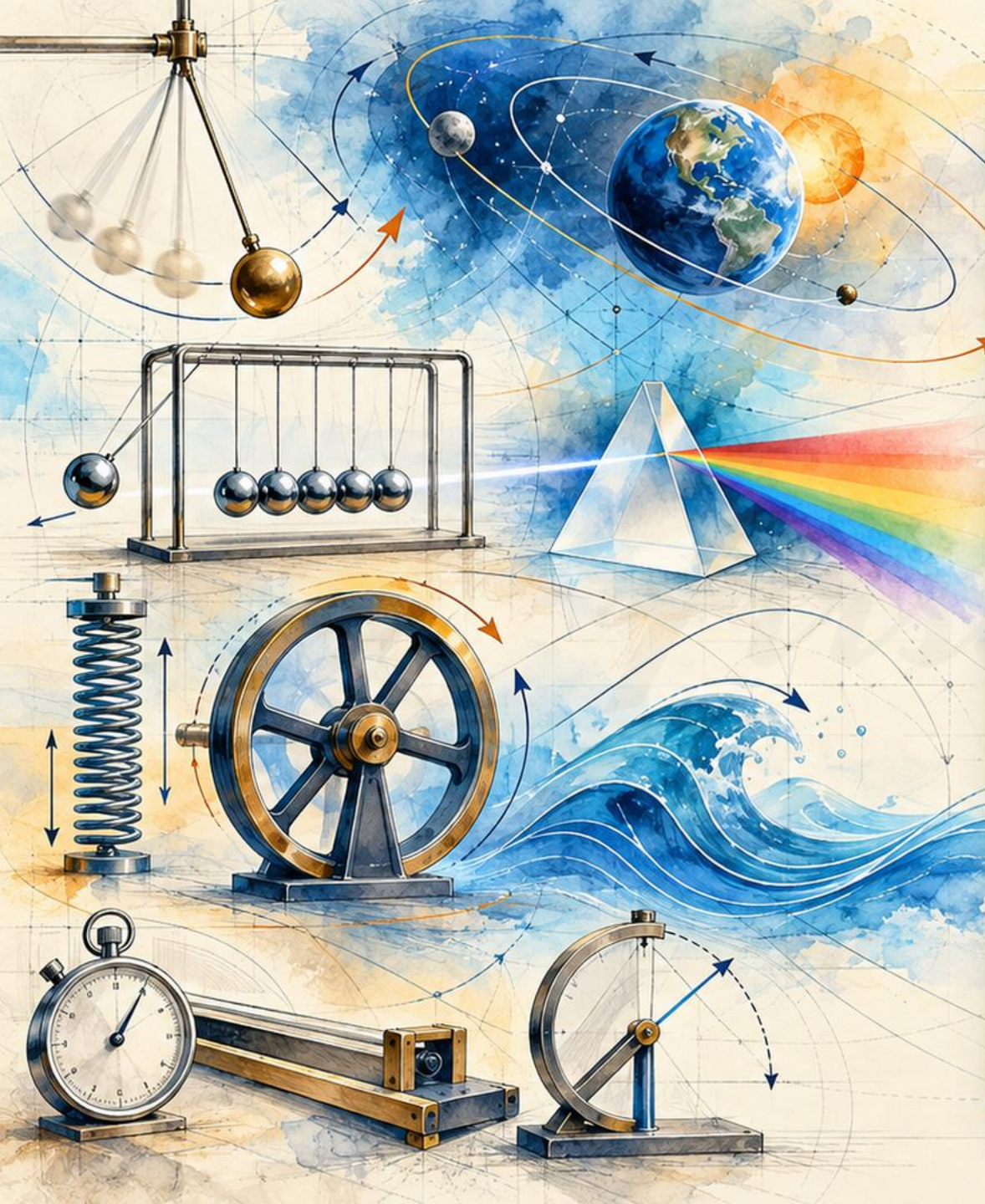




PHYSICS • CLASS 11

12

CHAPTER

Kinetic Theory

NCERT SOLUTIONS

EXERCISE SOLUTION: QUESTION 12.1

Question 12.1: Estimate the fraction of the volume occupied by oxygen gas at STP that is the actual volume of its molecules. Take the diameter of an oxygen molecule as $3 \text{ \AA}$.

Solution:

Treat each molecule as a sphere. Its radius is half the given diameter. Use one mole of gas; the volume fraction is independent of the sample size.

$$d = 3 \times 10^{-10} \text{ m}$$

$$r = 1.5 \times 10^{-10} \text{ m}$$

$$\begin{aligned} V_{\text{one}} &= \frac{4\pi}{3} r^3 = \frac{4\pi}{3} (1.5 \times 10^{-10})^3 \\ &\approx 1.414 \times 10^{-29} \text{ m}^3 \end{aligned}$$

$$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$$

$$\begin{aligned} V_{\text{molecules}} &= N_A V_{\text{one}} \\ &\approx 8.51 \times 10^{-6} \text{ m}^3 \text{ per mole} \end{aligned}$$

$$V_{\text{gas}} \approx 22.4 \text{ L} = 2.24 \times 10^{-2} \text{ m}^3 \text{ per mole}$$

$$\begin{aligned} \text{Fraction} &= \frac{V_{\text{molecules}}}{V_{\text{gas}}} = \frac{8.51 \times 10^{-6}}{2.24 \times 10^{-2}} \\ &\approx 3.8 \times 10^{-4} \end{aligned}$$

Molecular volume fraction ≈ 0.00038 , or 0.038% .

Most of the volume of this dilute gas is the space between molecules.

EXERCISE SOLUTION: QUESTION 12.2

Q.12.2 Molar volume is the volume occupied by one mole of an ideal gas. Show that it is 22.4 litres at STP, defined here as 1 atmospheric pressure and 0 °C.

Answer: Use the ideal-gas equation with absolute temperature and pressure in SI units.

$$PV = nRT$$

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

$$T = 273.15 \text{ K}$$

$$P = 1.013 \times 10^5 \text{ Pa}$$

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

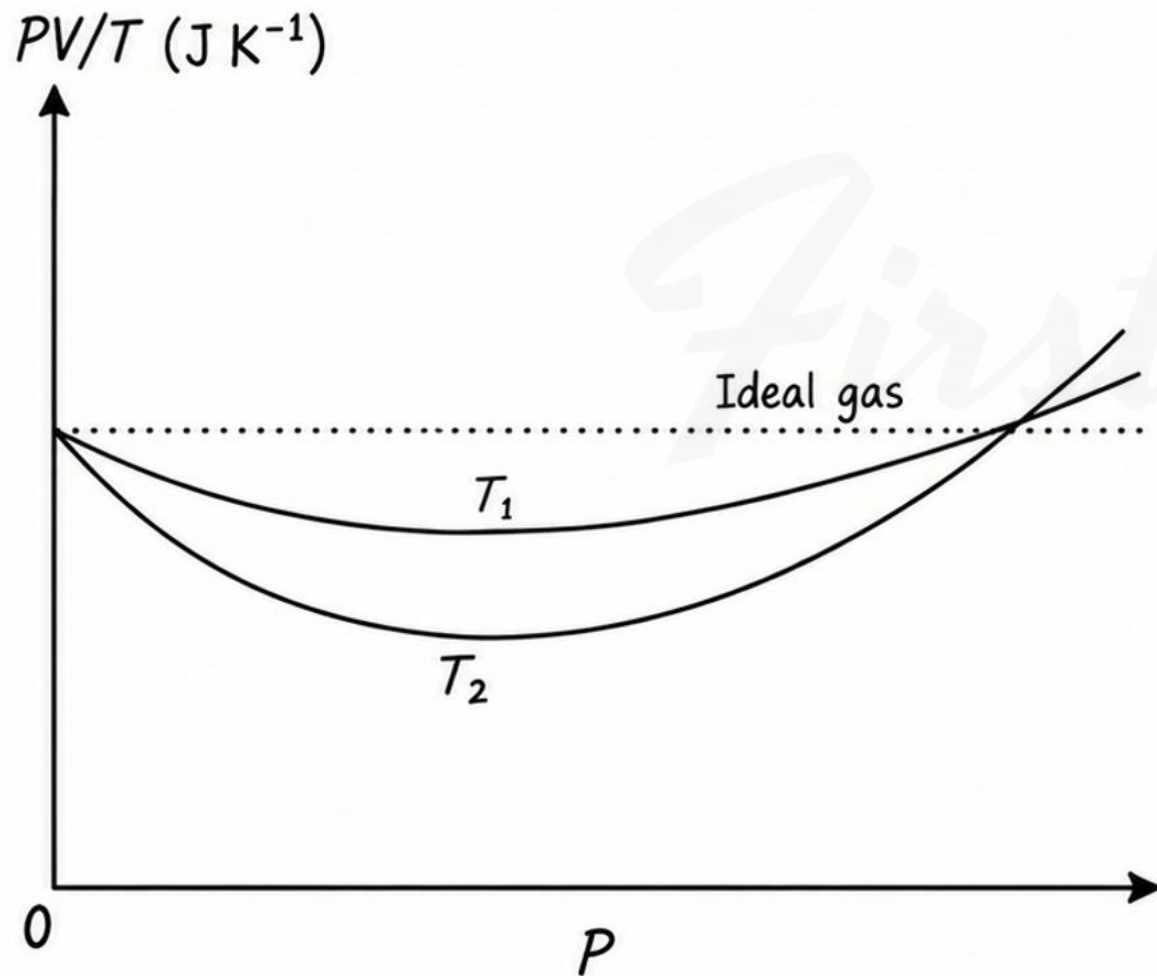
$$\begin{aligned} V &= \frac{nRT}{P} \\ &= \frac{(1)(8.31)(273.15)}{1.013 \times 10^5} \\ &\approx 2.2407 \times 10^{-2} \text{ m}^3 \\ 1 \text{ m}^3 &= 1000 \text{ L} \\ V &\approx 22.4 \text{ L} \end{aligned}$$

Molar volume at the stated STP $\approx 22.4 \text{ L mol}^{-1}$.

The result is the same for all ideal gases because it depends on the amount, pressure and temperature, not the gas species.

EXERCISE SOLUTION: QUESTION 12.3 (a-c)

The graph plots PV/T against pressure P for 1.00×10^{-3} kg of oxygen at two temperatures. (a) What does the dotted line mean? (b) Is T_1 greater or less than T_2 ? (c) Find the common vertical-axis intercept.



(a) **Answer:**

The dotted horizontal line represents ideal-gas behaviour.

$$PV/T = nR, \text{ independent of } P.$$

(b) **Answer:**

$$T_1 > T_2.$$

The shallower dip shows that attraction has less effect relative to molecular thermal motion at the higher temperature.

(c) **Answer:**

In the zero-pressure limit, both real-gas curves approach the ideal value.

$$m = 1.00 \text{ g}; \quad M_{\text{O}_2} = 32.0 \text{ g mol}^{-1}$$

$$n = 1.00/32.0 = 0.03125 \text{ mol}$$

$$\text{Intercept} = nR = (0.03125)(8.31) \approx 0.260 \text{ J K}^{-1}.$$

EXERCISE SOLUTION: QUESTION 12.3 (d)

Q. Would a similar PV/T -versus- P plot for 1.00×10^{-3} kg of hydrogen have the same zero-pressure intercept as the plot for 1.00×10^{-3} kg of oxygen? If not, what hydrogen mass gives the same ideal-limit value? Use $M_{H_2} = 2.02 \text{ g mol}^{-1}$, $M_{O_2} = 32.0 \text{ g mol}^{-1}$ and $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$.

Solution: Same mass

No. Equal masses do not contain equal numbers of moles. Hydrogen's smaller molar mass gives a larger number of moles and therefore a larger intercept.

$$\text{Intercept} = nR = \left(\frac{m}{M}\right)R$$

$$\text{Oxygen: } \left(\frac{1.00}{32.0}\right)(8.31) \approx 0.260 \text{ J K}^{-1}$$

$$\text{Hydrogen: } \left(\frac{1.00}{2.02}\right)(8.31) \approx 4.11 \text{ J K}^{-1}$$

Solution: Same intercept

The intercepts match when the two samples have the same number of moles.

$$\frac{m_{H_2}}{M_{H_2}} = \frac{m_{O_2}}{M_{O_2}}$$

$$\begin{aligned} m_{H_2} &= (1.00 \times 10^{-3}) \left(\frac{2.02}{32.0}\right) \text{ kg} \\ &= 6.3125 \times 10^{-5} \text{ kg} \end{aligned}$$

$$\begin{aligned} \text{Required hydrogen mass} &\approx 6.31 \times 10^{-5} \text{ kg} \\ &= 0.0631 \text{ g} \end{aligned}$$

This comparison uses the low-pressure ideal-gas limit.

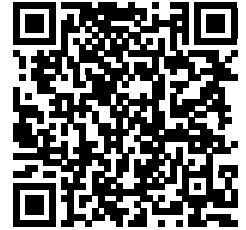


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