Friday, April 26/13
Science 122

Announcements

** **Need an activity re a course topic before the end of May.**

1. Quiz: Hydrodynamics -> Kurtis

2. Cutnell - Page 366 - Problems -> Mike N. and Mike C.
   Cutnell - Page 412 - Problems

3. Kinetic Theory of Gases

4. Cutnell - Page 413

   #28. 415 m/s
   #30. 746 K
   #31. 1.2×10^4 m/s
   #32. 2.098
   #33. 3.87×10^5 J
   #36. 5.0×10^1 s

   HW

5. Laws of Thermodynamics

Kinetic Theory of Gases

Kinetic theory makes several assumptions about the behavior of molecules in a gas.

- Molecules move in continuous, random motion.
- There are an exceedingly large number of molecules in any container of gas.
- The separation between individual molecules is large.
- Molecules do not act on one another at a distance; they do not exert electrical or gravitational forces on other molecules.
- All collisions between molecules, or between a molecule and the walls of a container are elastic (ie/ kinetic energy is not lost in these conditions).

Two results of kinetic theory are particularly important. They are derived using Newtonian mechanics and the assumptions above.

1. The relationship between the internal energy of a gas, U, and its temperature is:

$$\boxed{U = \frac{3}{2}PV = \frac{3}{2}nRT = \frac{3}{2}Nk_BT}$$

$$*PV = nRT = Nk_BT$$

2. The average kinetic energy per particle of gas is given by:

$$\boxed{\overline{E_k} = \frac{1}{2}mv_{rms}^2 = \frac{3}{2}k_BT}$$

$E_k = \frac{1}{2}mv^2$

$$\overline{KE} = \overline{E_k}$$

$$\boxed{v_{rms} = \sqrt{\frac{2\overline{E_k}}{m}}} \qquad \boxed{v_{rms} = \sqrt{\frac{3k_BT}{m}}}$$

*v_{rms} is the root-mean-square (rms) speed of a gas which can be considered to be the average speed of the molecules in a gas.

** translational motion - linear motion along a straight line or across a surface

☆

Example 6 - The Speed of Molecules in Air (Cutnell - Page 402)

Air is primarily a mixture of N_2 (28.0 g/mol) and O_2 (32.0 g/mol). Assume that each behaves as an ideal gas and determine the rms speeds of the nitrogen and oxygen molecules when the temperature of the air is 293 K.

T = 293 K

$$\boxed{\overline{E}_k = \frac{1}{2}mv_{rms}^2 = \frac{3k_BT}{2}}$$

$$\boxed{v_{rms} = \sqrt{\frac{2\overline{E}_k}{m}}} \qquad \boxed{v_{rms} = \sqrt{\frac{3k_BT}{m}}}$$

O_2

double molar mass of oxygen

$$m_{oxygen} = \frac{\text{molar mass}}{N_A}$$

g/mol

$$m_{oxygen} = \frac{32.0\ \text{g/mol}}{6.02 \times 10^{23}\ \text{mol}^{-1}}$$

$$m_{oxygen} = 5.316 \times 10^{-23}\ \text{g or } 5.316 \times 10^{-26}\ \text{kg}$$

$$m_{nitrogen} = 4.651 \times 10^{-23}\ \text{g or } 4.651 \times 10^{-26}\ \text{kg}$$

oxygen

$$v_{rms} = \sqrt{\frac{3k_BT}{m}}$$

$$v_{rms} = 478\ \text{m/s}$$

nitrogen

$$v_{rms} = \sqrt{\frac{3k_BT}{m}}$$

$$v_{rms} = 511\ \text{m/s}$$

$$\overline{E}_k = \frac{3k_BT}{2}$$

$$\overline{E}_k = \frac{3(1.38 \times 10^{-23}\ \text{J/K})(293)}{2}$$

$$\overline{E}_k = 6.065 \times 10^{-21}\ \text{J}$$

oxygen

$$v_{rms} = \sqrt{\frac{2\overline{E}_k}{m}}$$

$$v_{rms} = \sqrt{\frac{2(6.065 \times 10^{-21}\ \text{J})}{5.316 \times 10^{-26}\ \text{kg}}}$$

$$v_{rms} = 478\ \text{m/s}$$

nitrogen

$$v_{rms} = \sqrt{\frac{2\overline{E}_k}{m}}$$

$$v_{rms} = \sqrt{\frac{2(6.065 \times 10^{-21}\ \text{J})}{4.651 \times 10^{-26}\ \text{kg}}}$$

$$v_{rms} = 511\ \text{m/s}$$

Cutnell - Page 413

#28. 415 m/s
#30. 746 K
#31. 1.2×10^4 m/s
#32. 2.098
#33. 3.87×10^5 J
#36. 5.0×10^1 s

Hw