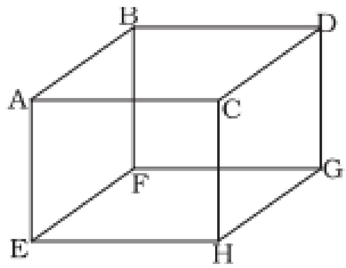
1

1 mole of an ideal gas is contained in a cubical volume V, ABCDEFGH at 302 K One face of the cube (EFGH) is made up of a material which totally absorbs any gas molecule incident on it.



At any given time:

the pressure on EFGH would be zero.

the pressure on all the faces will the equal.

the pressure of EFGH would be double the pressure on ABCD.

the pressure on EFGH would be half that on ABCD. A

the pressure on EFGH would be (1/6) of the pressure on other faces.

Solution: From the conservation of momentum:

p_molecule + P_wall_initial = p_mol_ini + 0 = p_mol = P_(wall+molecule) = P_wall_final

$$\Delta P_{wall} = P_{final-wall} - P_{wall-ini} = p_{mol-ini}$$

Pressure : $(\Delta P_{wall}/\Delta t)/A \;= p_{mol}/A\Delta t$

On side ABCD:

$$\Delta P_{wall} = P_{final-wall} - P_{wall-ini} = 2p_{mol-ini}$$

as the momentum change of the molecule is $\Delta p_{mol} = -2p_{mol-ini}$. Hence P_EFGH = (1/2) P_ABCD

2

Suppose the speed of every molecule in a gas were tripled. What would happen to the Kelvin temperature of the gas?

It would go up by a factor of 3

It would go up by sqrt(3)

It would go up by sqrt(2)

It would go up by a factor of 4

It would go up by a factor of 9 A

Solution: $P = \frac{2}{3}\left(\frac{N}{V}\right)\left(\frac{1}{2}\right) m\,\overline{v^2}; \overline{v^2} = \left(\frac{1}{N}\right)\sum v_i^2 \to \left(\frac{1}{N}\right)\sum(3v_i)^2 = 9\overline{v^2}$; As $P \to 9P \Rightarrow T \to 9T$

3

A tank of helium is used to fill some balloons. As each balloon is filled, the number of helium atoms remaining in the tank decreases. The process happens at some ambient temperature. If half of the volume of the gas in the tank is put inside a number of balloons, how does this affect the rms speed of molecules remaining in the tank?

RMS speed doubles for helium in the tank

RMS speed becomes half in the tank

RMS speed increases by a factor of sqrt(2)

RMS speed decreases by a factor of sqrt(2)

RMS speed remains the same. A

Solution: $v_{rms} = \sqrt{3k_B T/m}$; As the temperature remains the same so also v_{rms}

4

Let at an initial temperature the rms speed of nitrogen molecules is v0. Suppose the temperature of nitrogen gas is tripled and N2 molecules dissociate into atom. Then what will be the rms speed of atom?

sqrt(6) v0 A

v0/sqrt(6)

v0 sqrt(3)

v0/sqrt(3)

v0

Solution: $v_{rms} = \sqrt{3k_B T/m}$; $T \to 3T; m \to m/2$; $v_{rms} \to \sqrt{3k_B (3T)/(m/2)} = \sqrt{6} v_0$

5

A flask contains oxygen, hydrogen & chlorine in the ratio of 3:2:1 mixture at 27 °C

Molecular mass of Oxygen = 32; Molecular mass of Hydrogen = 2; Molecular mass of Chlorine = 70.9

Find the ratio of average kinetic energy per molecule of oxygen and hydrogen

1:2

1:1 A

1:16

2:1

1:8

Solution: $\overline{K.E.} = \frac{3}{2} nRT$; Average kinetic energy does not depend on the mass and only depends on temperature. Hence average kinetic energy per molecule of each gas is the same.

6

The ratio of mean speed of oxygen, chlorine, hydrogen is

4 : 1 : sqrt(0.45)

5 : 2 : sqrt(5)

1 : sqrt(0.45) :4 A

2 : sqrt(0.45) : sqrt(1.5)

32: sqrt(70.9) : 2

Solution: $\bar{v} = \sqrt{8k_BT/\pi m}$. At the same temperature (assumed as there is no otherwise situation described), $\bar{v} \propto 1/\sqrt{m}$;$\overline{v_{O_2}} : \overline{v_{Cl_2}} : \overline{v_{H_2}} = \frac{1}{\sqrt{m_O}} : \frac{1}{\sqrt{m_{Cl}}} : \frac{1}{\sqrt{m_H}} = \frac{1}{\sqrt{32}} : \frac{1}{\sqrt{70.9}} : \frac{1}{\sqrt{2}} = 1 : \sqrt{\frac{32}{70.9}} : \sqrt{\frac{32}{2}} = 1 : \sqrt{0.451} : 4$

7

M moles of an ideal polyatomic gas (CV=7R/2) are in a cylinder at temperature T. Heat of the amount Q is supplied to the gas. Some M/3 moles of the gas dissociate into atoms while temperature remains constant. Find the correct relation

3Q =4MRT A

2Q =3MRT

Q = 4MRT

7Q =4MRT

Q = 3MRT

Solution:

Total no of polyatomic moles after the heat is supplied =2M/3

Total no of monatomic moles after the heat is supplied =5M/3

Total internal energy after the split = (2M/3) (7/2) RT +(5M/3) (3/2) RT = (29/6)MRT

So Q=(29/6)MRT−(7/2)MRT = (8/6)MRT => 3Q=4MRT

8

The probability density of finding a particle in the speed interval v to v + dv is given by:

$$P(v) = 4\pi v^2 \left(\frac{m}{2\pi k_B T}\right)^{3/2} e^{-mv^2/(2k_BT)}$$

The area under the curves at T=T1 and T=T2 are denoted by A1 and A2, respectively. The temperatures are related by T2=2T1.

Which of the following is true:

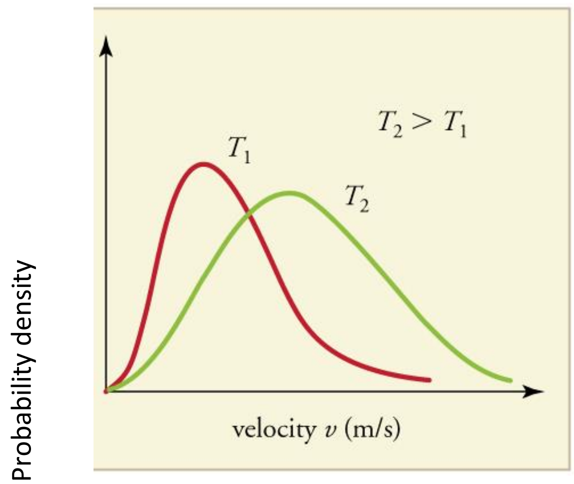
A2=1; A1=(1/2)

A2=2; A1=1

A2=(1/2); A1=1

A2=1; A1=1 A

A2=(3/2); A1=1



Solution: Area under the curve =1 and it is true for all variations.

9

We transfer 1000 J as heat Q to a diatomic gas, allowing the gas to expand with the pressure held constant. The gas molecules each rotate around an internal axis but do not oscillate. How much of the 1000 J goes into the increase of the gas's internal energy?

714.3 J A

428.6 J

285.7 J

328.2 J

750.4 J

Solution: $c_V = \frac{3+2}{2} R;\ C_V = nc_V$; At constant pressure, $Q = C_P \Delta T = \left(\frac{7}{2}\right) nR\Delta T$ => $\Delta T = Q/(7nR/2)$

$E_{int} = nc_V\, T;\ \Delta E_{int} = nc_V \Delta T = n(5R/2)Q\ \left(\frac{2}{7nR}\right) = \left(\frac{5}{7}\right) Q = 0.71428Q \approx 714.3$ J

10

If the molecules in a tank of hydrogen have the same rms speed as the molecules in a tank of oxygen, we may be sure that:

the pressures are the same

the hydrogen is at the higher temperature

the hydrogen is at the greater pressure

the temperatures are the same

the oxygen is at the higher temperature A

Solution: $v_{rms} = \sqrt{3k_B T/m}$; Thus $\sqrt{T_H/m_H} = \sqrt{T_O/m_O}$ implies $T_O = T_H\ m_O/m_H > T_H$

11

At which temperature the rms speed of oxygen exceeds the average speed of oxygen by 100 m/s?

1478 K

2072 K A

1235 K

734 K

300 K

Solution: sqrt(3kT/m) – sqrt(8kT/m pi) = 100 => sqrt(T) = sqrt(m/k)(100/((sqrt(3) – sqrt(8/pi))))

=> T= (m/k) (733.77)^2 K = (5.31*10^(-26)/(1.38*10^(-23)))* (733.77)^2 K = 2071.8 K

12

The temperature of low pressure hydrogen is reduced from 100 degree Celsius to 20 degree Celsius. The RMS speed of its molecules decreases by approximately:

80%

89%

46%

29%

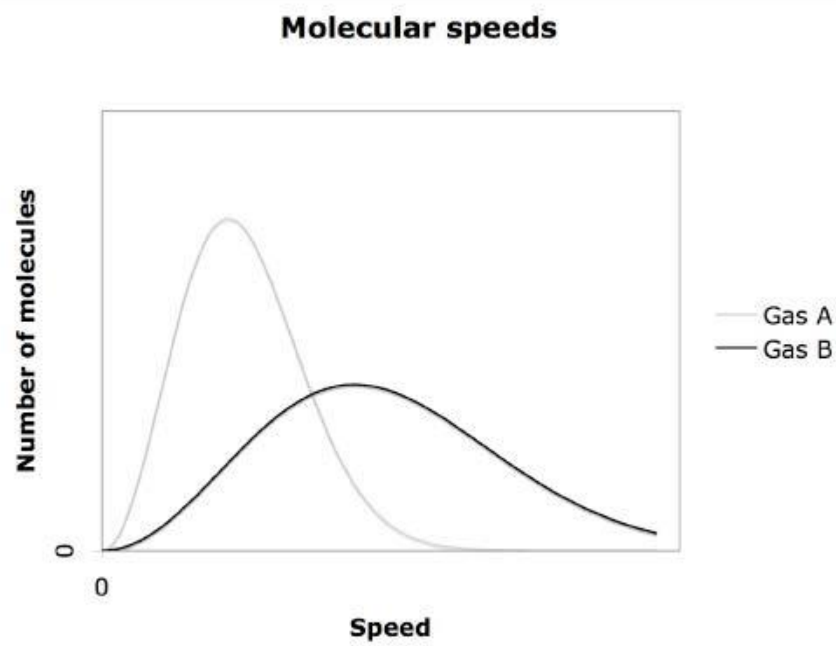
11% A

Solution: $v_{rms} = \sqrt{3k_B T/m}$; $\Delta v_{rms} = \sqrt{3k_B/m}\ (\sqrt{373} - \sqrt{293})$; $\Delta v_{rms}/v_{rms} = \left(\frac{(\sqrt{373} - \sqrt{293})}{\sqrt{373}}\right)$

$$\Delta v_{rms}/v_{rms} \approx 0.1137 \approx 11\%$$

13

Two gases in thermal equilibrium are observed to have the following distributions for the speeds of their molecules. Which of the following must be true?



Gas A has a lower temperature than gas B.

the molar internal energy of the molecules of both the gases are the same. A

Gas A is monatomic and gas B is diatomic.

the specific heat at constant volume of gas A is smaller than that of gas B.

pressure of the gas B alone is greater than that of gas A alone.

Solution: Internal energy of an ideal gas is a function of temperature only.

14

The pressure of an ideal gas is doubled in an isothermal process. The root-mean-square speed of the molecules

does not change

increases by a factor of sqrt(2)

decreases by a factor of sqrt(2)

increases by a factor of 2

decreases by a factor of 2

Solution: $v_{rms} = \sqrt{3k_B T/m}$; Temperature remains the same so also v_{rms}.

15

As the volume of an ideal gas is increased at constant pressure the average molecular speed

increases A

decreases

increases at high temperature, decreases at low

decreases at high temperature, increases at low

stays the same

Solution: $v_{avg} = \sqrt{8k_BT/\pi m}$; At P =constant; $T \propto V$ Hence as T increases so also v_{avg}.

16

Ideal monatomic gas A is composed of molecules with mass m while ideal monatomic gas B is composed of molecules with mass $4m$. The average molecular speeds are the same if the ratio of the Kelvin temperatures T_A/T_B is:

1/4 A

1/2

1

2

4

Solution: $v_{avg}^A = \sqrt{8k_BT_A/\pi m} = v_{avg}^B = \sqrt{8k_BT_B/\pi 4m}$ Hence, $T_A/m = T_B/4m$

17

Ideal monatomic gas A is composed of molecules with mass m while ideal monatomic gas B is composed of molecules with mass $4m$. The average translational kinetic energies are the same if the ratio of the Kelvin temperatures T_A/T_B is:

1/4

1/2

1 A

2

4

Solution: $\overline{K.E} = \frac{3}{2}k_BT$ depends only on temperature. Here both gases are monoatomic.