Question: What is the root mean square speed of nitrogen gas at 300K?

Concepts: To answer this question we need to understand how gas molecules behave at a fixed temperature, what is meant by "root mean square speed" and how it is calculated?

Connections:

What is given? We are given the identity and temperature of a gas sample.

What do I want to know? We want to know what the root mean square (rms) speed of the sample is. Kinetic Molecule Theory (KMT) tells us that gas molecules are in constant random motion. Every molecule is moving in its own unique path at its own speed. The temperature of a sample is a measure of the average kinetic energy of the entire sample, factoring in these differing speeds.

Remember that each molecule has its own kinetic energy. However, there will be at least one molecule/atom of gas that will have the same kinetic energy as the average of the entire sample. The speed of this molecule is called the "root mean square" speed (urms). This speed is determined by the temperature (which relates to kinetic energy) and the molecular mass of the atom/molecule. We can calculate this speed using equation: $u = \sqrt{\dfrac{3RT}{M}}$ Note that the only factors affecting the rms speed are temperature and mass.

Be sure you understand everything above before moving on to the solution below.

To solve this problem we need to calculate the rms speed (urms)

$$u = \sqrt{\frac{3RT}{M}}$$

R = 8.314 J/mol-K, T = 300K, M = 28 g/mol = 0.028 kg/mol

$$u = \sqrt{3 \times \frac{8.314\,J}{mol\,K} \times \frac{300\,K}{} \times \frac{mol}{0.028\,kg}} = 516.9\,m/s$$

Check

Unit analysis should be used to make sure that the correct value of R and the correct units for the molar mass are used.

The fact that the rms speed urms is related to kinetic energy, is the clue that we want to use the value of the gas constant R in energy units: 8.314 J/mol-K. Furthermore, we want the result of our calculation to be a speed (units of m/s). The energy unit Joule (J) is equal to 1 kg m2/s2.

The details of the unit analysis for the calculation is shown below: units of R = J/mol-K, units of M = kg/mol. The equation below is written with units only.