



Raffles Institution
Year 5 H2 Chemistry 2024

Tutorial 4 – The Gaseous State
(Suggested Answers for Discussion Questions)

Discussion Questions

- 11** Mass of CO₂ in 500 cm³ of saturated solution = 0.500 × 1.50 = 0.750 g
Mass of CO₂ released = 2.00 – 0.750 = 1.25 g
Amount of CO₂ released = 1.25/molar mass = 1.25/44.0 = 0.0284 mol
Volume of CO₂ released = 0.0284 × 24
= 0.682 dm³
= **682 cm³**

- 12 (a)** For a fixed amount of ideal gas at constant T, pV remains constant as p increases.
(b) Using the ideal gas equation, $pV = nRT$

$$V = \frac{(0.40)(8.31)(300)}{12.0 \times 10^5}$$
$$= 8.31 \times 10^{-4} \text{ m}^3$$
$$= 0.831 \text{ dm}^3$$

(c)

pressure, p / Pa	volume, V / dm ³	pressure x volume, pV / Pa dm ³
5.0×10^5	1.924	9.62×10^5
10.0×10^5	0.926	9.26×10^5
15.0×10^5	0.592	8.88×10^5

When $p = 12.0 \times 10^5$ Pa,
estimated $pV = 9.26 \times 10^5 - \frac{2}{5} (9.26 \times 10^5 - 8.88 \times 10^5)$
 $= 9.11 \times 10^5 \text{ Pa dm}^3$

When estimated $9.11 \times 10^5 \text{ Pa dm}^3$,
 $V = 9.11 \times 10^5 \text{ Pa dm}^3 \div 12.0 \times 10^5 \text{ Pa}$
 $= 0.759 \text{ dm}^3$

- (d)** Value of V in **(c)** is smaller than that in **(b)**. This implies that the gas occupies a volume smaller than what it would were it ideal. As the pressure exerted on the system is moderately high, the polar HC/ gas molecules come closer together and the intermolecular attractive forces (id-id and pd-pd) between the HC/ gas molecules become significant, causing the volume to be smaller than what it would were it ideal.

13 (a) 2 main assumptions are:

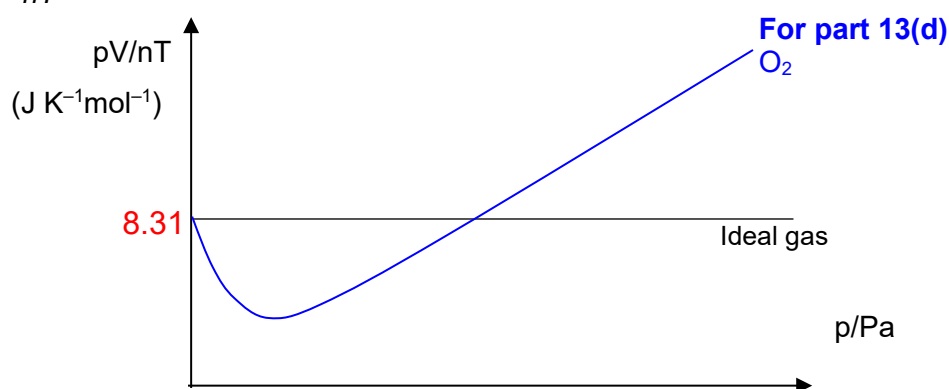
- The gas particles exert negligible intermolecular attractive forces on one another.
- The volume of gas particles is negligible compared to the volume of container.

Reject: volume of gas is negligible (missing 'particles')

Other assumptions:

- The gas particles are in constant random motion.
- Collision between gas particles are perfectly elastic.
- The average kinetic energy of gas particles is proportional to absolute temperature.

(b) $\frac{pV}{nT} = R = 8.31 \text{ J K}^{-1}\text{mol}^{-1}$



(c) Under low pressure and high temperature

- At low pressure, the gas particles are very far apart. Hence the volume of the gas particles can be considered negligible compared to the volume of the container. In addition, the intermolecular attractive forces between widely spaced gas particles are also negligible.
- At high temperature, the gas particles possess sufficiently high kinetic energy to overcome the intermolecular attractive forces. Hence, the intermolecular attractive forces can be considered negligible.

(d) At moderately high pressure:

- O_2 molecules come closer together and the intermolecular attractive forces between O_2 molecules become significant. This causes the gas to occupy a volume smaller than that of an ideal gas. This results in a smaller V and $pV/nT < 8.31$ (negative deviation).

At very high pressure:

- The volume of the system becomes very small. Thus, the volume occupied by the O_2 molecules become significant compared to the volume of the container.
- The O_2 molecules are so close together that the repulsive forces between their electron clouds become significant. Hence, the gas occupies a volume larger than that of an ideal gas. This results in a larger V and $pV/nT > 8.31$ (positive deviation).

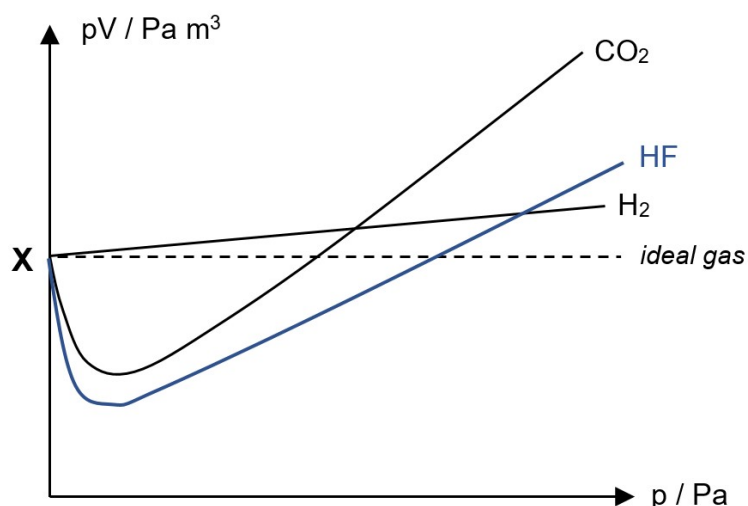
Notes for teaching:

In explaining deviation of a particular real gas versus ideal gas, it is still useful to look back at the two assumptions of ideal gas behavior (i.e. negligible IMF and negligible particle size) in (a) and how these two assumptions are violated when we look at a real gas.

Here, O_2 gas deviates from ideal gas behavior because 1) it experiences significant intermolecular attractive forces (id-id) and 2) molecular size of O_2 are not negligible – both points violate the ideal gas assumptions. The second point on repulsive forces will help to bring out the trend in positive deviation.

- 14 (a) (i) At the intercept of the pV axis (low pressure), both gases approach ideal gas behaviour.
 $\Rightarrow pV = nRT = (1)(8.31)(298) = \underline{2.48 \times 10^3 \text{ J (or Pa m}^3\text{)}}$ (to 3 sf)
- (ii) CO_2 shows greater negative deviation at moderately high pressure and greater positive deviation at very high pressure.
- For greater negative deviation:
 CO_2 has a greater electron cloud/ number of electrons compared to H_2 . Thus, CO_2 forms stronger instantaneous dipole – induced dipole interactions as its electron cloud is more polarisable.
 - For greater positive deviation:
The molecular size of CO_2 molecules is significantly larger than that of H_2 . The size of electron cloud for CO_2 is bigger than that of H_2 . This results in stronger repulsive forces between CO_2 molecules compared to H_2 molecules.

(b)



At moderately high pressures, HF deviates even more from ideality than CO_2 due to stronger hydrogen bonds between HF molecules as compared to the weaker id-id interactions between CO_2 molecules.

