforded for any reaction to take place.

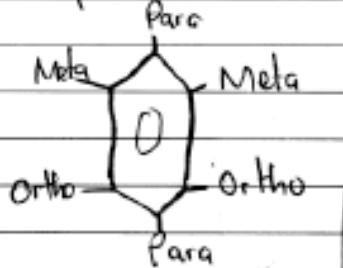
b) i) Addition reaction in benzene needs high energy because it does not require to lose or gain an electron because it has satisfied itself therefore when addition reaction takes place it requires high energy.

(ii) Nucleophilic substitution in benzene.

is not possible because it can not substitute any electron C₆H₆ benzene has satisfied itself.

iii) Because Methyl group is a special group hence it cannot shift but easily direct the incoming group to ortho or para position

iv) Nitro group direct the incoming group to meta position because it is near,



Extract 11 shows that, although the candidate attempted all parts of the question, none of the parts was correctly answered. For instance, the answers given in part (b) (iii) and (iv) do not indicate whether the candidate knew the factors which activate or deactivate the benzene ring and factors which determine the orientation of substitution in the benzene ring.

11.0 HALOGEN DERIVATIVES OF HYDROCARBONS

2019 PAST PAPERS

14. (a) Show a one step reaction, how the following molecules can be prepared. Indicate suitable reagents and conditions for their preparation.

- (i) Butan-2-ol from 2-iodobutane. (1 mark)
- (ii) Propane from 1-chloropropane. (1 mark)
- (iii) Ethylamine from iodoethane. (1 mark)
- (iv) Butane from bromoethane. (1 mark)
- (v) Methylbenzene from bromomethane (1 mark)
- (vi) But-2-ene from 2-bromobutane (1 mark)

(b) A haloalkane **P** ($C_5H_{11}Br$) reacts with aqueous sodium hydroxide to give **Q** ($C_5H_{12}O$). **Q** reacts with concentrated H_2SO_4 at $170^\circ C$ to form **R** (C_5H_{10}) which decolourises bromine water. When **R** is reacted with ozone followed by hydrolysis, methanal and a branched aldehyde **S** is formed. Deduce the structural formula of **P**, **Q**, **R** and **S** by showing the chemical reactions involved.

(4 marks)

14.	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{I}$ T	$\xrightarrow{NaOH \text{ (aq)}}$ $\xrightarrow{170^\circ C}$	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ $\xrightarrow{\text{H}_2 / \text{Ni}}$ $\xrightarrow{170^\circ C}$		$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$
	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$ $\xrightarrow{\text{KMnO}_4}$		$\text{CH}_3\text{CH}_2\text{CH}_2\text{COH}_2$
	$\text{CH}_3\text{CH}_2\text{CH}_2\text{COH}_2$ $\xrightarrow{\text{Hg}_2\text{Cl}_2 \text{ ether}}$		$\text{CH}_3\text{CH}_2\text{CH}_2\text{COH}_2\text{CH}_2\text{OH}_2$
	$\text{CH}_3\text{CH}_2\text{Br}$ $\xrightarrow[\text{AlCl}_3]{\text{ZnCl}_2}$		$\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$
	$\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ $\xrightarrow[\text{KOH}]{\text{Hg(OAc)}_2}$		$\text{CH}_3\text{CH}_2\text{CH}_2=\text{CHCH}_3$

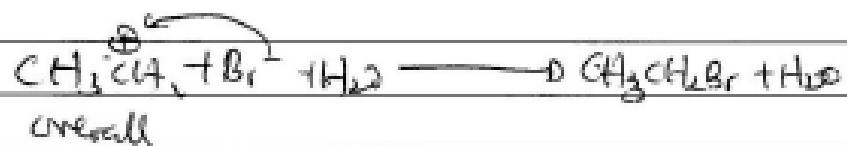
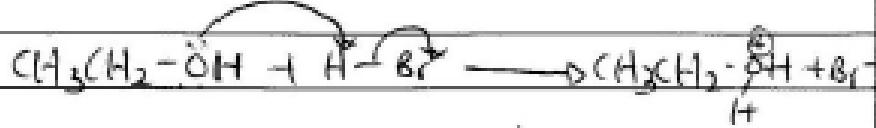
14 (b).	$P(C_2H_5Br) + NaOH \xrightarrow{aq}$	$Q(C_5H_{10}O)$
	$\textcircled{1} (C_5H_{10}O) + H_2SO_4 \xrightarrow{190^\circ C} R(C_5H_{10})$	
	$R(C_5H_{10}) + O_2 \xrightarrow{H_2O, \text{conc } H_2SO_4} H-\overset{\textcircled{2}}{C}-H + CH_3\overset{\textcircled{3}}{CH}CH_2$	
	Structures of P, Q, R and S.	
	$\begin{matrix} CH_3 & CH & CH_2CH_2Br \\ & & \\ CH_3 & & CH_3 \end{matrix} + NaOH \xrightarrow{aq} \begin{matrix} CH_3 & CH & CH_2CH_2CH_2OH \\ & & \\ CH_3 & & CH_3 \end{matrix}$	
	P	Q
	$\begin{matrix} CH_3 & CH & CH_2CH_2OH \\ & & \\ CH_3 & & CH_3 \end{matrix} \xrightarrow[\text{conc } H_2SO_4]{190^\circ C} \begin{matrix} CH_2 & CH & CH=CH_2 \\ & & \\ CH_3 & & CH_3 \end{matrix}$	
	Q	R
	$\begin{matrix} CH_2 & CH & CH=CH_2 \\ & & \\ CH_3 & & CH_3 \end{matrix} + O_2 \xrightarrow{H_2O} \begin{matrix} CH_2 & CH & CH_2 \\ & & \\ CH_3 & & CH_3 \end{matrix} + H-\overset{\textcircled{4}}{C}-H$	
	R	S
	Hence .	
	$P = \begin{matrix} CH_3 & CH & CH_2CH_2Br \\ & & \\ CH_3 & & CH_3 \end{matrix}$	
	$Q = \begin{matrix} CH_3 & CH & CH_2CH_2OH \\ & & \\ CH_3 & & CH_3 \end{matrix}$	
	$R = \begin{matrix} CH_2 & CH & CH=CH_2 \\ & & \\ CH_3 & & CH_3 \end{matrix}$	
	$S = \begin{matrix} CH_2 & CH & CH_2 \\ & & \\ CH_3 & & CH_3 \end{matrix} \overset{\textcircled{4}}{C}-H$	

Extract 14.1: A sample of correct responses in question 14.

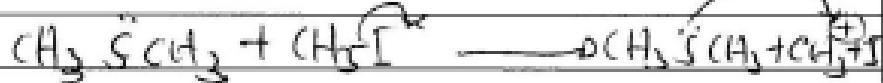
2018 PAST PAPERS

14. (a) Arrange the following alkyl chlorides in order of decreasing reactivity in an SN_1 reaction:
- | | |
|----------------------|-----------------------|
| (i) CH_3Br | (ii) $C(CH_3)_2Br$ |
| (iii) $CH(CH_3)_2Br$ | (iv) $CH_3CH_2CH_2Br$ |
- (2 marks)
- (b) Write mechanism for the following substitution reactions:
- | | |
|--|-----------|
| (i) $CH_3CH_2OH + HBr \longrightarrow CH_3CH_2Br + H_2O$ | (2 marks) |
| (ii) $CH_3SCH_3 + CH_3I \longrightarrow (CH_3)_3S^+I^-$ | (2 marks) |
- (c) When phenol is treated with Br_2 , a mixture of mono bromophenol, dibromo phenol and tribromo phenols are obtained. Write a synthesis mechanism to convert phenol to:
- | | |
|---------------------|-----------|
| (i) 2-bromophenol | (2 marks) |
| (ii) 4-bromophenol. | (2 marks) |

(b) (i)



(ii)

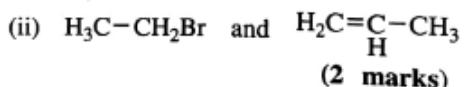
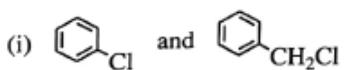


In Extract 14.2, the candidate gave correct reaction mechanisms for the two reactions in part (b)(i) and (ii).

2018 PAST PAPERS

13. (a) With the aid of reaction equations, outline six different applications of haloalkanes in organic synthesis processes. Use R—X as a haloalkane. **(6 marks)**

(b) For each pair of compounds given below, provide a chemical test to distinguish them.

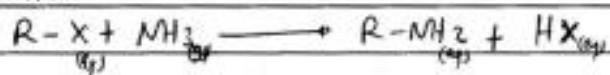


(2 marks)

(c) Silver nitrate solution does not precipitate the chloride in 1-chloropropene, but it does so in 1-chloropropane. Give a reason to account for this. **(2 marks)**

13	<p>(a) Uses of haloalkane in synthesis process.</p> <p>1. It is used in synthesis of alcohol</p> <p>reaction</p> $\text{reaction. } \text{R-X}_{\text{aq}} + \text{NaOH}_{\text{aq}} \longrightarrow \text{R-OH}_{\text{aq}}$
	<p>2. It is used in synthesis of alkene</p> <p>reaction. $\text{R-X}_{\text{aq}} + \text{KOH}_{\text{aq}} \xrightarrow{\text{Alcohol}} \text{R-CH=CH}_2_{\text{aq}} + \text{H}_2\text{O}_{\text{aq}} + \text{KX}_{\text{aq}}$</p>
	<p>3. Haloalkane are used in synthesis of Grignard reagent.</p> <p>reaction $\text{R-X}_{\text{aq}} + \text{Mg}_{\text{aq}} \xrightarrow{\text{dry ether}} \text{RMgX}_{\text{aq}}$</p>
	<p>4. Halo alkane are used in synthesis of ether.</p> <p>reaction. $\text{R-X}_{\text{aq}} + \text{Et}_2\text{O-NaOEt}_{\text{aq}} \longrightarrow \text{R-O-R}_{\text{aq}} + \text{NaX}_{\text{aq}}$</p>
	<p>5. Haloalkane are used in synthesis of nitrile compound</p> <p>$\text{R-X}_{\text{aq}} + \text{NaCN} \xrightarrow{\text{warm}} \text{R-CN}_{\text{aq}} + \text{NaX}$</p>

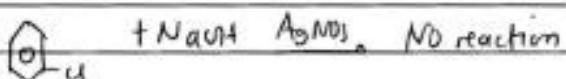
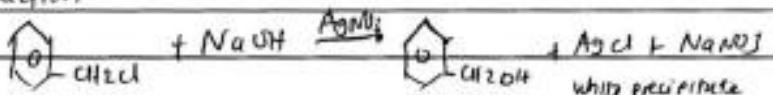
13 (a) (i) haloalkanes are used in synthesis of amine reaction



(b) (i) C_6H_5Cl and CH_3Cl

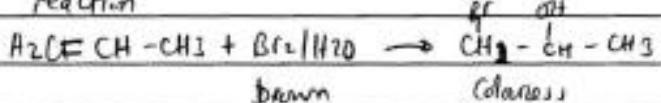
Are distinguished by reacting them with NaOH_{aq} .
Whereby chlorobenzene do not form precipitate in presence
of silver nitrate but phenylchloromethane it form a white
precipitate in presence of silver nitrate.

reaction



(ii) $\text{H}_3C-\text{CH}_2Br$ and $\text{H}_2C=CHCH_3$ Are distinguished by
using bromine water whereby propene cleaves the brown colour
of bromine water into colourless but bromoethane do not
react with bromine water

reaction



(iii) presence of π bond in chlorobenzene will prevent precipitation
of chloride by silver nitrate because chloro π bond is more reactive
than the bond between carbon and chlorine but it precipitate in CH_3Cl
 π propane due to absence of π bonds and propane is becomes more
reactive to react with AgNO_3 .

Extract 13.1 is an illustration of good responses from one of the candidates
who managed to answer all the parts of the question correctly and scored full
marks.

2017 PAST PAPERS

13. (a) Briefly explain why alkyl chlorides are not friendly to the environment.

(b) Write the structures of the following alkyl halides:

- (i) 2-chloro-3-methylpentane.
- (ii) Pent-2-ene.

(c) Give IUPAC names of the following compounds:

- (i) $\begin{array}{c} \text{Br} \\ | \\ \text{CH}_3\text{CHCHCH}_3 \\ | \\ \text{Cl} \end{array}$
- (ii) $\text{CICH}_2\text{C}\equiv\text{CCH}_2\text{Br}$
- (iii) $\text{CHF}_2\text{CBrClF}$
- (iv) $\text{CCl}_3\text{CHClCCl}_3$

(4 marks)

(d) A primary alkyl halide, A, ($\text{C}_4\text{H}_9\text{Br}$) reacted with alcoholic KOH to give compound B. Compound B reacted with HBr to give C which is an isomer of A. When C (in ether solution) reacted with Na metal, it gave compound D (C_8H_{18}).

- (i) Give the structure of A.
- (ii) Write equations for all the reactions.

(1 mark)

(3 marks)

13	<p>(a) Alkyl chlorides are not friendly to the environment because they are reactive and thereby react with environmental components bringing hazardous conditions for the living organism example CFCs cause destruction of ozone layer</p> <p>(b) (i) $\begin{array}{c} \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 \\ \\ \text{Cl} \end{array}$; 2-chloro-3-methylpentane</p> <p>(ii) $\text{CH}_3(\text{H}=\text{CHCH}_2\text{CH}_3)$; pent-2-ene</p> <p>(c) (i) 2-bromo-3-chlorobutane</p> <p>(ii) 1-bromo-4-chlorobut-2-yne</p> <p>(iii) 1-bromo-4-chloro-1,2,2-trifluoroethane</p> <p>(iv) 1,1,1,2,2,3,3-heptachloro propane</p>
----	---

(d) (i)	The structure of A is $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$
---------	--

The chemical reactions are	
(i)	
(ii)	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{KOH(solid)} \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
	A.
	B.
(iii)	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} \xrightarrow{\text{HgF}} \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$
	C.
(iv)	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 \xrightarrow[\text{Et}_2\text{O}, \text{dry ether}]{\text{Na, solution}} \begin{matrix} \text{CH}_3 \\ \\ \text{CH}_3\text{CH}_2\text{CH}-\text{CH}_2\text{CH}_2\text{CH}_3 \end{matrix}$
	D.

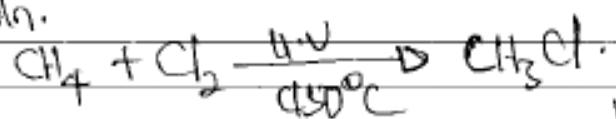
Extract 13.1 is an example of a well presented answer which made the candidate to score high marks.

2016 PAST PAPERS

3. (a) (i) Outline the stages in the formation of chloromethane from methane and chlorine at 450°C .
(ii) Give reason why the chloromethane obtained in (a) (i) is not pure. (5 marks)
- (b) Bromoalkanes may react with alcoholic potassium hydroxide solution to form alkenes. Basing on this statement answer the following questions:
- (i) What type of organic reaction is this reaction?
 - (ii) Write an equation for the reaction of 1-bromobutane with alcoholic potassium hydroxide. Show all mechanisms involved.
 - (iii) Draw the structural formula of the alkene obtained by reaction between 2-bromobutane and alcoholic potassium hydroxide. (5 marks)

(Q) (i) ChloroMethane
from Methane and chlorine
at 450°C.

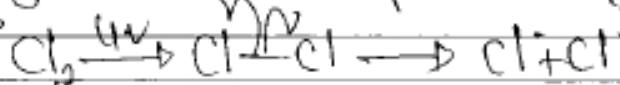
Soln.



This process involve three stages

1st stage: Chain initiation.

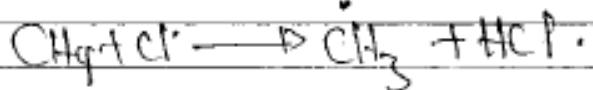
In this stage involve the formation of
two radicals



2nd stage: Chain propagation.

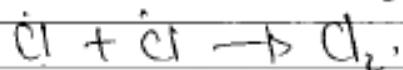
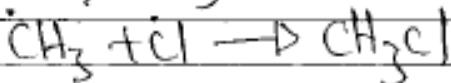
In this stage involve the formation of
following:

Cl react with $\text{CH}_4^{\cdot\cdot}$ and form
the CH_3



3rd stage: Chain termination.

In this stage the two radical combine
to form compound



(i) The reason for the chloromethane formed in the reaction to not be pure.

This is because at the chain termination stage there is production of different compound as it halts the reaction of free radicals.

That is



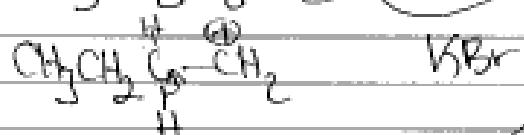
both CH_3CH_3 and Cl_2 remain as the impurities.

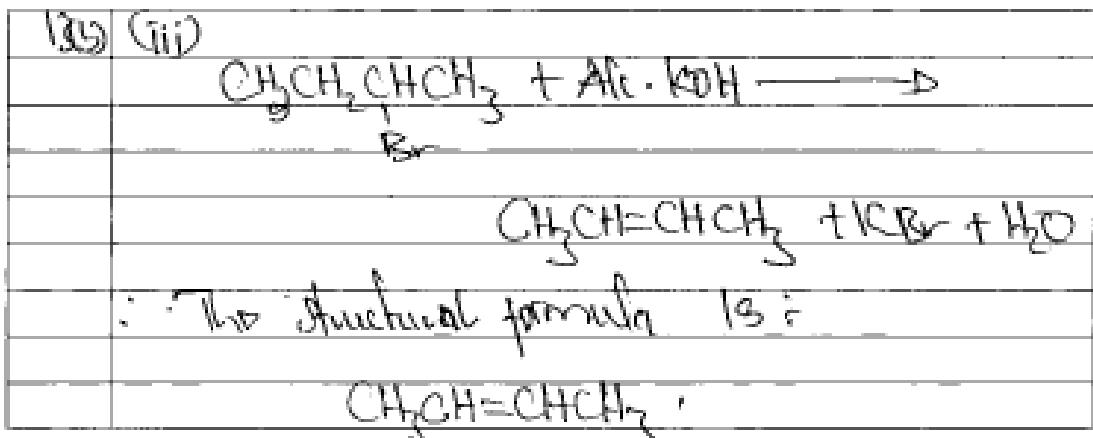
(ii) Soln.



(i) It is an Elimination reaction

(ii) reaction

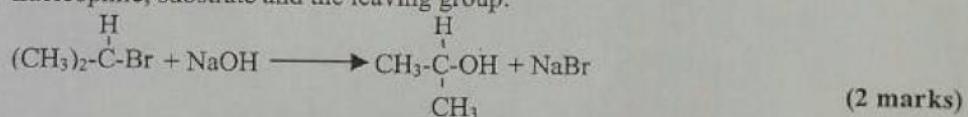




In Extract 13.1, the candidate correctly answered all the parts of the question. All mechanisms for the reactions are clearly shown.

2015 PAST PAPERS

- * 13. (a) Write the mechanism of the following substitution reaction, indicating clearly the nucleophile, substrate and the leaving group:



- (b) Carry out the following conversions:

- (i) Propane to 1-chloropropane.
 (ii) Propane to propene. (2 marks)

- (c) Complete the following reactions and name the organic product formed.

- * (i) $\text{CH} \equiv \text{CH} + \text{Cl}_2 \xrightarrow{\text{AlCl}_3}$
- (ii) $\text{CH} \equiv \text{CCH}_3 \xrightarrow[\text{HgSO}_4 \text{ at } 60^\circ\text{C}]{\text{Dil. H}_2\text{SO}_4}$
- (iii) $\text{CH} \equiv \text{CNa} + \text{CH}_3\text{I} \rightarrow$
- (iv) $\text{CH}_2 = \text{CH}_2 \xrightarrow{\text{aq. KMnO}_4, \text{OH}^-}$ (6 marks)

There are no answers for this question

12.0 HYDROXYL COMPOUNDS

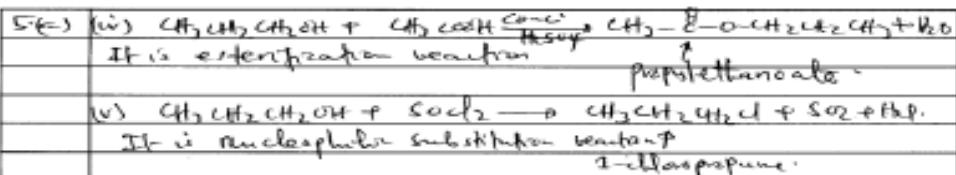
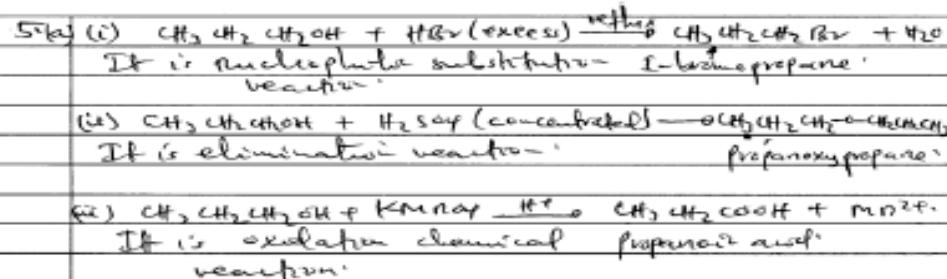
2021 PAST PAPERS - 2

5. (a) From the knowledge you have on hydroxyl group, write the chemical reaction equations with their IUPAC names showing what happen when propan-1-ol is treated with;

- excess HBr under reflux.
- a small amount of concentrated H_2SO_4 .
- acidified $KMnO_4$.
- ethanoic acid in the presence of concentrated H_2SO_4 .
- $SOCl_2$.

(10 marks)

(b) Compound A ($C_{10}H_{12}O$) gives off oxygen on treatment with sodium metal and also decolorizes Br_2 in CCl_4 to give organic compound B. Compound A on treatment with I_2 in $NaOH$ gives Iodoform and a salt C which after acidification gives a white solid D($C_7H_6O_2$). Using knowledge of organic chemistry, identify structures A, B, C and D. (10 marks)

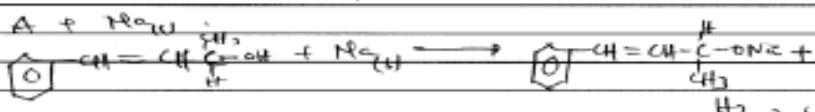


(b) organic compound A, should
 should have the hydroxyl group so that it
 can react with sodium metal.
 It should also have the terminal methyl group
 which react with iodofrom test.
 Since A decolorises Br_2 in CCl_4 it
 contains the double bonds.

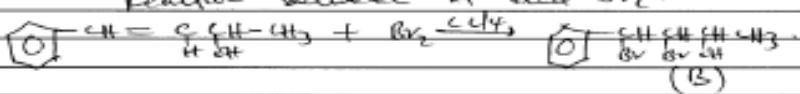
As compound A is aromatic compound
 Therefore the structure of compound A is

$$\begin{array}{c} \text{H} \\ | \\ \text{O}=\text{C}-\text{C}-\text{C}-\text{H} \\ | \quad || \\ \text{H} \quad \text{H} \end{array}$$

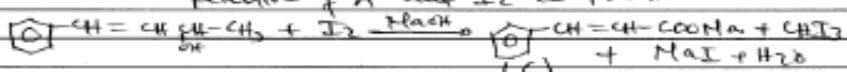
Consider the reaction:



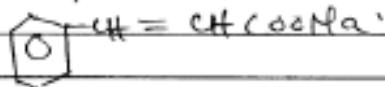
Reaction between A and Br_2 .



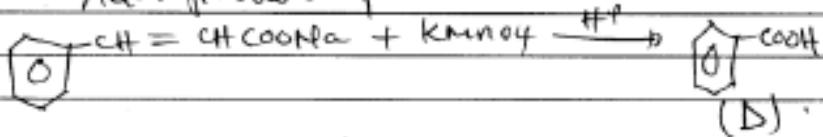
Reaction of A and I_2 in $NaOH$.



5.(b) therefore the structure of C is

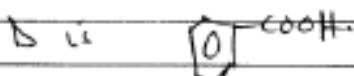
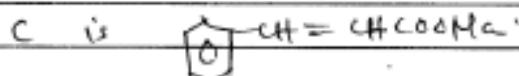
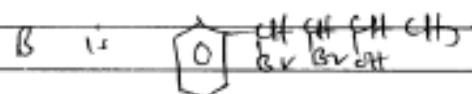
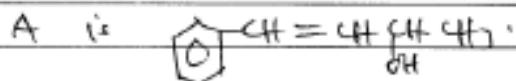


A carbonyl group



(D)

Hence the structures are:



Extract 15.2: A sample of correct responses in question 5

2019 PAST PAPERS - 2

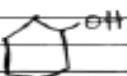
8. (a) An alcohol with a formula $\text{C}_6\text{H}_{11}\text{OH}$ does **not** react with bromine or bromine water.
- (i) What does the information about bromine tell you?
 - (ii) Identify the number of rings the compound possess.
 - (iii) Draw the structure of the alcohol.
 - (iv) Suggest the name for alcohol in (a)(ii). (6 marks)
- (b) (i) Show the structure and IUPAC name of the resulting organic compound when propan-1-ol reacts with ethanoic acid in mineral acid.
- (ii) Phenol has a structure very much like ethanol. Draw the structure of the molecules and predict whether anything would happen if the two liquids are mixed with hot benzoyl chloride in acidic medium. (9 marks)
- (c) (i) Can alcohols act as nucleophiles? Give reason for your answer.
- (ii) If you were using PCl_5 or SOCl_2 to test for the presence of OH^- groups, explain why the chemicals and apparatus must be dry. (5 marks)

Q8. (2) (i) The information tell that such an Alcohol does not contain double bond or triple bond in its chain.

(2) (ii) The Compound possess a single ring which is

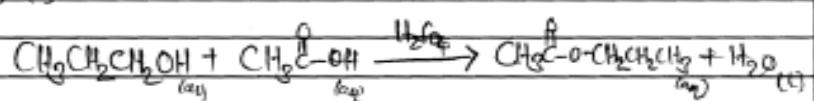


(2) (iii) The Structure of the Alcohol is

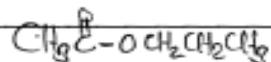


(2) (iv) IUPAC name : Cyclohexanol

Q8. (b) (i)



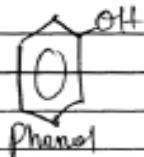
STRUCTURE



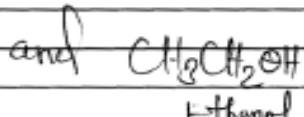
IUPAC NAME

Propylethanoate

OR (b) (ii) The structure of the Molecules are as follows

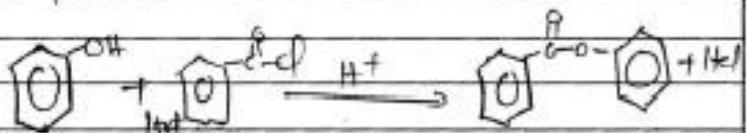


Phenol

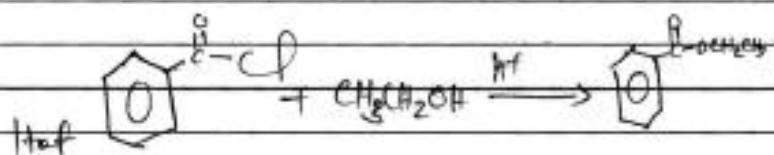


Ethanol

Q8. (b) (ii) Phenol reacts with hot bromoethane in acidic medium to form phenyl bromoate as follows:



Also Ethanol reacts with hot bromoethane to form ethyl bromoate as follows:



Q. (c) (i) Yes Alcohol can act as Nucleophile this is because it possess lone pairs found on oxygen. thus it can donate the lone pairs to an Electrophile.
i.e. $\text{CH}_3\text{CH}_2\ddot{\text{O}}\text{H} \rightarrow \text{lone pairs}$

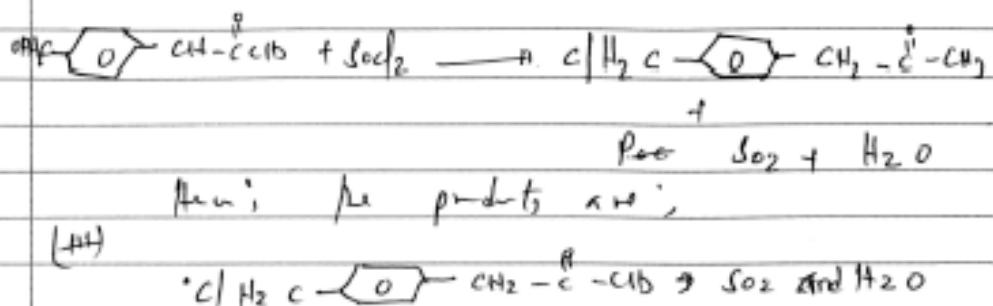
Q8. (c) (ii) The Chemical and Apparatus must be dry on testing the presence of OH^- group, because when water is present it will give the wrong results as also it possess OH^- group So the Apparatus and Chemicals should be kept dry so as to have Accurate measured results.
i.e. $\text{H}_2\text{O} \xrightarrow{\text{(aq)}} \text{H}^+ + \text{OH}^-$

Extract 22.2: A sample of correct responses in question 8.

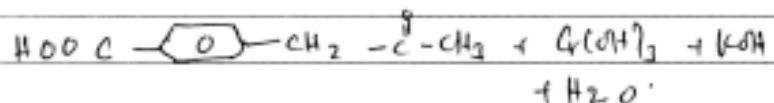
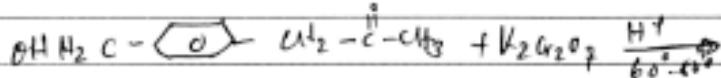
2015 PAST PAPERS - 2

B	(a) (i) (ii)	$\text{CH}_3 - \overset{\overset{\text{O}}{\parallel}}{\text{C}} - \text{CH}_3$	propanone (carbonyl).
	(iii)	$\text{CH}_3 - \text{CH} = \text{CH}(\text{OH})$	prop-1-en-1-ol. (Alcohol)
	(iv)	$\text{CH}_3 - \text{COOH}$	ethanoic acid (carboxylic acid).
	(v)	$\text{H} - \text{COO} - \text{CH}_3$	methyl/methanone (Ester).
	(vi) (i)	$\text{CH}_3 - \text{CH}_2 - \text{OH}$	Ethanol (Alcohol).
	(ii)	$\text{CH}_3 - \text{O} - \text{CH}_3$	methoxymethane (Ether).
B	(b) (i) Hydroxyl group, OH^- (Alcohol group). (ii) Carbonyl group (ketone, -C=O group) (iii) Benzene (O) (iv) Alkene group (carbon-carbon single bond, C=C)		
B	(c) (i)	$\text{HOH}_2\text{C}-\text{O}-\text{CH}_2-\overset{\overset{\text{O}}{\parallel}}{\text{C}}-\text{CH}_3 \xrightarrow[\text{warm.}]{\text{NaBH}_4, \text{Et}_2\text{O}}$	$\text{CH}_3 + \text{H}_2\text{O}$
		$\text{HOH}_2\text{C}-\text{O}-\text{CH}_2\text{COONa} + \text{H}_2\text{O}$	
	∴ Products are: (i) Triiodomethane (ii) Sodium iodide (iii) NaI (iv)		

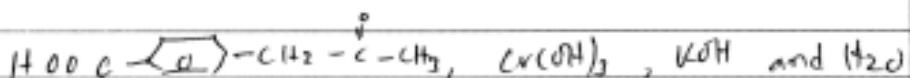
8 (C) (ii)



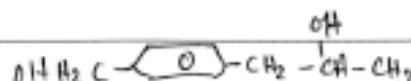
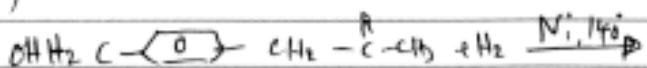
(iii)



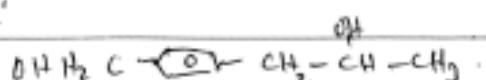
Here; products are;



(iv)



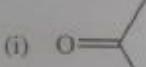
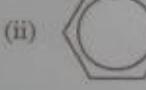
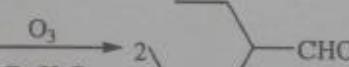
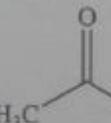
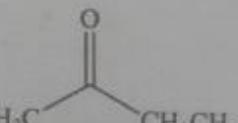
Here, the product is



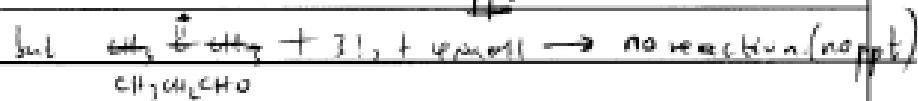
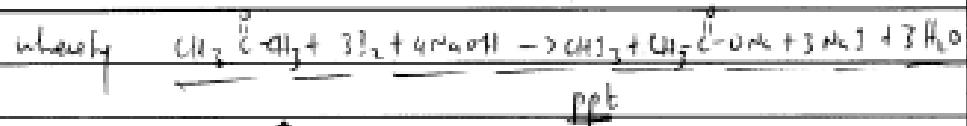
Extract 8.1 shows a sample answer from one of the candidates who managed to perform all parts of the question correctly.

13.0 CARBONYL COMPOUNDS

2021 PAST PAPERS – 2

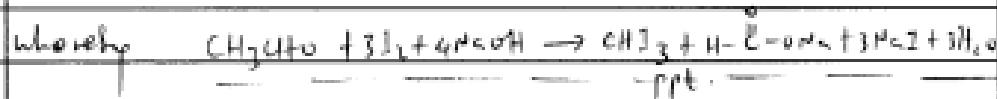
6. (a) How can you distinguish the following? Support your answer with chemical equation.
(i) Propanal and propanone.
(ii) Ethanal and benzaldehyde.
(iii) Pentanal and pentan-2-one.
(iv) 3-pentanone and 2-pentanone. (8 marks)
- (b) An organic compound A which has a characteristic odour is treated with 50% NaOH to give B (C_7H_8O) and C which is a sodium salt of an organic acid. Oxidation of B gives back A. Heating C with soda lime yields an aromatic hydrocarbon D. Deduce the structures A, B, C and D. (8 marks)
- (c) Complete the following equations by giving the missing reagents/products:
- (i)  $\xrightarrow{[Ag(NH_3)_2]^+}$
- (ii)  $\xrightarrow{CrO_3}$
- (iii) $\xrightarrow[Zn/H_2O]{O_3}$ 2 
- (iv) + $\xrightarrow[Zn/H_2O]{O_3}$  + 

Q6. a) i) $\text{CH}_3\text{CH}_2\text{CHO}$ and $\text{CH}_3\overset{\delta}{\text{C}}\text{CH}_3$ can be distinguished by iodine form reaction.

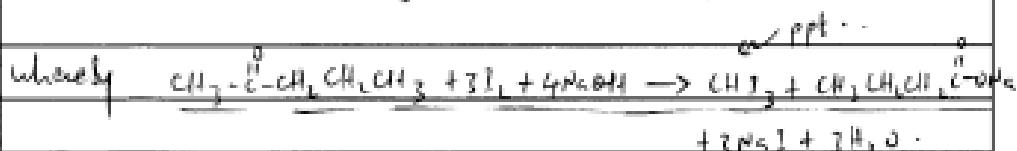


ii) CH_3CHO and $\text{C}_6\text{H}_5\text{CHO}$ can be distinguished by

iodine form reaction.



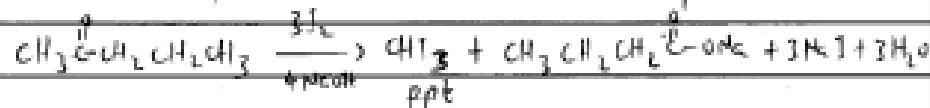
iii) $\text{CH}_3(\text{CH}_2\text{CH}_2\text{CH}_2)\text{CHO}$ and $\text{CH}_3\overset{\delta}{\text{C}}\text{CH}_2\text{CH}_2\text{CH}_3$ can be distinguished by iodine form reaction (or ferric nitro test)



while

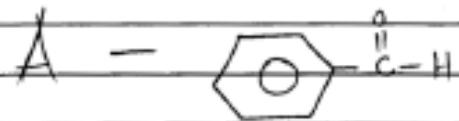


iv) $\text{CH}_3\overset{\delta}{\text{C}}\text{CH}_2\text{CH}_2\text{CH}_3$ and $\text{CH}_3\overset{\delta}{\text{C}}\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$ can be distinguished by iodine form reaction whereby

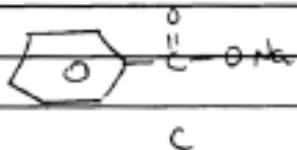
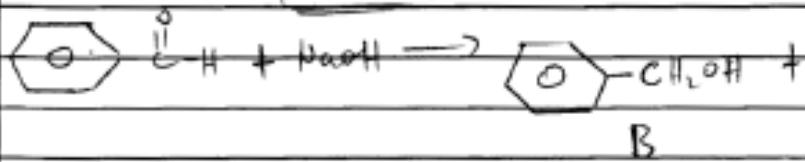


while 3-pentanone cannot give positive iodine form reaction.

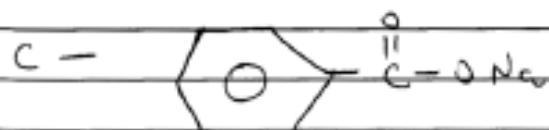
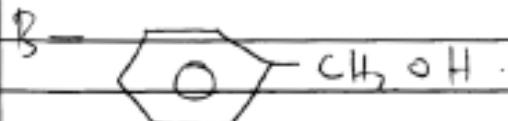
Q6. b)



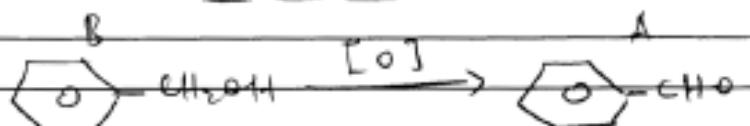
Reaction 1



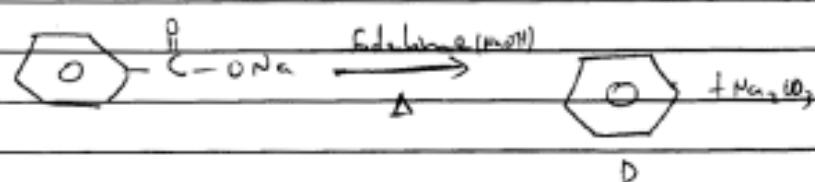
Thus;



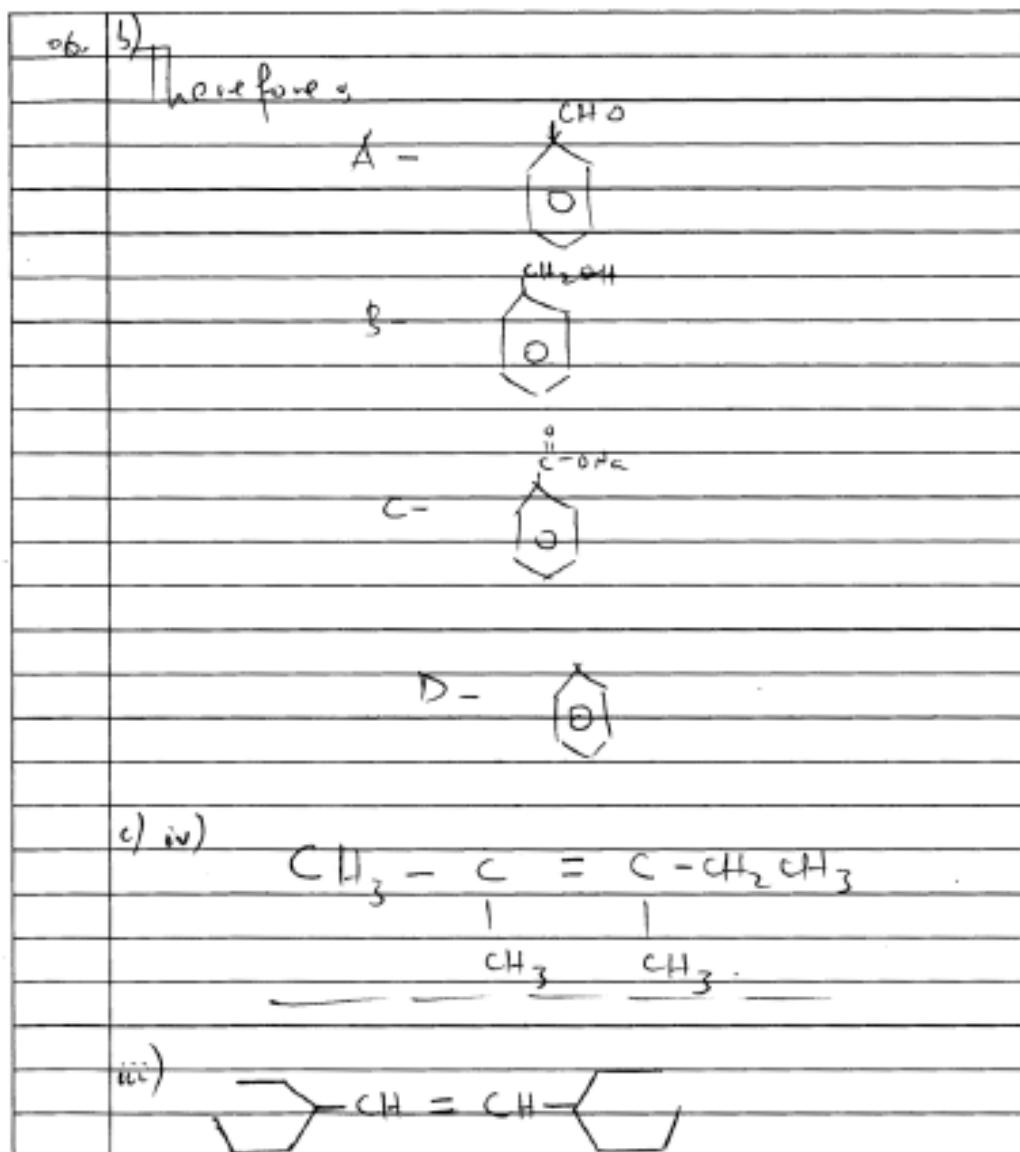
Reaction 2;



Reaction 3;



D



Extract 16.1: A sample of correct responses in question 6

2019 PAST PAPERS – 2

9. (a) An unknown compound with a molecular mass of 86 amu contains 69.8% carbon, 11.6% hydrogen and the rest is oxygen. The compound does not reduce Fehling's solution but gives a positive Iodoform test. Describe the possible structures of the compound. **(11 marks)**
- (b) By using the chemical reactions, show how propanone reacts with the following compounds:
- Hydroxylamine.
 - Hydrazine.
 - Phenyl hydrazine.
 - Phosphorus pentachloride.
- (6 marks)**
- (c) Explain the following statements:
- o*-hydroxybenzaldehyde is a liquid at room temperature while *p*-hydroxybenzaldehyde is a high melting solid.
 - It is incorrect to name butanone as butan-2-one.
- (3 marks)**

9	Q) Element's symbol	C	H	O
	Percentage composition (%)	69.8	11.6	18.6
	Relative atomic mass	12	1	16
	Relative number of atoms	69.8/12	11.6/1	18.6/16
		= 5.817	= 11.6	= 1.1625
	Divide by smallest	5.817/1.1625	11.6/1.1625	1.1625/1.1625
	Empirical formula	5	10	1
	∴ Empirical formula is $C_5H_{10}O$			
	From: (Empirical formula) n = Molecular Mass $(C_5H_{10}O)n = 86$			

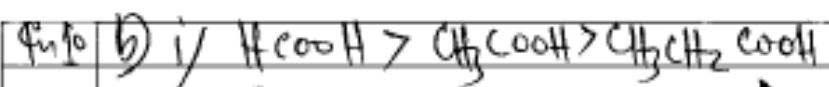
9	$(12 \times 5 + 1 \times 10 + 16)n = 86$
	$86n = 86$
	$n = 1$
	∴ Molecular formula = $(C_5H_{10}O)_1$ = $C_5H_{10}O$
	- The compound is not an aldehyde as it does not reduce Fehling's solution
	∴ Possible structures are:
	i) $CH_3 CH_2 CH_2 C\ddot{O}CH_3$ pentan-2-one
	ii) $CH_3 CH_2 CH(C\ddot{O})CH_3$ 3-methyl butan-2-one.
	Tollen's test:
	$CH_3 CH_2 CH_2 C\ddot{O}CH_3 + I_2 + NaOH \rightarrow CH_3CH_2CH_2COONa + CH_3I + NaI + H_2O$ yellow precipitate
	$CH_3 C\ddot{O}H CH_2CH_3 + I_2 + NaOH \rightarrow CH_3C\ddot{O}Na + CH_3I + NaI + H_2O$ yellow precipitate
	b) i) $CH_3 C\ddot{O}CH_3 + NH_2OH \rightarrow CH_3 C\ddot{O}N - OH + H_2O$
	ii) $CH_3 C\ddot{O}CH_3 + NH_2 - NH_2 \rightarrow CH_3 C\ddot{O}N - NH_2 + H_2O$
	iii) $CH_3 C\ddot{O}CH_3 + \text{benzene ring} \xrightarrow{NaN_3} \text{benzene ring} - NH - N = C - CH_3 + H_2O$
	iv) $CH_3 C\ddot{O}CH_3 + PCl_5 \rightarrow CH_3 - \overset{Cl}{C} - CH_3 + POCl_3$

gc i)	 2-hydroxybenzaldehyde forms intramolecular hydrogen bonds between the oxygen in the OH group and oxygen in the CHO group; This hinders the molecule to bond with other molecules by intermolecular hydrogen bonds hence it is liquid at room temperature. - However,  forms intermolecular hydrogen bonds as both and OH groups of the same molecule are far away from each other. These bonds make it solid at room temperature as each molecule can form two hydrogen bonds.
ii)	$\text{CH}_3\text{C}(\text{CH}_3)\text{COCH}_3$; This is because for butanone the ketone group always occupies carbon number 2 and hence there is no very significant reason of putting 2 on the name of the compound butanone

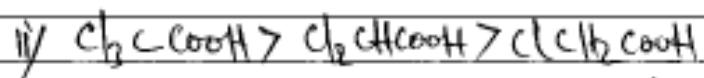
Extract 23.1: A sample of correct responses in question 9.

2016 PAST PAPERS – 2

10. (a) Acetic acid, ethyl alcohol and acetaldehyde in the form of solutions are given in three different test tubes. By which chemical tests, could these be identified from one another? (6 marks)
- (b) Arrange the following compounds in the order of decreasing acidic strength:
 (i) CH_3COOH , $\text{CH}_3\text{CH}_2\text{COOH}$ and HCOOH .
 (ii) ClCH_2COOH , Cl_3CCOOH and Cl_2CHCOOH . (2 marks)
- (c) Identify the structures and the names of the compounds represented by letters in the following reaction sequences:
- (i) $\text{CH}_3-\overset{\text{O}}{\underset{\text{||}}{\text{C}}}-\text{CH}_3 \xrightarrow{\text{LiAlH}_4} \text{A} \xrightarrow{\text{HBr}} \text{B} \xrightarrow{\text{alc. KOH}} \text{C}$.
- (ii) $\text{CH}\equiv\text{CH} \xrightarrow[\text{H}^+/\text{Hg}^{2+}]{\text{H}_2\text{O}} \text{D} \xrightarrow[\text{H}_2\text{O}/\text{H}^+]{\text{CH}_3\text{MgBr}} \text{E} \xrightarrow[\text{H}_2\text{SO}_4]{\text{K}_2\text{Cr}_2\text{O}_7} \text{F}$. (6 marks)
- (d) Ozonolysis of an alkene, (C_6H_{12}), followed by its hydrolysis yielded two products P and Q. P gives a positive iodoform test but a negative Tollen's test. Q give a positive Tollen's test, but a negative iodoform test. Identify structures and names of the alkene and products P and Q. (6 marks)



Decreasing acidic strength



Decreasing the acidic strength

Qn 10 c) i)

A.



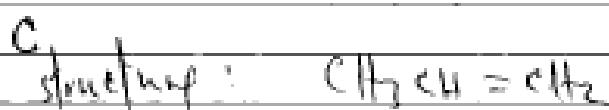
Name: Propan-2-ol

B.



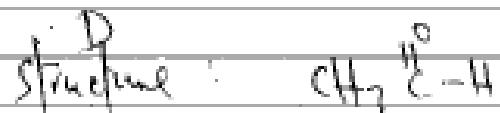
Name: 2-bromo-propane

C.



Name: Propene / Prop-1-ene

D.



Name: Ethanal

E.



Name: Propan-2-ol

F.



Name: Propanone

Qn 13 d)

Solution

Analysis of the ozonolysis products:

→ Since P gives the positive iodoform test it must be having terminal methyl group.

But

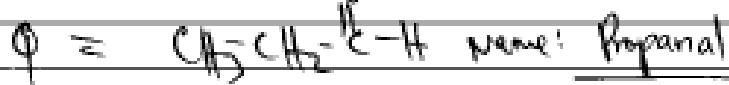
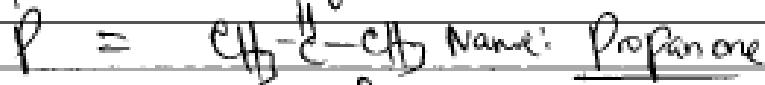
As long as it gives negative Fehling's test then it must be a ketone and not aldehyde

→ Since Q gives the positive Fehling's test then it must be aldehyde and not ketone.

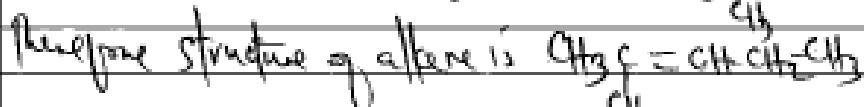
But

As long as it fails the gives negative - iodoform test then it lacks the terminal methyl group.

Therefore from the analysis of the ozonolysis product the structures of P and Q are as follows



From the ozonolysis products then the structure of alkene can be obtained as below



Its name is 2-methylpent-2-ene

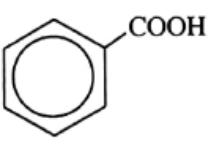
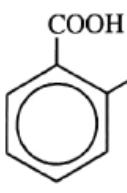
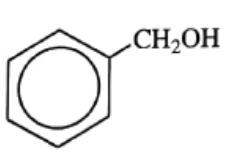
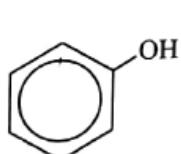
In Extract 24.1, the candidate correctly arranged the provided compounds in the order of decreasing acidity, identified structures and names of compounds represented by the given letters in the two reaction sequences and finally, correctly identified the structures and names of compound S, P and Q.

14.0 CARBOXYLIC ACIDS AND DERIVATIVES

2018 PAST PAPERS - 2

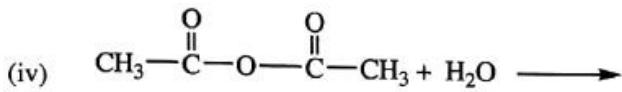
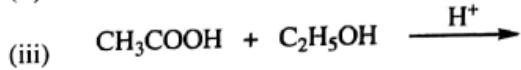
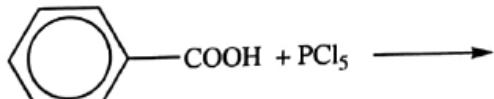
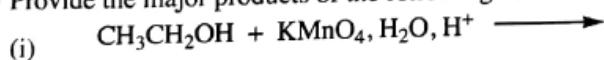
10. (a) Arrange the following compounds in the order of increasing acidic strength.

(i)



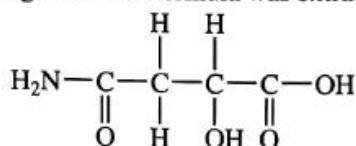
(ii) Ethanoic acid, propanoic acid, methanoic acid, 2-chloroethanoic acid and 2-methylpropanoic acid. (4 marks)

(b) Provide the major products of the following reactions:



(6 marks)

(c) A compound with the following structural formula was extracted from certain yellow flowers:



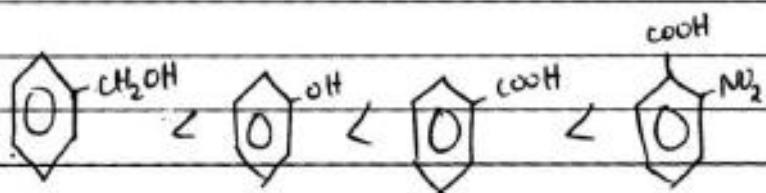
From your knowledge in organic chemistry, give the products that will be formed when this compound is treated with:

- (i) Nitrous acid.
- (ii) Ethanol.
- (iii) LiAlH₄.
- (iv) Potassium dichromate.
- (v) PCl₅.

(7.5 marks)

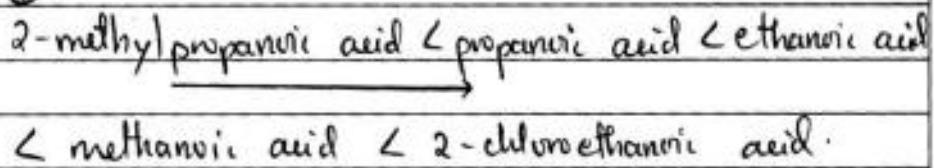
(d) Briefly explain the uses and hazards of carboxylic acids.

(2.5 marks)

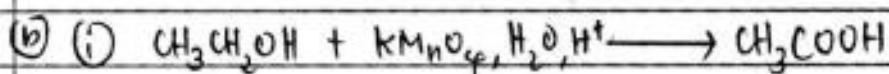


increasing acidity strength

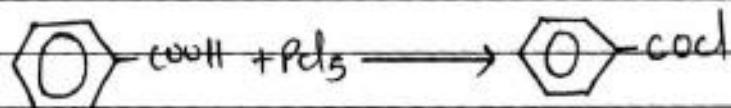
(ii)



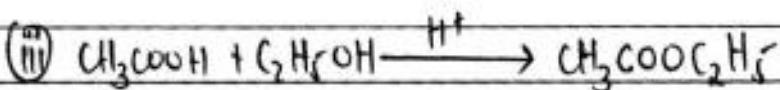
increasing acidic strength



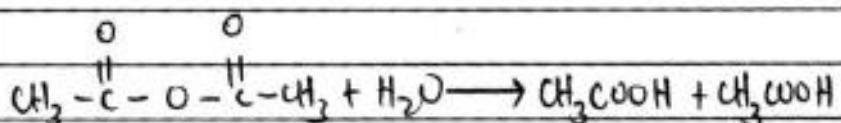
(ii)



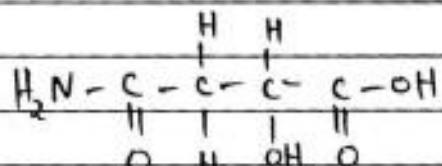
(iii)



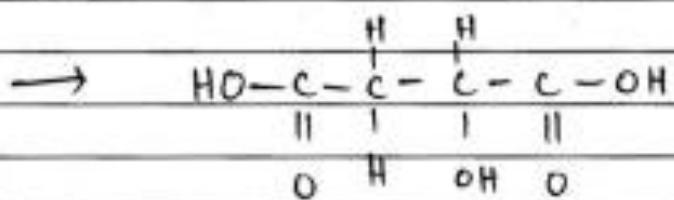
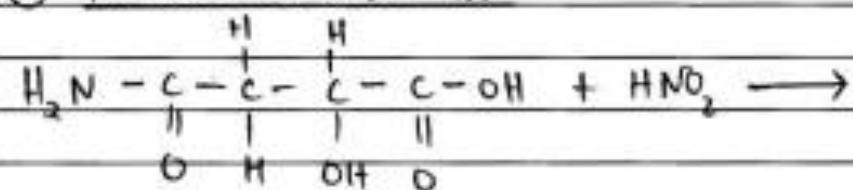
(iv)



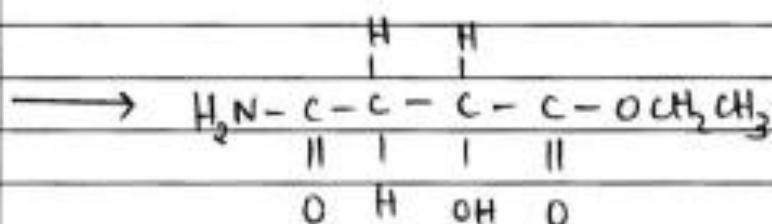
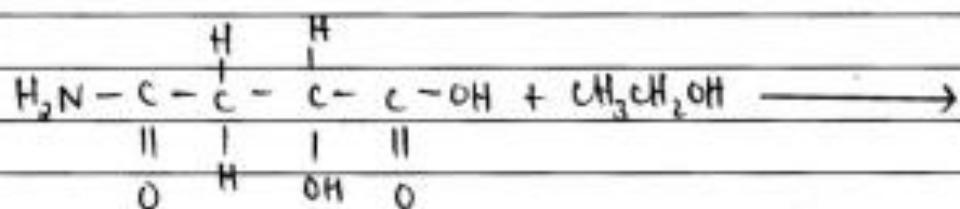
(c) given



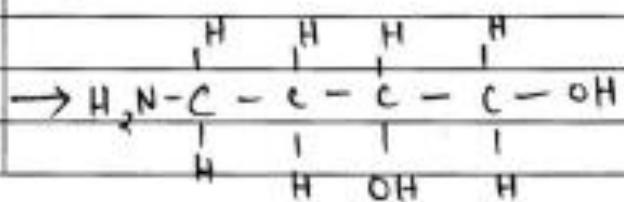
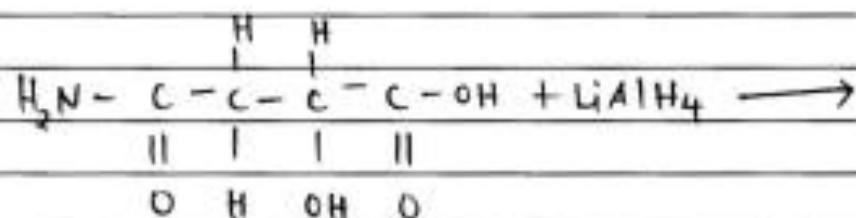
10 (i) Nitrous acid (HNO_2)



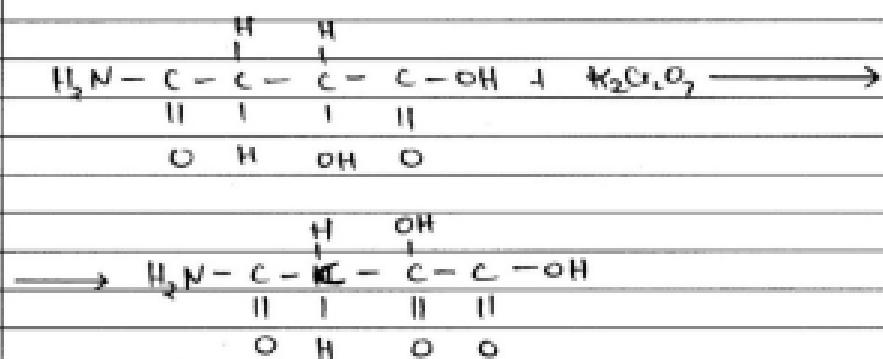
(ii) Ethanot ($\text{CH}_3\text{CH}_2\text{OH}$)



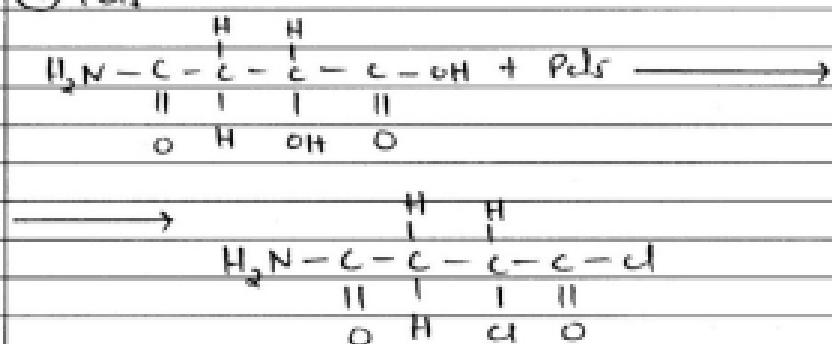
(iii) LiAlH_4



10. (iv) $K_2Cr_2O_7$ (Potassium dichromate)



(v) $PbCl_4^-$



(vi) Uses of carboxylic acid

- They are used as vinegar for domestic use as acetic acid.
- They are used in industries for making esters which in turn do produce soaps for home use.
- They are used in manufacture of ~~yogurt~~ yogurt
- They are used in making medicine like aspirin i.e. Sodium salt of salicylic acid.

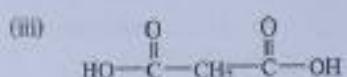
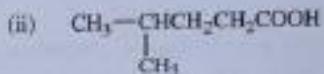
10. (vii) Hazards of carboxylic acid

- They cause environmental pollution once they are in contact with the environment and hence contribute to ozone layer destruction
- They are carcinogenic hence cause cancer
- They cause burning on the skin once in contact with the skin.

Extract 24.1 represents a set of responses from one of the candidate who was conversant with the topic of carboxylic acid and derivatives by answering properly nearly all parts of the question.

2017 PAST PAPERS - 2

(b) (a) Name the following organic compounds:



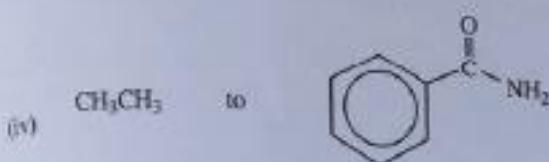
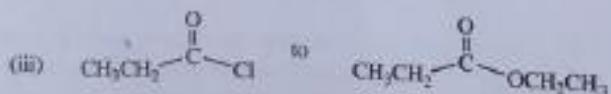
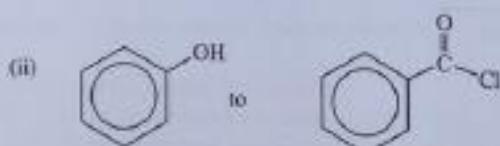
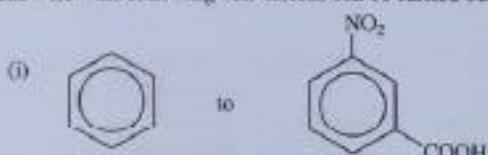
(4 marks)

(b) What are the effects of the following on the acidity of carboxylic acids?

- (i) Chlorine as a withdrawing atom.
- (ii) Large sized alkyl group.

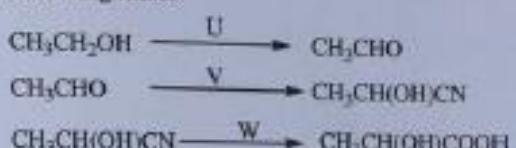
(4 marks)

(c) Show how the following conversions can be carried out:



(7 marks)

(d) Lactic acid ($\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$) occurs naturally in sour milk. The compound can be synthesized from ethanol by the following route:



- (i) Give the reagents and conditions if any, for steps U, V and W above.
- (ii) Give the names of the organic reactions represented by steps V and W.
- (iii) Name the lactic acid by IUPAC system.

(5 marks)

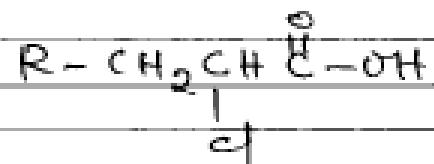
10 (a) i, Benzene carboxylic acid
or
Benzoic acid.

ii, 4-methylpentanoic acid

iii, Propan-1,3-dioic acid

iv, 4-hydroxyhexanoic acid

10 (b) i, Consider

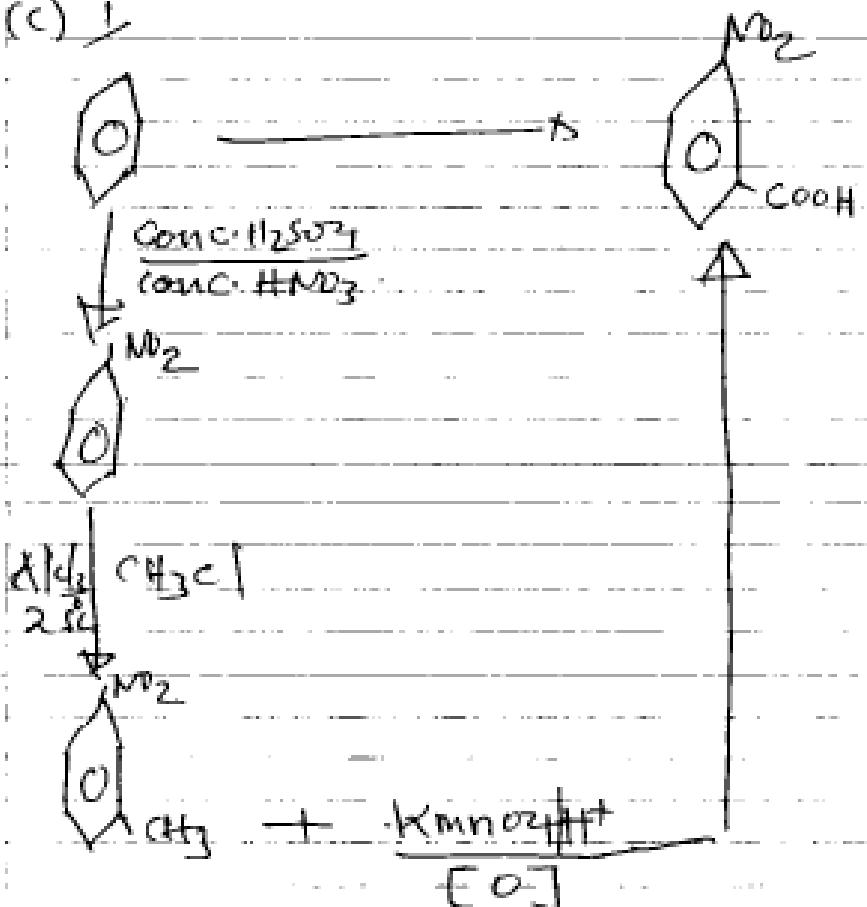


When chlorine as a with drawing group (Cl) attached on the acid hydrogen & the acidity of the carboxylic acid since it causes the weakening of the OH bond strength hence H^+ is easily released into the solution.

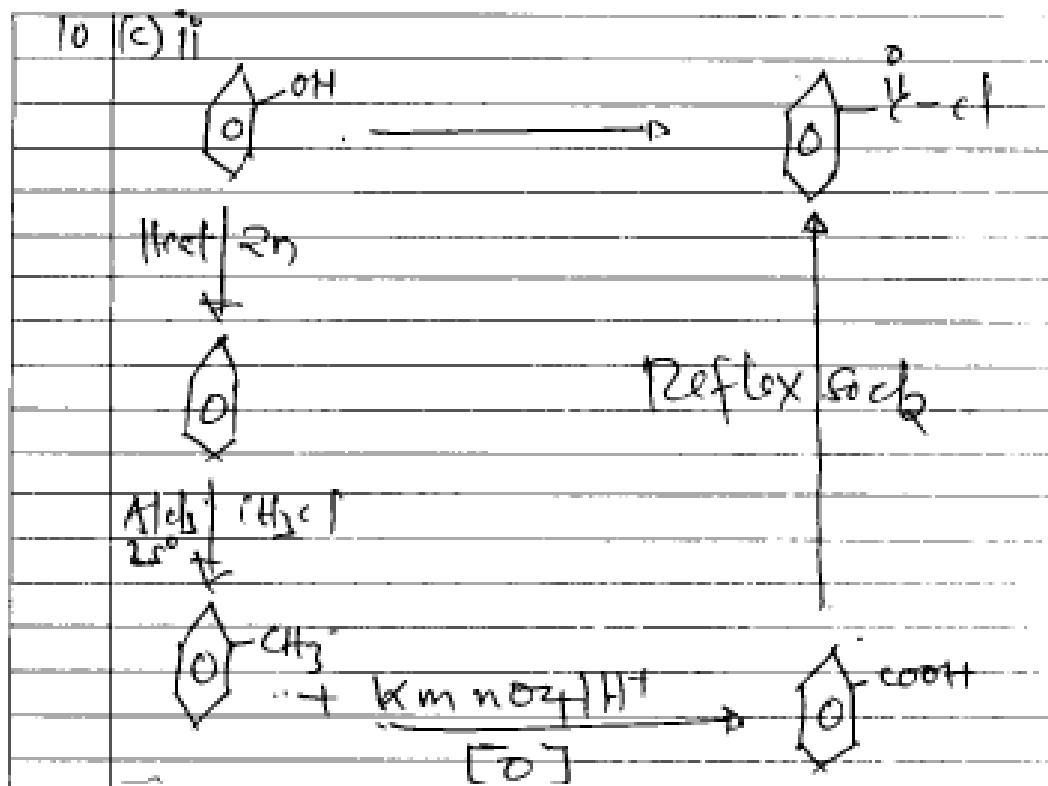
ii It increase the acidity strength of carboxylic acid by negative inductive effect (-I)

10 (b) iii The large sized alkyl group base the acidity of carboxylic acid to DECREASE, since it supplier the electrons to the $\text{O} \rightarrow \text{H}$ bond causing the bond to be strong so that it can not release H^+ into the solution easily.

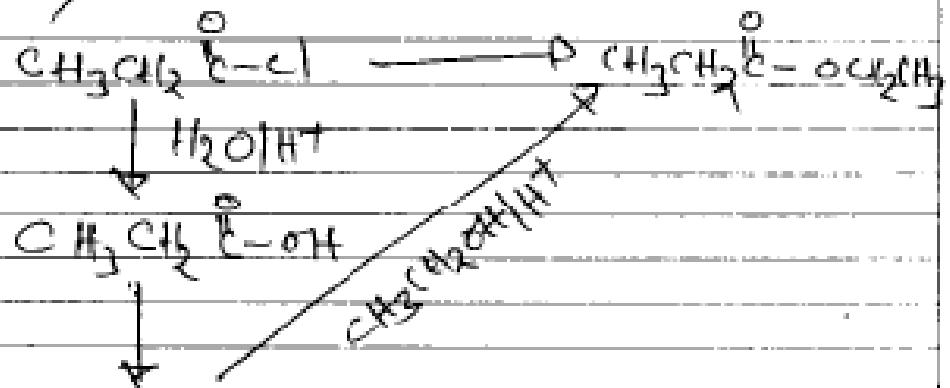
10 (c) i



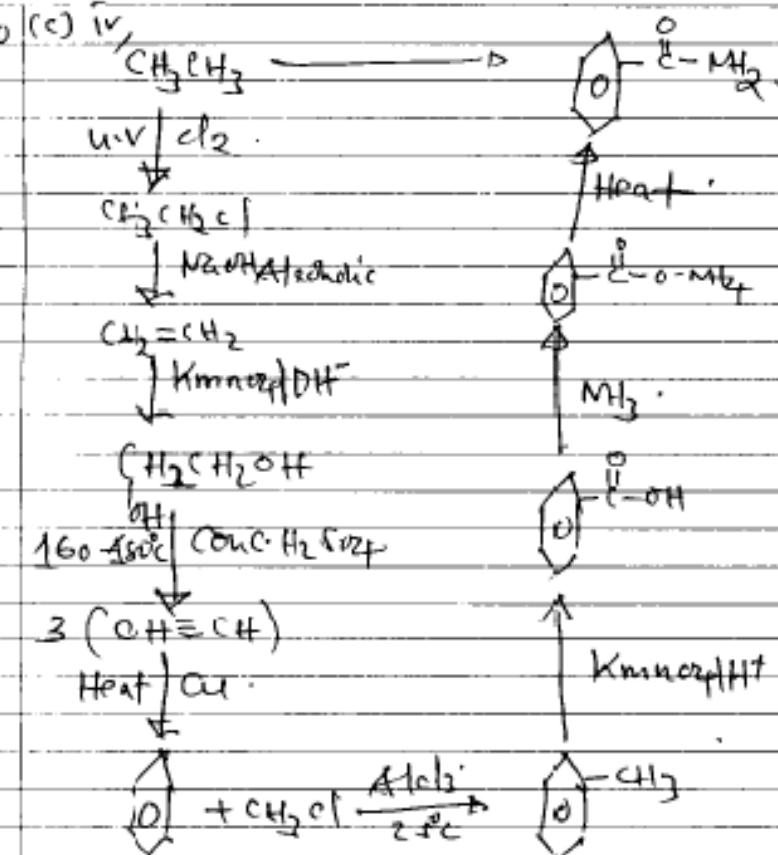
10 (c) ii



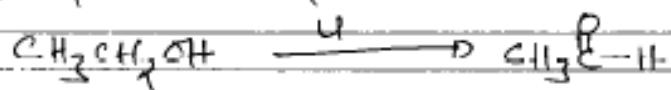
10 (c) iii



10 (c) iv



10 (d) i) For step stop u.

Reagent: MnO_2 or H_2CrO_4 Condition: Acidic Conditions(H⁺)

10 (d) i, for step v



Reagents: HCN

10 (d) ii, for step w



Reagent: $\text{H}_2\text{O} / \text{H}^+$

Condition: Acidic condition (H^+)

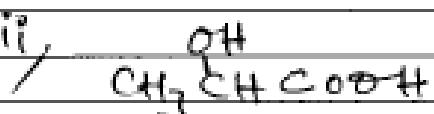
10 (d) iii, for step v

Reaction name: Nucleophilic addition reaction

dii, for step w

Reaction name: Hydrolysis under Acidic medium.

10 (d) iii,



Name: 2-hydroxypropanoic acid.

Extract 24.1 shows responses of a candidate who managed to perform well in all the parts of the question. The work of the candidate is systematically presented.