Revision Topic 4:
Gases

1 The mineral dolomite is a double carbonate of magnesium and calcium, with the formula $CaMg(CO_3)_2$. This mineral dissolves in most dilute mineral acids such as hydrochloric acid to generate carbon dioxide gas together with a mixture of Group II metal salts according to the chemical reaction shown below.

$$CaMg(CO_3)_2\,(aq) + 4HCl\,(aq) \rightarrow MgCl_2\,(aq) + CaCl_2\,(aq) + 2CO_2\,(g) + 2H_2O\,(l)$$

(a) Determine the volume of carbon dioxide generated at 27°C and 101 kPa upon the reaction between 92 g of the mineral dolomite and an excess of hydrochloric acid, assuming that carbon dioxide behaves ideally. [Given that the M_r of dolomite is 184].

[2]

No of moles of dolomite = **92/184** = 0.500 **[1/2]**

$CaMg(CO_3)_2 \equiv 2CO_2$

No of moles of carbon dioxide = **0.500 X 2** = 1.00 **[1/2]**

Using PV = nRT

Volume of carbon dioxide produced = $\frac{1.00?\ .314?\ 27+273)}{(101?\ 0^3)}$ **[1/2]**

= **<u>0.0247 m³</u> [1/2]**

(b) By considering the reaction of a given mass of mineral dolomite with an excess of hydrochloric acid, predict the volume ratio of the carbon dioxide generated at –15°C and 79 kPa relative to that generated at 35°C and 200 kPa.

Using the combined gas law, $\frac{p_2V_1}{T_1}=\frac{p_2V_2}{T_2}$

$\frac{79\text{諧}_1}{(-15+273)}=\frac{200\text{諧}_2}{(273+35)}$ **[1]**

$\Rightarrow \frac{V_1}{V_2}=2.12$ **[1]**

[2]

[Total : 4 marks]

2 A mixture of three gases with the composition by volume of 40% nitrogen, 10% oxygen and 50% hydrogen in a 10 dm^3 vessel, exerts a pressure of 6 atm at 10 °C.

(a) Calculate the partial pressure of hydrogen gas.

[1]

Mole fraction of hydrogen gas = 50/100 = 0.500 **[1/2]**

Partial pressure of hydrogen gas = mole fraction x total pressure
= 0.500 x 6 = **<u>3.00 atm</u>** **[1/2]**

(b) In an experiment, a certain amount of nitrogen gas is injected into the vessel to increase the total pressure to 8 atm, calculate the number of moles of nitrogen gas that has to be injected to attain this new total pressure, without changing the volume of the vessel.

[2]

Using $\boxed{PV = nRT}$

Original no. of mol of gas in vessel = PV/RT

$$= \frac{(6x1.01x10^5)(10x10^{-3})}{(8.31)(10+273)}$$

= 2.577 **[1/2]**

No of moles of gas when pressure is increased to 8 atm

$$= \frac{(8x1.01x10^5)(10x10^{-3})}{(8.31)(10+273)}$$

= 3.436 **[1/2]**

⇒ No. of mol of gas that has to be injected = 3.436 – 2.577 = **<u>0.859</u> [1]**

<u>Alternatively,</u>

Change in pressure = 8 – 6 = 2 atm **[1/2]**

No. of mol of gas that has to be injected for pressure to be increased to 8 atm
= PV/RT

$$= \frac{(2x1.01x10^5)(10x10^{-3})}{(8.31)(10+273)}$$ **[1/2]**

= **<u>0.859</u> [1]**

(c) In a separate experiment, the volume of the vessel is reduced to 4 dm^3 at constant temperature. Calculate the new pressure of the system. *(Ans : 15 atm)* **[1]**

Using $\boxed{P_1V_1 = P_2V_2}$ at constant temperature,

(6)(10) = (P)(4) **[1/2]**

New Pressure = **<u>15.0 atm</u> [1/2]**

(d) Under what conditions do real gases deviate from ideality? Explain your reasoning. **[3]**

Real gases deviate from ideality at high pressure and low temperature.

At high pressure,

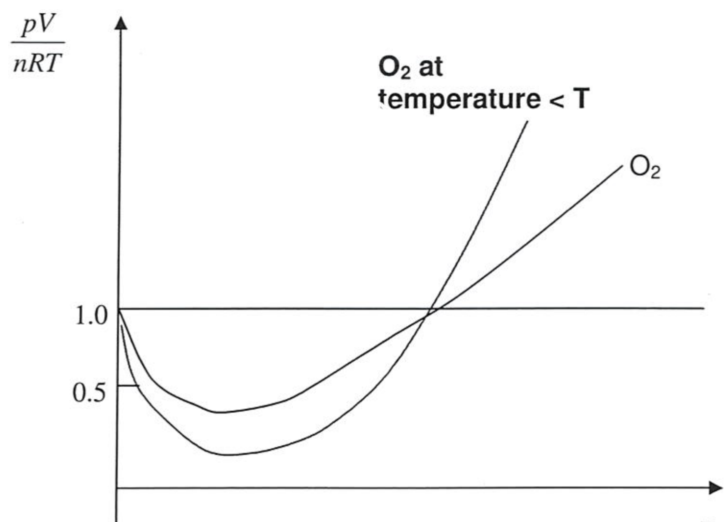
- volume of the container is **<u>decreased</u>** } [1/2]
- gas particles come **<u>close together</u>**
- **volume occupied by the gas particles** becomes **<u>significant</u>** compared to the volume of the container } [1/2]
- **P<u>V</u>** is **<u>larger</u>** than that of an ideal gas.

At low temperature,

- the gas particles possess **<u>less kinetic energy</u> [1/2]**
- the particles tend to attract each other during collisions
- **intermolecular forces of attraction** between the gas particles become **<u>significant</u> [1/2]**
- The impact of a given particle on the walls of the container is **<u>decreased</u> [1/2]**
- **<u>Pressure</u>** exerted by the gas is **<u>less</u>** than that of an ideal gas. } **1/2**
- **<u>PV</u>** is **<u>smaller</u>** than that of an ideal gas.

(e) The figure above shows the compressibility factor for O_2 at a given temperature **T** as a function of pressure.

On the graph below, sketch the shape of the compressibility curve for oxygen if the temperature is further decreased below **T**. **[1]**



1 mark for correct trend

Anything missing/wrong (e.g. no labeling), minus ½ mark till zero

[Total : 8 marks]

3(a) State the two main assumptions of the *kinetic theory* for an ideal gas. **[2]**

The **intermolecular forces of attraction** between **gas particles** are **negligible**. **[1 or 0]**
The **(total) volume of gas particles** is **negligible/insignificant** compared to the **volume of the container**. **[1 or 0]**

(b) (i) Use the ideal gas equation to derive an expression relating ρ (the density of the gas) and P (the pressure of the gas). **[5]**

Use the ideal gas equation to derive **any correct expression relating ρ (the density of the gas) and P (the pressure of the gas).**

PV = nRT

$$P = \frac{m}{V}\frac{RT}{M_r}$$

$$P = \rho\frac{RT}{M_r}$$ **[1 or 0, no working no marks]**

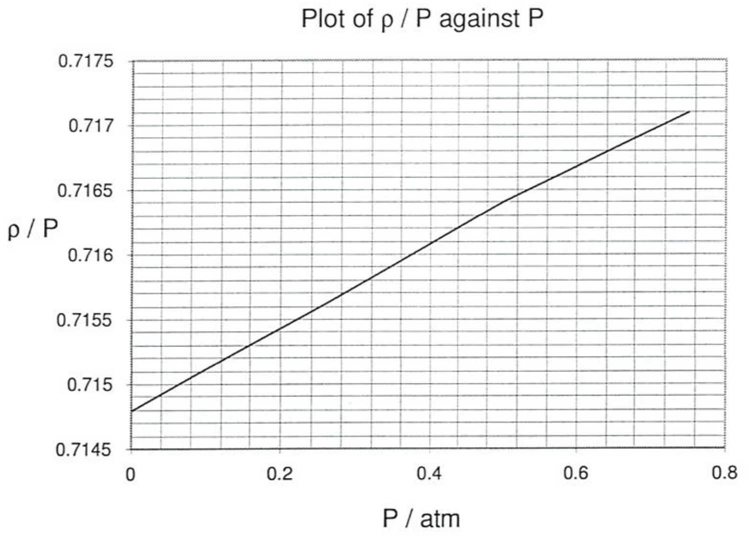
$$p = \frac{PM_r}{RT}$$

(ii) The following results were obtained when the density of a fixed mass of gas **Y** is measured at a series of pressures at 0°C.

Density, ρ / g dm^{-3}	0.1789	0.3582	0.5378
Pressure, P / atm	0.25	0.50	0.75
ρ / P (g dm^{-3} atm^{-1})	**0.7156**	**0.7164**	**0.7171**

Correct tabulation of ρ / P values to 4 sf [1]

Fill in the ρ / P values to **4** significant figures in the table above and plot a graph of ρ / P against P at 0°C in the grid provided below.



Correct graph plotting with points clearly denoted [1 or 0]

(iii) Based on the graph, does gas **Y** behave ideally? Explain your answer.

The gas is not ideal/real [1 or 0] * no/wrong reasoning, no marks

A horizontal straight line would have been obtained if the gas is ideal,

[1/2] since $\frac{\rho}{P} = \frac{M_r}{RT} =$ **constant at a given temperature for a fixed mass of gas. [1/2]**

(iv) By extrapolating the graph, and taking the ρ/P value at zero pressure as ideal, calculate the relative molecular mass of the gas **Y**. Take R=0.082 dm^3 atm K^{-1} mol^{-1}.

$$\frac{\rho}{P} = \frac{M_r}{RT}$$

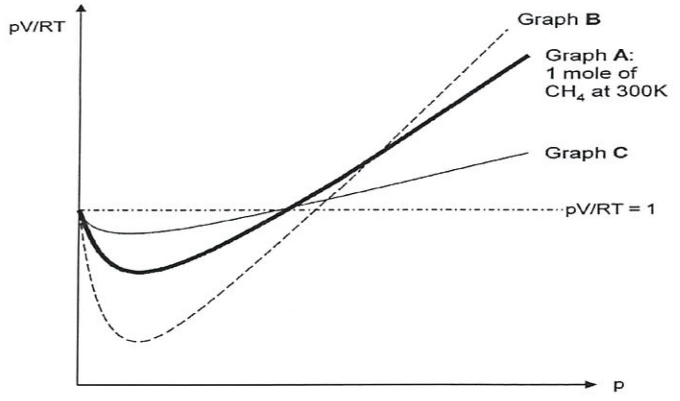
At P = 0, $\frac{\rho}{P}$ **= 0.7148**

$$0.7148 = \frac{M_r}{(0.082)(273)}$$ **[M1/2]** ⇒ M_r **= 16.0 (1 d.p) [A1/2, no 1 d.p -1/2]**

(c) The values of pV/RT are plotted against p for one mole of the following gases at the specified temperature:

- One mole of CH_4 at 300K
- One mole of CH_4 at 500K
- One mole of NH_3 at 300K

Given that graph **A** is obtained for 1 mole of CH_4 at 300K, identify and explain what Graphs **B** and **C** represent. **[3]**



Graph	**B**	**C**
Represents	1 mole of **<u>NH_3 at 300K</u>** **[1/2]**	1 mole of **<u>CH_4 at 500K</u>** **[1/2]**
Explanation	NH_3 at 300K deviates more than CH_4 at 300K. This is because **<u>NH_3 molecules</u>** are held by ***<u>stronger</u>* <u>intermolecular forces of attraction</u> [1]** (H-bonds) as compared to that between CH_4 molecules. **** impt –must state comparative terms for strength***	CH_4 at 500K deviates less than CH_4 at 300K. This is because at **<u>higher temperature</u>**, CH_4 molecules possess **<u>higher kinetic energy</u>** and **<u>do not attract/interact each other</u>** when they collide. **[1/2]** Hence, there is **<u>negligible intermolecular forces of attraction</u>** between the gas <u>particles</u>. **[1/2]**

[Total : 10 marks]