Quadrant II – Transcript and Related Materials

Programme: Bachelor of Science (Second Year)

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Unit: 01

Module Name: Deviations of Real Gases from Ideal Behaviour, Compressibility Factor and Causes of Deviation

Module No: 02

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Notes

Introduction:

- An ideal gas obeys the gas law or the gas equation PV=RT at all pressure and temperature.
- Since no gas is ideal, all gases show significant deviations from the ideal behaviour.
- Gases which fail to obey the ideal gas equation are termed as non-ideal or real gas.
- Real gases obeys the equation PV=RT at low pressure and temperature.
- At higher pressure and lower temperature greater deviations are observed from the ideal behaviour.
- The easily liquefiable and highly soluble shows large deviations from ideal behaviour, so gases like CO_2, SO_2 and NH_3 shows much larger deviations than H_2, O_2, N_2, etc.

Compressibility Factor (Z)

- The extent to which a real gas departs from the ideal behaviuor is represented by a new function is called the compressibility factor

$$Z = \frac{PV}{(PV)_{ideal}} = \frac{PV}{nRT} = \frac{PV_m}{RT}$$

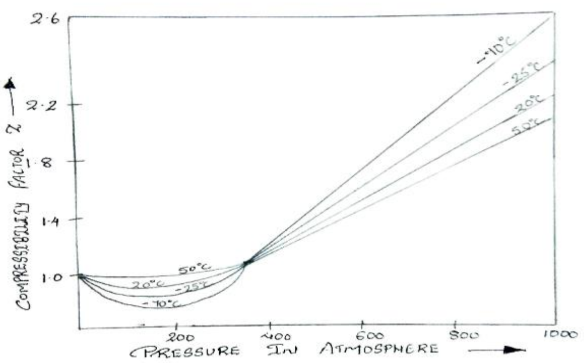
V_m – molar volume that is the volume occupied by one mole of ideal gas.

- For an ideal gas Z=1 and it is independent of temperature and pressure.
- The deviations from ideal behaviour of a real gas is determined by the value of 'Z' being greater of less than one.
- The difference between unity and the value of the compressibility factor of a gas is a measure of the degree of non-ideality of the gas.
- The deviations from ideality is shown by a plot of Compressibility factor (Z) against Pressure (P)

<u>Effect of Pressure Variation on Deviations</u>

- At extremely low pressure all gases have Compressibility factor (Z) close to unity which shows that the gases behave ideally
- At very high pressure all gases have 'Z' more than unity indicating that the gases are less compressible than an ideal gas that is because at high pressure, the molecular repulsive forces are dominant.

Graph of Compressibility Factor against Pressure (atm)



- In the graph of 'Z' against 'P' at moderately low pressure, CO_2, CH_4 and NH_3 are more compressible than an ideal gas that is PV is less than $(PV)_{ideal}$ and Z<1, this is because at low pressure the long-range attractive forces are dominant and favour compression.

- The compressibility factor 'Z' goes on decreasing with increase in pressure, passes through a minimum at a certain stage and then increases with increase in pressure.

- The gases become less compressible than an ideal gas that is $PV > (PV)_{ideal}$ so Z>1, this is. So, in the graph CO_2 and CH_4 exhibit marked deviation from ideal behaviour only at high pressure, CH_4 shows large deviations at low pressure.

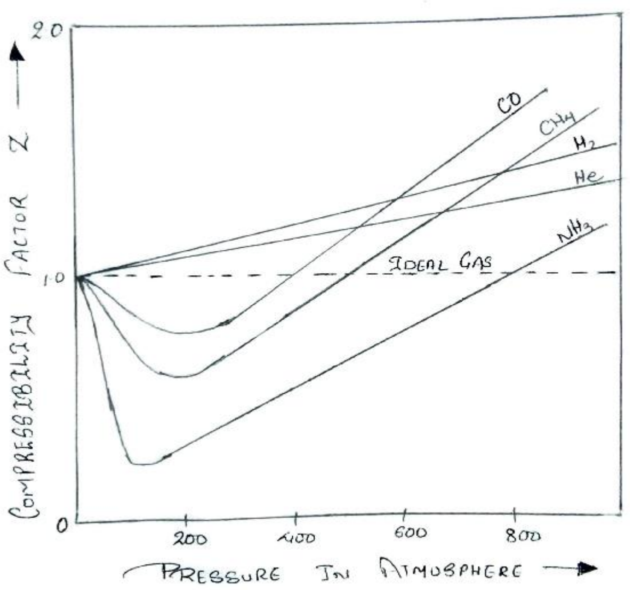
- H_2 and He_2 at 0°C are less compressible than the ideal gas at all pressure that is Z>1, however if temperature is low (below -165°C for H_2 and below -240°C for He_2) these gases give the same type of Z-P plots like NH_3, CO2 and CH_4 at 0°C.

- For CO2 and CH4 at 0°C the 'Z' value will increase with increase in pressure.

Effect of Temperature on Deviations

- At high temperature the molecules have sufficient Kinetic Energy to overcome intermolecular attractive forces and the effect of non-zero molecular volume predominate.
- As the temperature is lowered the Kinetic Energy of the gas molecule decreases.

Graph of Compressibility Factor (Z) against Pressure at Varying Temperature



- From the shape of the curve it is observed that the deviations from the ideal gas behavior becomes less and less with increase in temperature that is the deep in curve becomes smaller and smaller
- At 50°C the curve remains horizontal for pressure between 0 to 100 atmosphere and 'Z' becomes equal to unity, so the 'PV' remains constant and the Boyle's law is obeyed within this pressure range at 50°C and the temperature is called the Boyle's point or Boyle's Temperature
- Below 50°C the 'Z' values first decreases, approaches a minimum and then increases as the pressure is increased continuously.
- Above 50°C the 'Z' value shows a continuous rise with increase in pressure.
- At -165°C hydrogen gas obeys Boyle's law for an appreciable range of pressure and below -165°C the plot of Z against P first falls and then a rise as pressure is increased continuously, below -165°C 'Z' shows a continuous rise with increase in pressure.

- The Boyle's temperature for He is -240^{o}C