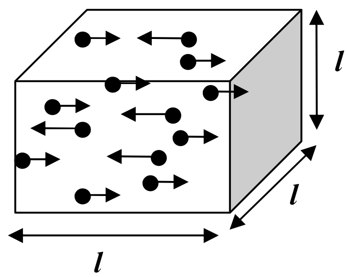
Lesson 11:3
(Please listen to the explanations, fill in the blanks and do the 4 questions enclosed which will be discussed in the class)

5. Derivation of an expression for the pressure of an ideal gas from the Kinetic theory of Gases. (vigorous derivation is not required)



a) The kinetic theory of gases states that pressure of a gas is due to the _______________ exerted by _______________________ on the _________ of the container.

b) There is a change in ________________ of gas molecules during the collisions.

c) The rate of change of momentum results in a ____________ acting on the wall.

d) Force exerted by a ____________ amount of molecules normally per unit area of the wall gives rise to an average __________________.

e) Pressure p exerted by N gas molecules, each of mass m, moving with a mean square speed $<u^2>$ in volume V is given by:

$$p = \frac{1}{3}\frac{Nm}{V} < u^2 >$$

where $< u^2 > = (u_1^2 + u_2^2 + ... + u_N^2)/N$

f) $p = \frac{1}{3}\frac{Nm}{V} < u^2 > = \frac{1}{3}\rho < u^2 >$ as $\frac{Nm}{V} = \rho$

where Nm : total mass of gas, V : total volume of gas and ρ, density.

Questions

1) How does pressure arise?

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2) Three gas molecules in a sample are moving with speeds 40 ms^{-1}, 50 ms^{-1} and 60 ms^{-1}
   a) The mean square speed $\langle u^2 \rangle$ of the sample is

   b) The root mean square speed, u_{rms} =

   c) If the density of the sample is 0.3 kgm^{-3}, calculate the pressure exerted by the molecules.

6. The average translational KE of the molecules in an ideal gas is directly proportional to the thermodynamic temperature T.

- From the ideal gas: pV = nRT -- equation (1)

  From kinetic theory, $pV = \frac{1}{3} Nm < u^2 >$ -- equation (2)

  Equate (1) & (2)

$$\frac{1}{3} Nm < u^2 >= nRT$$

$$\frac{1}{2} m < u^2 >= \frac{3}{2} \frac{nR}{N} T$$

$$\frac{1}{2} m < u^2 >= \frac{3}{2} kT \quad \text{------ (5)}$$

number of mole n = $\frac{N}{N_A}$

$$\frac{nR}{N} = \frac{R}{N_A}$$

$\frac{R}{N_A}$ = k Boltzmann's constant = 1.38 x 10^{-23}

Average KE of one molecule = ______________________

Total KE of n moles of molecules = ______________________

For ideal gas, internal energy of n moles molecules = total average KE = ______________________

- average KE = $\frac{1}{2} m < u^2 > \propto$ T ; as $\frac{3k}{2}$ is a constant
- $< u^2 >= \frac{3kT}{m}$ and the root-mean-square speed, $u_{rms} = \sqrt{< u^2 >} = \sqrt{\frac{3kT}{m}}$

- Mass of one molecule, m = nucleon number x atomic mass constant u or molar mass/Avogadro constant N_A

Questions

A sample, consists of 0.2 moles of hydrogen and 0.4 moles of helium, is held at 300 K. Assuming they behave ideally, determine:

a) <KE> of the sample =

b) Total KE of the sample =

c) Internal energy of the sample =

Questions

1. The pressure p of an ideal gas of density ρ is given by the expression

$$p = \frac{1}{3}\rho < u^2 >$$

(i) Identify the quantity $<u^2>$.

____

(ii) Deduce an expression for the average translational kinetic energy of a gas molecule in terms of the thermodynamic temperature, T and the Boltzmann's constant, k.

[4]

2. A sample of helium gas is at temperature 20 ^oC.
   (a) Determine the average translational kinetic energy of one helium atom. [2]

[6.07e-21J]

   (b) Calculate the root-mean-square speed of the atoms at 20 ^oC. [2]
   (mass of a helium atom = 6.6×10^{-29} kg)

[1.36e4ms^{-1}]

   (c) Calculate the root-mean-square speed of the atoms at 60 ^oC.

3. Seven molecules have speeds of 200, 300, 400, 500, 600, 700, and 800 ms^{-1}, respectively.
   a) calculate:
      i. their mean speed
      ii. square mean speed
      iii. their mean square speed

   b) Calculate the average KE of molecules in air at 300 K.

[500, 2.5e5, 2.9e5, 6.21e-21]

4. Sketch two graphs to show how
   a. the average KE and
   b. the root mean square speed of gas molecules in air vary with the temperature.