PHYSICS

NCERT - NCERT PHYSICS(ENGLISH)

KINETIC THEORY

Solved Example

1. The density of water is $1000 kg m^{-3}$. The density of water vapour at $100^\circ C$ and 1 atmospheric pressure is $0.6 kg m^{-3}$. The volume of a molecule multiplied by the total number gives what is called, molecular volume. Estimate the ratio (or fraction) of the molecular volume to the total volume occupied by the water vapour under the above conditions of temperature and pressure.

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2. Estimate the volume of a water molecule using the data of one molecule. What is its approximate size?

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3. What is the average distance between atoms (interatomic distance) in water ?

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4. A vessel contains two non-reactive gases neon (monoatomic) and oxygen (diatomic). The ratio of their partial pressures is 3:2. Estimate the ratio of

(i) number of molecules, and

(ii) mass density of neon and oxygen in the vessel.

Atomic mass of neon = 20.2 u, and molecular mass of oxygen = 32.0 u.

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5. A flask contains argon and chlorine in the ratio 2:1 by mass. The temperature of the mixture is $27^{\circ} C$. Obtain the ratio of

(i) average kinetic energy per molecule, and

(ii) root mean square speed of the molecules of two gases.

Atomic mass of argon = 39.9 u, Molecular mass of chlorine = 70.9 u.

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6. Uranium has two isotopes of masses 235 and 238 units. If both are present in uranium hexa fluoride gas, which would have the larger average speed ? If atomic mass of fluorine is 19 units, estimate the percentage difference in speed at any temperature.

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7. (a) When a molecule (or an elastic ball) hits a (massive) wall, it rebounds with the same speed. When a ball hits a massive bat held firmly, the same thing happens However, when the bat is moving towards the ball, the ball rebounds with a different speed. Does the ball move faster or slower?

(b) When gas in a cylinder is compressed by pushing in a piston. Its temperature rises. Guess at an explanation of this in terms of kinetic theory using (a) above

(c) What happens when a compressed gas pushes a piston out and expands. What would you observe?

(d) Sachin Tendulkar uses a heavy cricket bat while playing. Does it help him in any way?

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8. A cylinder of fixed capacity 44.8 litre contains helium gas at standard temperature and pressure.

What is the amount of heat needed to raise the temperature of the gas in the cylinder by $15.0^{\circ} C$? $\left[R = 8.31 J mol^{-1} K(-1)\right]$

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9. Estimate the mean free path for a water molecule in water vapour at 373 K. Given diameter of water molecule $= 2 \text{Å}$ and number density of water molecule (at NTP) $= 2.7 \times 10^{25} m^{-3}$. Compare it with interatomic distance for water $= 40 \text{Å}$.

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Exercise

1. Estimate the fraction of molecular volume to the actual volume occupied by oxygen gas at STP. Take the diameter of an oxygen molecule to be 3Å.

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2. Molar volume is the volume occupied by 1 mole of any (Ideal) gas at standard temperature and pressure (STP , $0^\circ C$, 1 atmospheric pressure). Show that it is 22.4 litres. Take $R = 8.31 J mol^{-1} K^{-1}$.

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3. Fig shows of PV/T versus P for $1.00 \times 10^{-3} kg$ of oxygen gas at two different temperatures.

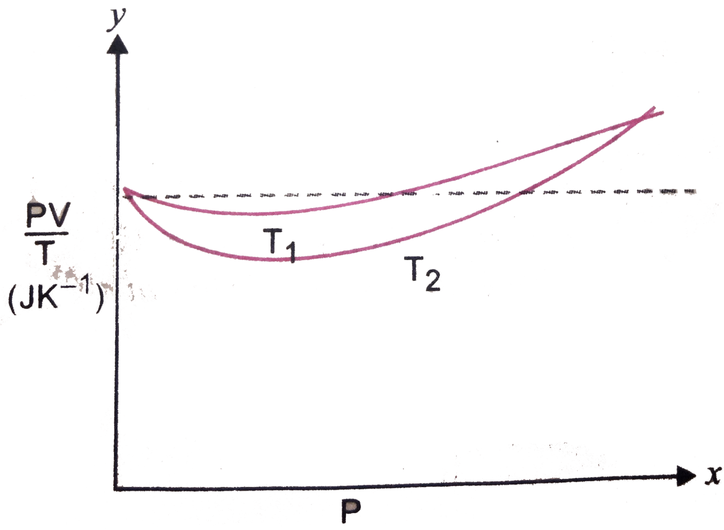
(a) What does the dotted plot signify ?

(b) Which is true : $T_1 < T_2 \text{ or } T_2 < T_1$?

(c) What is the value of PV/T where the curves meet on the Y-axis ?

(d) If we obtained similar plot for $1.00 \times 10^{-3} kg$ of hydrogen, would we get the same value of PV/T at the point where the curves meet on the y-axis ? If not, what mass of hydrogen yield the same value of PV/T (for low pressure high temperature region of the plot) ? (Molecular mass of $H = 2.02u$, of

$O = 32.0u$, $R = 8.31 J\text{mol}^{-1} K^{-1}$



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4. An oxygen cylinder of volume 30 litres has an initial gauge pressure of 15 atm. And a temperature of $27^{\circ} C$. After some oxygen is withdrawn from the cylinder, the gauge pressure drops to 11 atm. And its temperature drops to $17^\circ C$. Estimate the mass of oxygen taken out of the cylinder. $\left(R = 8.1J\text{mole}^{-1}K^{-1}\right.$, molecular mass of $O_2 = 32u)$.

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5. An air bubble of volume $1.0cm^3$ rises from the bottom of a lake 40 m deep at a temperature of $12^\circ C$. To what volume does it grow when it reaches the surface, which is at a temperature of $35^\circ C$. ? Given $1atm = 1.01 \times 10^5 Pa$.

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6. Estimate the total number of air molecules (inclusive of oxygen, nitrogen, water vapour and other constituents) in a room of capacity $25.0m^3$ at a temperature of $27^\circ C$ and 1 atm pressure. (Boltzmann constant $= 1.38 \times 10^{-23} JK^{-1}$).

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7. Estimate the average thermal energy of a helium atom at (i) room temperature $(27^\circ C)$ (ii) the temperature on the surface of the sun (6000K), (iii) the temperature of 10 million kelvin (the typical core temperature in the case of a star)

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8. Three vessel of equal capacity have gases at the same temperature and pressure. The first vessel contains neon (monoatomic), the second contains chlorine (diatomic), and the third contains uranium hexafluoride (polyatomic). Do the vessels contains equal number of respectice molecules ? Is the root mean square speed of molecules the same in the three cases ? If not, which case is v_{rms} the largest?

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9. At what temperature is the root mean square speed of an atom in an argon gas cylinder equal to the r.m.s. speed of a helium gas atom at $-20^{\circ}C$? (Atomic mass of Ar = 39.9 u, of He = 4.0 u).

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10. Estimate the mean free path and collision frequency of a nitrogen molecule in a cylinder containing nitrogen at 2 atm and temperature $17^{\circ}C$. Take the radius of a nitrogen molecule to be roughly 1.0Å. Compare the collision time with the time the molecule moves freely between two successive collisions. (Molecular mass of nitrogen = 28.0 u).

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11. A metre long narrow bore held horizontally (and close at one end) contains a 76 cm long mercury thread, which traps a 15 cm column of air. What happens if the tube is held vertically with the open end at the bottom?

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12. From a certain apparatus, the diffusion rate of hydrogen has an average value of $28.7cm^3s^{-1}$. The diffusion of another gas under the same condition is measured to have an average rate of $7.2cm^3s^{-1}$. Identify the gas.

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13. A gas in equilibrium has uniform density and pressure throughout its volume. This is strictly true only if there are no external influences. A gas column under gravity, for example, does not have uniform density (and pressure). As you might expect, its density decreases with height. The precise dependence is given by the so-called law of atmospheres

$$n_2 = n_1 \exp[-mg(h_2 - h_1)/(k_B T)]$$

where n_2, n1 refer to number density at heightsh_2 and h_1 respectively. Use this relation to derive the equation for sedimentation equilibrium of a suspension in a liquid column:

$$n_2 = n_1 \ \exp\ [-mgN_A(\rho - \rho')(h_2 - h_1)/(\rho \ \ \mathrm{RT})]$$

where ρ is the density of the suspended particle, and ρ that of surrounding medium. [N_A is Avogadro's number, and R the universal gas constant.] [Hint : Use Archimedes principle to find the apparent weight of the suspended particle.]

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14. Given below are densities of some solids and liquids. Give rough estimates of the size of their atoms :

Substance	Atomic Mass (u)	Density (10^3 Kg m^{-3})
Carbon (diamond)	12.01	2.22
Gold	197.00	19.32
Nitrogen (liquid)	14.01	1.00
Lithium	6.94	0.53
Fluorine (liquid)	19.00	1.14

[Hint : Assume the atoms to be 'tightly packed' in a solid or liquid phase, and use the known value of Avogadro's number. You should, however, not take the actual numbers you obtain for various atomic sizes too literally. Because of the crudeness of the tight packing approximation, the results only indicate that atomic sizes are in the range of a few Å].

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