ADVANCED LEVEL PHYSICAL CHEMISTRY TOPICAL TEST.

THE GASEOUS STATE OF MATTER.

Inst. Attempt all questions in this paper.

1. (a) State the following ideal gas laws;

(i) Boyle's law. ***(1mark)***

It law states, *that the volume of a given mass of a gas is inversely proportional to its pressure at constant temperature.* ✓

(ii) Charles' law. ***(1mark)***

It states that, *the volume of a given mass of gas is directly proportional to its absolute temperature at constant pressure.* ✓

(iii) Gay Lussac's law. ***(1mark)***

It states that, *the pressure of a fixed mass of gas is directly proportional to the absolute temperature at constant volume.* ✓

(b) (i) State the ideal gas equation. ***(1mark)***

PV = nRT ✓

(ii) Calculate the relative molar mass of a 0.20g gas that occupies 268cm^3 at 18^{o}C at a pressure of 100400Nm^{-2}. ***(3marks)***

From $\frac{P1V1}{T1}$ x $\frac{P2V2}{T2}$ ✓

$V_2 = \frac{P1V1T2}{P2T1} = \frac{100400 \times 268 \times 10^{-6} \times 273}{101325 \times 291}$ ✓

$V_2 = 2.49 \times 10^{-3} m^3$ ✓

From PV = nRT ✓

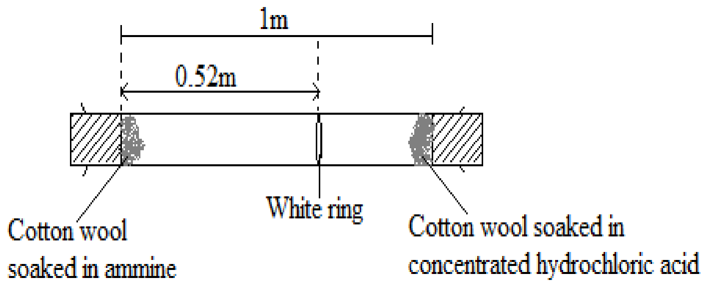
$Mr = \frac{nRT}{PV}; = \frac{0.20 \times 8.314 \times 291}{100400 \times 2.49 \times 10^{-3}}$ ✓

$Mr = 19gmol^{-1}$ ✓

2. (a) State the Thomas ***Graham's law*** of gaseous effusion. ***(1mark)***

It states that, *the rate at which gases effuse at constant temperature and pressure is inversely proportional to the square root of their densities.* ✓

(b) Two pieces of cotton wool, one soaked in an amine and the other in concentrated hydrochloric acid were placed at the opposite end of a 1m glass tube. After some time, a white ring was formed at 0.52m from the end containing the amine.



(i) Calculate the molecular mass of the amine. ***(3marks)***

Distance moved by amine = 0.52m; Distance moved by HCl = (1-0.52) = 0.48m ✓
The time, t, taken for both amine and HCl to move to where the white ring is formed is the same.

$R_A = \frac{\text{Distance}}{\text{time}} = \frac{0.52}{t}$; $R_{HCl} = \frac{\text{Distance}}{\text{time}} = \frac{0.48}{t}$

From Graham's law

$\frac{R_A}{R_{HCl}} = \sqrt{\frac{Mr._{HCl}}{M_{r.\ Amine}}}$ ✓

$\frac{0.52}{t} \times \frac{t}{0.48} = \sqrt{\frac{36.5}{Mr._{Amine}}}$ ✓

$\frac{0.52}{0.48} = \sqrt{\frac{36.5}{M_A}}$ ✓

$\left(\frac{0.52}{0.48}\right)^2 = \frac{36.5}{M_A}$ ✓

$M_A = \left(\frac{0.52}{0.48}\right)^2 \times 36.6 = \mathbf{31.1}$ ✓

(ii) Determine the molecular formula and hence structural formula of the amine. ***(2½marks)***

$CnH_{(2n+1)}NH_2 = 31$ ✓
12n+2n+1+14+2 =31 ✓
14n+17 = 31
14n = 14
n =1 ✓
Molecular formula is CH_3NH_2 ✓
Structural formula is CH_3NH_2 ✓

(iii) Give the IUPAC name of the above amine. ***(½mark)***
Methylamine/ aminomethane ✓

3. (a) what is meant by the following terms;

(i) Partial pressure. ***(1mark)***

Partial pressure is the pressure which a gas exerts if it alone occupied a vessel alone, which was initially occupied by a mixture of gases. ✓
Accept; Partial pressure is the product of the mole fraction of the gas and the total pressure of the gases. ✓

(ii) Mole fraction. ***(1mark)***

This is the ratio of the number of moles of a component of a gas to the total number of moles of the components in the mixture. ✓

(b) (i) State the John ***Daltons law of partial pressures***. ***(1mark)***

It states that, *the total pressure exerted by a mixture of gases that do not chemically react is equal to the sum of the partial pressures of the components in the mixture*. ✓

(b) 2.0g of carbon dioxide and 4.5g of oxygen were mixed in 1 litre container. If the total pressure is 120atm. calculate the partial pressure of each in the container. ***(2½marks)***

Solution

Moles of carbon dioxide = $\frac{2.0}{44}$ = 0.045 moles. ✓

Moles of oxygen = $\frac{4.5}{32}$ = 0.14 moles ✓

Total number of moles = 0.045+0.14 = 0.185 moles ✓

Partial pressure of oxygen = $\frac{0.14}{0.185}$x 120 = **90.81 atm**. ✓

Partial pressure of carbon dioxide = $\frac{0.045}{0.185}$x 120 = **29.19 atm**. ✓

4. (a) State the kinetic theory of gases. ***(1marks)***

The theory states that gases consist of molecules that are in constant random motion in all directions. ✓

(b) State four assumptions of the kinetic theory of gases. ***(4marks)***

The forces of attraction between the gas molecules and walls of the container are negligible; ✓

Gas molecules are in state of rapid random motion colliding with each other and with the walls of the container hence constituting pressure; ✓

The collision of the gas molecules is perfectly elastic and there is no loss in kinetic energy; ✓

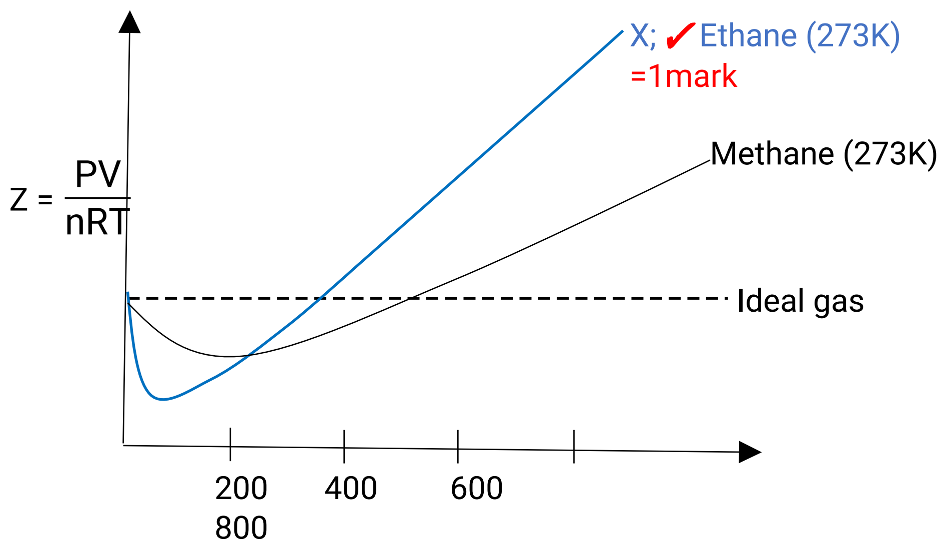
Gases consist of small particles called molecules. ✓

The average kinetic energy of the molecules is directly proportional to the absolute temperature and is independent of the chemical nature of the gas. ✓
1mark@; Any four.

5. (a) Explain what is meant by term compressibility factor? ***(1mark)***

Compressibility factor is the measure of deviation of a gas from ideal gas behaviour. ✓

(b) A graph of $Z = \frac{PV}{nRT}$ against pressure for 1 mole of methane is shown below



(a) Give the reason for the behaviour of methane gas at 273K when the pressure is lower than 200 atm. ***(2marks)***

As the pressure increases from zero to 200 atm; ✓ the van der Waals forces of attraction between methane molecules becomes more significant✓ due to closeness of the molecules✓ as compared to the effect of molecular volume. ✓ *leading to a slight fall on the compressibility factor below that of ideal gas.*
½mark@ =2marks

(b) Give a reason for the behaviour of methane at 273K when the pressure is higher than 200K.

Increases in pressure beyond 200 atm, the effect of molecular volume can no longer be ignored✓ and it outweighs that due to molecular attraction✓. The effect increases the value of the compressibility factor✓ hence a rise in the graph. ½mark@ = 1½marks

(c) On the same axis, sketch a graph of ethane at 273K and give reasons for your sketch. Label the curve X. ***(4mark)***

Reason:

The curve for X falls greater than methane, ✓because ethane is bigger and weighs more✓ therefore exerts a greater molecular attraction among its molecules than methane✓.

Below 200 atm, the effect due to molecular attraction outweighs that due to molecular volume causing a decrease in the compressibility factor.

Above 200 atm (as pressure increases), ✓ the effect due to molecular volume outweighs that due to molecular attraction causing a rise in compressibility factor✓. The large size of ethane molecules causes the effect due to its molecular volume to be more greater than in methane at high pressures, making the deviation more for X✓ ½marks@ =3marks.

6. (a) What is meant by the following terms as applied to liquefaction of gases?

(i) Critical temperature. ***(1mark)***

Critical temperature is the maximum temperature at which a gas can be liquefied and beyond which no liquefaction takes place no matter how much pressure is applied. ✓

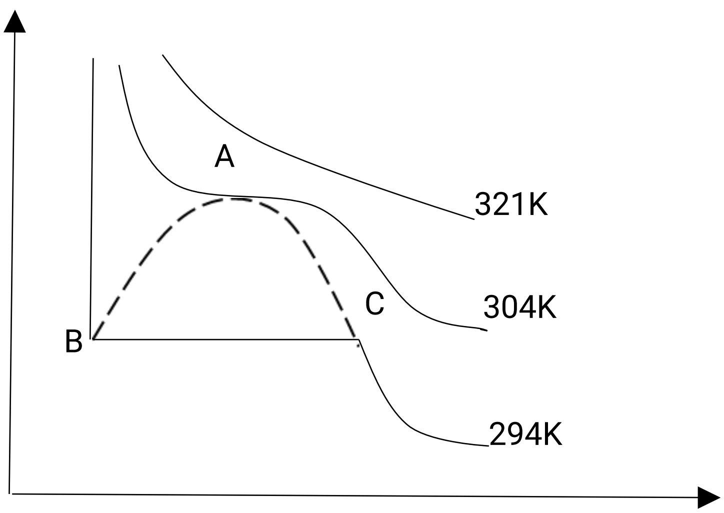
(ii) Critical pressure. ***(1mark)***

This the minimum pressure which is just enough to liquefy one mole of a gas at its critical temperature. ✓

(iii) Critical volume. ***(1mark)***

Critical volume is the volume occupied by one mole of a gas at its critical temperature and pressure. ✓

(b) The diagram below shows the Thomas ***Andrews*** isotherms of carbon dioxide gas.



(i) What is the critical temperature of the gas? ***(1mark)***

304K✓

(ii) Which isothermal almost represents an ideal gas? ***(½mark)***

Isotherm 321K✓

(iii) What does the region ABC represent? ***(1mark)***

Region of condensation of the gas. ✓

Accept; region of gas being in equilibrium with liquid.

(c) State two conditions for liquefying a gas. ***(1mark)***

Temperature below (less than) the critical temperature. ✓

High pressure. ✓ ½mark@=1mark