1010 Root Mean Square Velocity Problem

What is the average velocity or root mean square velocity of a molecule in a sample of oxygen at 0 °C?

Solution

Gases consist of atoms or molecules that move at different speeds in random directions. The root mean square velocity (RMS velocity) is a way to find a single velocity value for the particles. The average velocity of gas particles is found using the root mean square velocity formula

$\mu_{rms} = (3RT/M)^{1/2}$

where
μ_{rms} = root mean square velocity in m/sec
R = ideal gas constant = 8.3145 (kg·m²/sec²)/K·mol
T = absolute temperature in Kelvin
M = mass of a mole of the gas in **kilograms**.

The temperature must be converted to Kelvin and the molar mass must be found in kg to complete this problem.

Step 1 Find the absolute temperature using the Celsius to Kelvin conversion formula:

T = °C + 273
T = 0 + 273
T = 273 K

Step 2 Find molar mass in kg:

From the periodic table, molar mass of oxygen = 16 g/mol.

Oxygen gas (O_2) is comprised of two oxygen atoms bonded together. Therefore:

molar mass of O_2 = 2 x 16
molar mass of O_2 = 32 g/mol

Convert this to kg/mol:

molar mass of O_2 = 32 g/mol x 1 kg/1000 g
molar mass of O_2 = 3.2×10^{-2} kg/mol

Step 3 - Find μ_{rms}

$\mu_{rms} = (3RT/M)^{1/2}$

$\mu_{rms} = [3(8.3145\ (kg \cdot m^2/sec^2)/K \cdot mol)(273\ K)/3.2 \times 10^{-2}\ kg/mol]^{1/2}$

$\mu_{rms} = (2.128 \times 10^5\ m^2/sec^2)^{1/2}$

$\mu_{rms} = 461\ m/sec$

Answer:

The average velocity or root mean square velocity of a molecule in a sample of oxygen at 0 °C is 461 m/sec.