8. KINETIC THEORY & MOLECULAR VELOCITIES

SOLUTIONS

TEACHING TASK

JEE MAINS LEVEL QUESTIONS

Kinetic theory of gases

1. The pressure of a gas is due to (CEE 1992)

A) the collison of gas molecules against each other

B) the random moment of gas molecules

C) the intermolecular forces of attraction between the gas molecules

D) the collision of gas molecules against the walls of the container

Answer:D

Solution:Pressure is caused by gas molecules hitting the container walls, transferring momentum

2. The correct statements regarding kinetic molecular theory are

a) The distance between the molecules is high compared to size of the gaseous molecules

b) The motion of the gaseous molecules are affected by gravitational force

c) The attractive forces between the gaseous molecules are very high.

d) The total K.E of a sample of gaseous molecules remains constant at a given temperature

A) b, d B) b, c C) a, d D) c, d

Answer:C

Solution:(a) The distance between molecules is large compared to their size (gases are mostly empty space).

(d) The total K.E. of gas molecules remains constant at a given temperature (since K.E. depends only on temperature).

(b) is wrong because gravitational forces are negligible, and (c) is wrong because attractive forces are very weak in gases.)

3. Which is wrong according to kinetic theory

A) Average K.E. of molecules is proportional to the absolute temperature

B) Collisions between molecules are perfectly elastic

C) Pressure is due to collisions between molecules

D) There are no attractive forces between the molecules of a gas

Answer:C

Solution:Pressure is due to collisions of molecules with the container walls, not between molecules themselves.

4. Which of the following statements is not a postulate of kinetic molecular theory of gases ?

A) K.E. is dependent on temperature

B) K.E. is dependent on pressure

C) The Molecular collisions are perfectly elastic collisions

D) The pressure of the gas is due to collisions of gas molecules on the walls of the vessel

Answer:B

Solution:K.E. depends only on temperature, not pressure

5. When gas molecules collide on the walls of the vessel, the energy of the molecules changes into

A) Heat B) Temperature C) Light D) None

Answer:D

Solution:Collisions are elastic, so energy is not lost as heat, temperature, or light—it is just transferred as momentum.

6. The absolute temperature of a gas

A) is a measure of the number of molecules in the gas

B) is a measure of the volume of the gas

C) indicates the nature of the gas

D) is a measure of the average kinetic energy of the molecules

Answer:D

Solution:From kinetic theory, $KE = \frac{3}{2}k_B T$ so temperature directly relates to average K.E.)

Kinetic Gas Equation

7. Boltzmann constant represents the gas constant per

A) mole B) an Avogadro number of molecules

C) any number of molecules D) molecule

Answer:D

Solution:The Boltzmann constant (k_B) is defined as: $k_B = \frac{R}{N_A}$

where N_A is Avogadro's number (6.022×10^{23} molecules/mol)

Thus, k_B is the gas constant per molecule, not per mole.

8. The ratio of kinetic energies of 2gm of H_2 and 4g of CH_4 at a given temperature is

A) 4:1 B) 2:32 C) 1:4 D) 16:2

Answer:A

Solution:Average kinetic energy per molecule depends only on temperature($KE = \frac{3}{2}k_B T$)

Total kinetic energy depends on the number of molecules in the sample.

For 2g of H_2 (Molar mass = 2 g/mol):Moles of H_2 =2/2=1mole

Number of molecules = $1 \times N_A = N_A$

For 4g of CH_4 (Molar mass = 16 g/mol):

Moles of CH_4=4/16=0.25 moles

Number of molecules = $0.25 \times N_A = N_A/4$

Ratio of Total Kinetic Energies:

$$\frac{KE_{H_2}}{KE_{CH_4}} = \frac{N_A}{\frac{N_A}{4}} = 4:1$$

9. Helium atom is 2 times heavier than hydrogen molecule. At 298K Average kinetic energy of Helium atom is

A) 2 times that of H_2 molecule B) same as that of H_2 molecule

C) 4 times that of H_2 molecule D) 1/2 times that of H_2 molecule

Answer:B

Solution:Average kinetic energy per molecule depends only on temperature, not mass or molecular weight: $KE = \frac{3}{2}k_B T$

Since both He and H2 are at the same temperature (298K), their average KE is the same.

10. At 27^{0}C the total kinetic energy of 8 grams Hydrogen is .... times, the total kinetic energy of 8 grams of oxygen (E-1991)

A) 2 B) 4 C) 8 D) 16

Answer:D

Solution:Total KE depends on the number of molecules (since KE per molecule is the same at the same temperature).

Moles of H_2 =8/2=4moles

Number of molecules = 4×N_A

Moles of O_2 = 8/32=0.25moles

Number of molecules = 0.25×N_A

Ratio of Total Kinetic Energies: $\frac{KE_{H_2}}{KE_{O_2}} = \frac{4N_A}{0.25N_A} = 16:1$

11. The kinetic gas equation is applicable when the gas is present in a

A) Cubic vesselB) Spherical vesselC) Vessel of any shape D)Cylindrical vessel

Answer:C

Solution:The kinetic gas equation ($PV = \frac{1}{3}mnc^2$) is derived based on molecular collisions with walls, independent of container shape.

It assumes random motion and elastic collisions, which hold true regardless of whether the vessel is cubic, spherical, cylindrical, etc.

Molecular Velocities

12. Four molecules of a gas have the velocities 3 x 10^4 cm/sec. 4 x 10^4 cm / sec. 2 x 10^4 cm/sec. and 5 x 10^4 cm/sec. The r.m.s. velocity of the molecules is

A) 3.675 x 10^3 cm/s B) 36.75 x 10^3 cm/s C) 36.75 x 10^4 cm/s D) 3.675 x 10^2 cm/s

Answer:B

Solution:

$$v_{rms} = \sqrt{\frac{v_1^2 + v_2^2 + v_3^2 + v_4^2}{4}}$$

$$v_{rms} = \sqrt{\frac{(3\times10^4)^2 + (4\times10^4)^2 + (2\times10^4)^2 + (5\times10^4)^2}{4}}$$

$$v_{rms} = 3.674\times10^4 cm/\sec$$

$$v_{rms} = 36.74\times10^3 cm/\sec$$

13. Most probale velocity of hydrogen molecules at T^0 C is υ_0. At $(2T+273)^0$ C, all the molecules are dissociated into atoms. Then new most probable velocity will be

A) υ_0 B) $2\upsilon_0$ C) $3\upsilon_0$ D) $4\upsilon_0$

Answer:B

Solution:Most probable velocity $v_0 = \sqrt{\frac{2RT}{M}}$

where ,M = molar mass of H_2 = 2 g/mol.

After dissociation:$H_2 \rightarrow$ 2H (atoms)

Molar mass of H = 1 g/mol

New temperature = 2T+273 K

New most probable velocity: $v_0^{'} = \sqrt{\frac{2R(2T+273)}{1}}$

$$v_0 = \sqrt{\frac{2RT}{2}} = \sqrt{\frac{RT}{1}}$$

If T is in °C, we convert to Kelvin: Initial T_K=T+273

New T_K' =2T+273=2t+273+273=2(t+273)

$$v_0^{'} = \sqrt{\frac{2R(2T+273)}{1}} = \sqrt{\frac{2R.2(T+273)}{1}} = \sqrt{\frac{4R(T+273)}{1}} = 2\sqrt{\frac{R(T+273)}{1}}$$

$$v_0 = \sqrt{\frac{2RT}{2}} = \sqrt{\frac{RT}{1}} = \sqrt{\frac{R(T+273)}{1}}$$

compare υ_0 and $v_0^{'}$

$v_0^{'}$ =2 υ_0

14. Which of the following order of root mean square speed of different gases at the same temperature is true ?

A) $(U_{rms})_{H_2} > (U_{rms})_{CH_4} > (U_{rms})_{NH_3} > (U_{rms})_{CO_2}$ B) $(U_{rms})_{H_2} < (U_{rms})_{CH_4} < (U_{rms})_{NH_3} < (U_{rms})_{CO_2}$

C) $(U_{rms})_{H_2} < (U_{rms})_{CH_4} > (U_{rms})_{NH_3} > (U_{rms})_{CO_2}$ D) $(U_{rms})_{H_2} > (U_{rms})_{CH_4} < (U_{rms})_{NH_3} < (U_{rms})_{CO_2}$

Answer:A

Solution:Lighter gases have higher U_{rms} at the same temperature.

H_2=2gms,CH_4=16gms,NH_3=17gms,CO_2=44gms

$(U_{rms})_{H_2} > (U_{rms})_{CH_4} > (U_{rms})_{NH_3} > (U_{rms})_{CO_2}$

15. The root mean square velocity of a gas is ‘c’. If pressure of gas is doubled at constant temperature, what will be the root mean square velocity of the gas sample

A) 2c B) $\sqrt{2c}$ C) c D) $\frac{c}{\sqrt{2}}$

Answer:C

Solution:Root mean square velocity (v_{rms}) depends only on temperature and molar mass: $v_{rms} = \sqrt{\frac{3RT}{M}}$

Pressure change at constant temperature does not affect v_{rms}

16. At 25^0 C the gas with maximum R.M.S. velocity is

A) He B) CO_2 C) N_2 D) NH_3

Answer:A

Solution:R.M.S. velocity (v_{rms}) is given by: $v_{rms} = \sqrt{\frac{3RT}{M}}$

where M = molar mass of the gas.

Lighter gases have higher v_{rms} at the same temperature.

Molar masses:He = 4 g/mol,CO_2 = 44 g/mol,N_2 = 28 g/mol,NH_3 = 17 g/mol

He has the smallest molar mass, so it has the highest V_{rms}

17. R.M.S. Velocity of a gas is calculated with the formula $\sqrt{\frac{3PV}{M}}$ If volume is increased by 3 times, the R.M.S. velocity of the gas

A) Increases by 3 times B) Decreases by 9 times

C) Increases by $\sqrt{3}$ times D) Does not change

Answer:D

Solution:$v_{rms} = \sqrt{\frac{3PV}{M}}$

PV=nRT,n=1

PV=RT

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

Volume change does not affect v_{rms} unless temperature changes.

18. At 300K, the no. of molecules possessing most probable velocity are 100. At 400K the no. of molecules possessing most probable velocity are

A) 90 B) 100 C) 110 D) 120

Answer:A

Solution:The most probable velocity (v_{mp}) shifts with temperature: $v_{mp} = \sqrt{\frac{2RT}{M}}$

The number of molecules at v_{mp} is inversely proportional to $\sqrt{T}$

$$\frac{N_2}{N_1} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{300}{400}} = \sqrt{0.75} \approx 0.87$$

N_2 =100×0.87˜87

19. A molecule of sulphur dioxide is 4 times heavier than an atom of oxygen gas. The average kinetic energy of an oxygen molecule at 298K is

A) 1/4th of SO_2 molecule B) Same as that of SO_2 molecule

C) 1/2 of that of SO_2 molecule D) 4 times that of SO_2 molecule

Answer:B

Solution:Average kinetic energy per molecule depends only on temperature: $KE_{avg} = \frac{3}{2}k_B T$

It is independent of molecular mass.

Thus, O_2 and SO_2 have the same average KE at the same temperature.

20. In a gas 10% molecules have a velocity of 2km/sec and 8% molecules have a velocity of 1.5 Km/sec and 82% molecules have a velocity 1km. per sec. The most probable velocity of molecules is

A) 1 km/sec. B) 1.5 km/sec C) 2 km / sec. D) 15 km/sec.

Answer:A

Solution:Most probable velocity (v_{mp}) is the velocity possessed by the maximum number of molecules.

Given:

82% of molecules have

v=1km/sec (highest percentage).

10% have v=2km/sec.

8% have v=1.5km/sec.

Thus, 1 km/sec is the most probable velocity.

JEE ADVANCED LEVEL QUESTIONS

Multi Correct Answer Type

21. Identify the incorrect statement among the following

(A) Most probable speed increases with increase in temperature

(B) Fraction of total molecules with most probable velocity decreases with increase in temperature

(C) Area under the curve increases with increase in temperature

(D) Same fraction of molecules possess different velocities at same temperature

Answer:C,D

Solution:1.Correct: Most probable speed (v_{mp}) increases with temperature ($v_{mp} \alpha \sqrt{T}$).

2.Correct: As temperature increases, the Maxwell-Boltzmann distribution flattens, reducing the fraction of molecules at v_{mp}.

3.Incorrect: The area under the curve (total number of molecules) remains constant; only the distribution changes.

4.Incorrect: At a given temperature, the fraction of molecules having a specific velocity varies (it's not the same for all velocities).

22. Which of the following relations regarding molecular velocities are true ?

a) Most probable velocity = 0.8166 x RMS velocity

b) RMS velocity = 0.9213 x Average velocity

c) Average velocity = $\sqrt{\frac{8RT}{\pi M}}$ d) $C_P > \overline{C} > C$

Answer:A,C

Solution:a) Most probable velocity $= \sqrt{\frac{2}{3}}$ x RMS velocity=0.8166 x RMS velocity

b) Incorrect. Correct relation: RMS velocity =1.085x Average velocity

c) Average velocity = $\sqrt{\frac{8RT}{\pi M}}$ -->correct

d)Incorrect. Correct order:$C_P < \overline{C} < C$

Statement Type

A) If A and R are correct, R is correct explanation for A.

B) If A and R are correct, R is not correct explanation of A.

C) If A is correct and R is wrong. D) If A is wrong and R is correct.

23. A : In max well distribution curve with increase in temperature the fraction of molecules possessing most probable velocity increases.

R : With increasing temperature molecular velocities increases.

Answer:D

Solution:Assertion (A): False.

As temperature increases, the Maxwell-Boltzmann distribution flattens and broadens, causing the peak (most probable velocity) to decrease in height.

Thus, the fraction of molecules at v_{mp} decreases (not increases).

Reason (R): True but irrelevant.

While molecular velocities do increase with temperature, this does not explain the fraction at v_{mp} .

24. Assertion(A): C_{RMS} is greater than C_P for any ideal gas.

Reason (R): Velocity of gas molecules increases with an increase of temperature

Answer:B

Solution:Assertion (A): True.

For any gas:

$$v_{rms} = \sqrt{\frac{3RT}{M}}, v_{mp} = \sqrt{\frac{2RT}{M}}$$

$$v_{rms} > v_{mp}$$

Reason (R): True but not explanatory.

While temperature increases velocities, it doesn't explain why $v_{rms} > v_{mp}$

25. Assertion(A): Different gases at the same conditions of temperature and pressure have same root mean square speed.

Reason (R): Average K.E of a gas is directly proportional to temperature in Kelvin

Answer:D

Solution:Assertion (A): False.

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

Even at the same T, v_{rms} depends on molar mass (M), so different gases do not have the same v_{rms} .

Reason (R): True but irrelevant.

While average KE α T, it doesn't imply equal v_{rms} for different gases.

Comprehension Type

The root mean square speed of an ideal gas is given by : $u_{rms} = \sqrt{\frac{3RT}{M}}$. Thus we conclude that u_{rms} speed of the ideal gas molecules is proportional to square root of the temperature and inversely proportional to the square root of the molar mass. The translational kinetic energy per mole can also be given as $\frac{1}{2}Mu_{rms}^2$. The mean free path (λ) is the average of distances travelled by a molecules in between two successive collisions whereas collision frequency (C.F.) is expressed as number of collisions taking place in unit time. The two terms λ and C.F. are related by : C.F.=$\frac{u_{rms}}{\lambda}$

26. A jar contains He and H_2 in the molar ratio 1 : 5. The ratio of mean translational kinetic energy is in the ratio at the same temperature is :

A) 1 : 5 B) 5 : 1 C) 2 : 1 D) 1 : 1

Answer:D

Solution:Since KE depends only on temperature, He and H_2 will have the same average KE per molecule (or per mole) at the same T.

Thus, the ratio of their mean KE is 1 : 1, regardless of their molar ratio.

27. Which of the following relation is correct for an ideal gas regarding its pressure (P) and translational kinetic energy per unit volume (E) ?

A) $P = \frac{2}{3}E$ B) $P = \frac{3}{2}E$ C) $P = \frac{1}{2}E$ D) $P = 2E$

Answer:A

Solution:For an ideal gas, the total translational KE of all molecules is: $KE_{Total} = \frac{3}{2}Nk_BT$

Divide the total KE by the volume (V) to get E: $E = \frac{KE_{Total}}{V} = \frac{3}{2}\frac{Nk_BT}{V}$

Using the ideal gas law ($PV = Nk_BT$), substitute $P = \frac{Nk_BT}{V}$

$$E = \frac{3}{2}P$$

$$P = \frac{2}{3}E$$

28. If n represents number of moles, n_0 is number of molecules per unit volume, k is Boltzmann constant, R is molar gas constant, T is absolute temperature and N_A is Avogadro's number then which of the following relations is wrong ?

A) $P = n_0kT$ B) $P = n_0RT$ C) $P = \frac{NKN_AT}{V}$ D) $n_0 = N_A \times \frac{n}{V}$

Answer:B,C

Solution:1) $P = \frac{1}{3}n_0mv^2$

$$\frac{1}{2}mv^2 = \frac{3}{2}kT$$

$$P = n_0kT$$

4) $n_0 = \frac{nN_A}{V}$

Matching Type

29 **Answer:C**

Solution:

LIST - 1	**LIST - 2**
A) Average velcoity	2) $\sqrt{\frac{8RT}{\pi M}}$
B) Most probable velocity	3) $\sqrt{\frac{2RT}{M}}$
C) Kinetic energy of a gas	1) $\frac{3}{2}nRT$
D) Kinetic energy of a gas molecule	

E) RMS velocity 4) $\sqrt{\frac{3RT}{M}}$

A) E-1; C-3; B-2; A-4 B) E-3; D-4; B-2; A-1

C) B-2; A-3; E-1; C-4 D) D-3; E-4; A-2; B-1

Integer Type

30. The root mean square velocity of a gas is doubled when the temperature is increases or decreases by _____

Answer:4

Solution: $v_{rms} = \sqrt{\frac{3RT}{M}}$

Condition: v rms is doubled. $2v_{rms} = \sqrt{\frac{3RT^{'}}{M}}$

Squaring both sides: $4v^{2}_{rms} = \frac{3RT^{'}}{M}$

Substitute $v^{2}_{rms} = \frac{3RT}{M} : 4\frac{3RT}{M} = \frac{3RT^{'}}{M}$

$T^{'} = 4T$

31. The K.E of N molecule of O_2 is x Joules at -123^{0}C. Another sample of O_2 at 27^{0}C has a KE of 2x Joules . The latter sample contains _____N molecules of O_2

Answer:1

Solution:

$$KE = \frac{3}{2}nRT$$

$$x = \frac{3}{2} \times \frac{N}{N_A} \times R \times 150 ----- (1)$$

$$2x = \frac{3}{2} \times \frac{N^{'}}{N_A} \times R \times 300 ----- (2)$$

$$\frac{x}{2x} = \frac{\frac{3}{2} \times \frac{N}{N_A} \times R \times 150}{\frac{3}{2} \times \frac{N^{'}}{N_A} \times R \times 300}$$

$$\frac{1}{2} = \frac{N}{N'} \times \frac{150}{300}$$
$$N' = N$$

LEARNERS TASK

CONCEPTUAL UNDERSTANDING QUESTIONS (CUQ'S)

Kinetic theory of gases

1. Postulate of kinetic theory is

(A) Atom is indivisible **(B)** Gases combine in a simple ratio

(C) There is no influence of gravity on the molecules of a gas

(D) None of the above

Answer:C

Solution:There are no intermolecular forces acting between the molecules (this includes ignoring gravity).

2. According to kinetic theory of gases,

(A) There are intermolecular attractions

(B) Molecules have considerable volume

(C) No intermolecular attractions

(D) The velocity of molecules decreases after each collision

Answer:C

Solution:Kinetic theory assumes no intermolecular forces (except during collisions).

(A) Incorrect: Intermolecular attractions are negligible.

(B) Incorrect: Molecules are treated as point masses with negligible volume.

(D) Incorrect: Collisions are elastic; speed remains constant (only direction changes).

3. Kinetic energy of a gas depends upon its

(A) Molecular mass **(B)** Atomic mass

(C) Equivalent mass **(D)** None of these

Answer:D

Solution:The kinetic energy of a gas depends only on its temperature, not on the mass of its molecules.

4. The kinetic theory of gases perdicts that total kinetic energy of a gaseous assembly depends on

(A) Pressure of the gas **(B)** Temperature of the gas

(C) Volume of the gas **(D)** Pressure, volume and temperature of the gas

Answer:B

Solution: $KE = \frac{3}{2}nRT$

It depends only on temperature and moles of gas, not pressure or volume

Kinetic Gas Equation

5. In deriving the kinetic gas equation, use is made of the root mean square velocity of the molecules because it is

(A) The average velocity of the molecules

(B) The most probable velocity of the molecules

(C) The square root of the average square velocity of the molecules

(D) The most accurate form in which velocity can be used in these calculations

Answer:C

Solution:Root mean square velocity is defined as the square root of the average of the squares of the velocities of individual molecules.

$$v_{rms} = \sqrt{\frac{v_1^2 + v_2^2 + --- + v_n^2}{n}}$$

6. Boyle's law according to kinetic gas equation is

A) $PV = \frac{2}{3}KT$ B) $PV = \frac{3}{2}KT$ C) PV = nRT D) PV = RT

Answer:A

Solution:

$$PV = \frac{1}{3}mNC^2$$

$$PV = \frac{1}{3}MC^2$$

$$PV = \frac{2}{3}\frac{1}{2}MC^2$$

$$PV = \frac{2}{3}KE$$

$$KE \alpha T$$

$$KE = KT$$

$$PV = \frac{2}{3}KT$$

7 If E_k is the average kinetic energy per mole of a gas, then

A) $PV = \frac{3}{2}E_k$ B) $P = \frac{3}{2}V.E_k$ C) $PV = \frac{2}{3}E_k$ D) 3 PV = E_k

Answer:C

Solution:For an ideal gas, the average kinetic energy per mole is given by: $E_k = \frac{3}{2}RT$

For 1 mole of gas:PV=RT

$$E_k = \frac{3}{2}PV$$

$$PV = \frac{2}{3}E_k$$

8. At the same temperature and pressure which one of the following gas will have highest kinetic energy per mole.

A) H_2 B) O_2 C) CH_4 D)KE same for all

Answer:D

Solution:The average kinetic energy per mole of an ideal gas depends only on temperature

9. When two molecules of an ideal gas collide

A) heat is liberated B) no heat is liberated

C) heat is absorbed D) there is a decrease in the total K.E.

Answer:B

Solution:In an ideal gas, collisions between molecules are perfectly elastic, meaning:

No energy is lost as heat.

The total kinetic energy of the system is conserved.

10. The kinetic energy of a mole of ideal gas in calories is approximately equal to

A) 3 times its absolute temperature B) 2 times its absolute temperature

C) 4 times its absolute temperature D) 2/3 times its absolute temperature

Answer:A

Solution: $E_k = \frac{3}{2}RT$

$E_k \approx \frac{3}{2} \times 2 \times T = 3T$

11. A closed flask contains H_2 O in all its three states solid, liquid and vapour at 0^0 C. in this the average K.E. of water molecules will be

A) greatest in the vapour state B) same in all the three states

C) greatest in the solid state D) greater in the liquid than in the vapour state

Answer:B

Solution:The average kinetic energy (KE) of molecules depends only on temperature:

$$KE_{avg} = \frac{3}{2}k_B T$$

At 0°C (273 K), all phases (solid ice, liquid water, water vapor) are in thermal equilibrium, meaning they share the same temperature.

Therefore, the average KE is identical for molecules in all three states.

Molecular Velocities

12. The quantity $\left(\frac{PV}{kT}\right)$ represents :

A) mass of the gas B) KE of the gas

C) number of moles of the gas D) number of molecules in the gas

Answer:B

Solution:From the kinetic theory of gases, the total kinetic energy (KE) of a gas is related to PV by: $PV = \frac{2}{3}E_k$

where E_k is the total KE of the gas molecules.

Thus, PV is directly proportional to the KE of the gas.

13. R.M.S. velocity of a gas molecule is equal to

A) $\sqrt{\frac{2RT}{M}}$ B) $\sqrt{\frac{3RT}{M}}$ C) $\sqrt{\frac{8RT}{\pi M}}$ D) $\sqrt{\frac{RT}{M}}$

Answer:B

Solution:The root mean square (RMS) velocity is derived from the kinetic theory as

$:v_{rms} = \sqrt{\frac{3RT}{M}}$

14. The RMS velocity of the molecule is minimum if the gas is

A) N_2 B) SO_2 C) CO_2 D) SO_3

Answer:D

Solution:RMS velocity is inversely proportional to the square root of molar mass (M): $v_{rms} \alpha \sqrt{\frac{1}{M}}$

SO_3 has the highest molar mass, so it will have the lowest RMS velocity.

15. The ratio between the most probable velocity, mean velocity and root mean square velocity is

A) $\sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3}$ B) 1 : 2 : 3 C) $1 : \sqrt{2} : \sqrt{3}$ D) $1: \sqrt{\frac{8}{\pi}} : \sqrt{3}$

Answer:A

Solution: $v_{mp} = \sqrt{\frac{2RT}{M}}, \bar{v} = \sqrt{\frac{8RT}{\pi M}}, v_{rms} = \sqrt{\frac{3RT}{M}}$

$v_{mp} : \bar{v} : v_{rms} = \sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3}$

16. The relation between R.M.S velocity,average velocity and most probable velocity is

A) R.M.S velocity > Average velocity > Most probable velocity.

B) Average velocity> R.M.S velocity> Most probable velocity

C) R.M.S.velocity = Average velocity > Most probable velocity

D) Most probable velocity> Average velocity>R.M.S. velocity

Answer:A

Solution: $v_{mp} : \bar{v} : v_{rms} = \sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3}$

$v_{rms} > \bar{v} > v_{mp}$

17. At S.T.P. the order of RMS velocities of H_2,N_2,O_2 and HBr molecules is

A) $H_2>N_2>O_2>HBr$ B) $HBr>O_2>N_2>H_2$ C) $HBr>H_2>N_2>O_2$ D) $N_2>O_2>H_2>HBr$

Answer:A

Solution: $v_{rms} = \sqrt{\frac{3RT}{M}}$

Lighter molecules move faster at the same temperature.

Molar Masses of Gases:H_2 : 2 g/mol

N_2: 28 g/mol

O_2 : 32 g/mol

HBr: 81 g/mol

18. The RMS velocity of gas molecules at NTP cannot be calculated from one of the following formula

A) $\sqrt{\frac{3P}{d}}$ B) $\sqrt{\frac{3PV}{M}}$ C) $\sqrt{\frac{3RT}{M}}$ D) $\sqrt{\frac{3RT}{d}}$

Answer:D

Solutin:$C_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3P}{d}}$

19. In the calculation of RMS velocity in cm/sec the units of R should be in

A) ergs/mole/K B) joules/mole/K C) cals/mole/K D) ergs

Answer:A

Solution: $v_{rms} = \sqrt{\frac{3RT}{M}}$

If velocity is required in cm/sec, all units must be in the CGS system.

In CGS:Mass is in grams

Distance is in centimeters

Energy is in ergs

So, R must be in: ergs/mole/K

20. Average velocity is equal to

A) 0.8 r.m.s. velocity B) 0.981 r.m.s velocity

C) 0.9213 rms velocity D)0.7567 r.m.s. velocity

Answer:B

Solution: $\bar{v} = \sqrt{\frac{8RT}{\pi M}}$, $v_{rms} = \sqrt{\frac{3RT}{M}}$

$$\frac{\bar{v}}{v_{rms}} = \frac{\sqrt{\frac{8RT}{\pi M}}}{\sqrt{\frac{3RT}{M}}} = 0.9213$$

JEE MAINS LEVEL QUESTIONS

Kinetic Gas Equation

21. The energy of a gas per liter is 300 J its pressure will be :

A) $30\times10^5 N/m^2$ B) $6\times10^5 N/m^2$ C) $10^5 N/m^2$ D) $2\times10^5 N/m^2$

Answer:D

Solution:The kinetic energy per unit volume (E) is related to pressure (P) by: $E=\frac{3}{2}P$

E=300J

$E/m^3=300 \times 10^5$

$$P=\frac{2}{3}E$$

$$P=\frac{2}{3}(300\times10^5)=2\times10^5$$

22. According to kinetic theory of gases, The energy per mole of the gas is equal to (E-1985)

A) RT B) 0.67RT C) 0.5RT D) 1.5RT

Answer:D

Solution:For an ideal monatomic gas, the total energy per mole is the sum of translational kinetic energy: $E=\frac{3}{2}RT=1.5RT$

23. The kinetic energy of 16 grams of oxygen at 27^0 C is

A) 400 cals B) 450 cals C) 1800cals D) 200 cals

Answer:B

Solution: $n = \frac{16}{32} = 0.5moles$

Calculate kinetic energy (using R ˜ 2 cal/mol·K):

$$KE = \frac{3}{2}nRT = \frac{3}{2} \times 0.5 \times 2 \times 300 = 450cals$$

24. At the same temp. total K.E. of 16 grams of methane is .... times that of 16 grams of SO_2

A) Same B) Two times C) Four times D) Three times

Answer:C

Solution:The total kinetic energy depends only on:Number of moles (n),Temperature (T)

For 16 grams of each:

CH_4 (M=16 g/mol): n = 1 mole

SO_2 (M=64 g/mol): n = 0.25 moles

$$\frac{KE_{CH_4}}{KE_{SO_2}} = \frac{1mole}{0.25moles} = 4$$

25. The kinetic energy of 4 moles of nitrogen gas at 127^0C is _________ cals. $\left(R = 2cal.mole^{-1}.K^{-1}\right)$

A. 4400 B. 3200 C. 4800 D. 1524

Answer:C

Solution:T=127+273=400K

$$KE = \frac{3}{2}nRT = \frac{3}{2} \times 4 \times 2 \times 400 = 4800cals$$

26. If the temperature is raised from 20^0C to 40^0C, the average kinetic energy of neon atoms changes by a factor of which of the following (AIEEE 2004)

A. $\frac{1}{2}$ B. $\frac{313}{293}$ C. $\sqrt{\frac{313}{293}}$ D. 2

Answer:B

Solution:

$$KE = \frac{3}{2} nRT$$

$$E_1 = \frac{3}{2} nR(293)$$

$$E_2 = \frac{3}{2} nR(313)$$

$$E_2 = \frac{313}{293} \times E_1$$

Molecular Velocities

27. RMS velocity of O_2 at 15^0 C

A) 1.5 x 10^4 cm/sec B) 4.5 x 10^4 cm/sec

C) 6 x 10^4 cm/sec D) 8.9 x 10^4 cm/sec

Answer:B

Solution:

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$$v_{rms} = \sqrt{\frac{3 \times 8.314 \times 10^7 \times 288}{32}}$$

$$v_{rms} = \sqrt{232 \times 10^7} = 48166.637 = 4.8166 \times 10^4 \approx 4.5 \times 10^4 cm/\sec$$

28. The rms velocity of a gas at a certain temperature is found to be 12,240 cm/sec. The most probable velocity of that gas is in cm/sec is

A) 10^3 B) 10^4 C) 11280 D) 1128

Answer:B

Solution:

$$v_{mp} = 0.816 \times v_{rms}$$

$$v_{mp} = 0.816 \times 12240$$

$$v_{mp} = 10000 = 10^{4 cm/\sec}$$

29. The ratio of RMS velocities of molecular hydrogen and molecular oxygen at the same temperature is

A) 4 : 1 B) 1 :4 C) 1:2 D) 1:8

Answer:A

Solution: $\frac{v_{rms,H_2}}{v_{rms,O_2}} = \sqrt{\frac{M_{O_2}}{M_{H_2}}} = \sqrt{\frac{32}{2}} = 4$

30. Four molecules of a gas have the velocities 3×10^4 cm/sec. 4×10^4 cm / sec. 2×10^4 cm/sec. and 5×10^4 cm/sec. The r.m.s. velocity of the molecules is

A) 3.675×10^3 cm/s B) 36.75×10^3 cm/sC) 36.75×10^4 cm/s D) 3.675×10^2 cm/s

Answer:B

Solution:

$$v_{rms} = \sqrt{\frac{v_1^2 + v_2^2 + v_3^2 + v_4^2}{4}}$$

$$v_{rms} = \sqrt{\frac{(3\times10^4)^2 + (4\times10^4)^2 + (2\times10^4)^2 + (5\times10^4)^2}{4}}$$

$$v_{rms} = 3.674\times10^4 \, cm/\sec$$

$$v_{rms} = 36.74\times10^3 \, cm/\sec$$

31. For one mole of hydrogen gas, kinetic energy is 4×10^8 ergs. Then its RMS velocity is

A) 4×10^4 cm/sec B) 2×10^4 cm / sec

C) $10^7 / 4$ cm/ sec D) 10^4 cm / sec.

Answer:B

Solution:

$$KE = \frac{3}{2}RT = \frac{1}{2}Mv^2_{rms}$$

$$v_{rms} = \sqrt{\frac{2\times KE}{M}} = \sqrt{\frac{2\times4\times10^8}{2}} = 2\times10^4 \, cm/\sec$$

32. By what factor, the mean velocity is to be multiplied to get the RMS velocity.

A. $\frac{1.224}{1.128}$ B. $\frac{1.128}{1.224}$ C. $\frac{1}{1.128}$ D. $\frac{1}{1.224}$

Answer:A

Solution: $\frac{v_{rms}}{\bar{v}} = \frac{\sqrt{\frac{3RT}{M}}}{\sqrt{\frac{8RT}{\pi M}}} = \frac{1.224}{1.128}$

JEE ADVANCED LEVEL QUESTIONS

Multi Correct Answer Type

33. Which of the following indicates Kinetic gas equation ?

a) $PV = \frac{3M}{C^2}$ b) $PV = \frac{1}{3} mnC^2$ c) $P = \frac{1}{3} dC^2$ d) $KE = \frac{3}{2} RT$

Answer:b,c

Solution:

$$PV = \frac{1}{3} mnc^2$$

$$d = \frac{mn}{V}$$

$$dV = mn$$

$$PV = \frac{1}{3} dVc^2$$

$$P = \frac{1}{3} dc^2$$

34. The Kinetic energy of a gas depends upon

a) nature of the gas b) absolute temperature

c) molecular weight of the gas d) number of moles of the gas

Answer:b,d

Solution:Average KE per molecule: $KE_{avg} = \frac{3}{2} k_B T$

Depends only on temperature (T), not molecular weight or gas type.

Total KE for a gas sample: $KE_{total} = \frac{3}{2}nRT$

Depends on:Number of moles (n) ,Temperature (T) .

Statement Type

35. Assertion(A): H_2 and O_2 have same RMS velocity at the same temperature.

Reason (R): R.M.S velocity of a gas molecules is directly proportional to square

Answer:D

Solution:Assertion (A):False.

RMS velocity depends on molar mass (M) and temperatureT): $v_{rms} = \sqrt{\frac{3RT}{M}}$

H_2 (M=2g/mol) and O_2 (M=32g/mol) cannot have the same v_{rms} at the same T.

Reason (R):True. $v_{rms} \alpha \sqrt{T}$

36. Assertion(A): At 300K, kinetic energy of 16 gms of methane is equal to the kinetic energy of 32 gms of oxygen.

Reason (R): At constant temperature, kinetic energy of one mole of all gases is equal

Answer:A

Solution:n_{H2}=1mole,n_{O2}=1mole

KE per mole depends only on T (not gas type)

Comprehension Type

Root mean square velocity (U_{rms}) : It is defined as the square root of the mean of the squares of the velocities possessed by all the molecules present in the given sample of gas

$$U_{rms} = \sqrt{\frac{U_1^2 + U_2^2 + ...U_n^2}{N}}$$

37. The RMS velocities of two gases at the same temperature are u_1 and u_2, their masses are m_1 and m_2 respectively. Which of the following expression is correct?

1) $\frac{m_2}{u_1}=\frac{m_2}{u_2}$ 2) $m_1u_1 = m_2 u_2$ 3) $\frac{m_1}{u_1}=\frac{m_2}{u_2}$ 4) $m_1{u_1}^2 = m_2{u_2}^2$

Answer:D

Solution:

$$u=\sqrt{\frac{3RT}{M}}$$
$$u_1=\sqrt{\frac{3RT}{m_1}}, u_2=\sqrt{\frac{3RT}{m_2}}$$
$$\frac{u_1}{u_2}=\frac{\sqrt{\frac{3RT}{m_1}}}{\sqrt{\frac{3RT}{m_2}}}=\frac{\sqrt{\frac{1}{m_1}}}{\sqrt{\frac{1}{m_2}}}=\sqrt{\frac{m_2}{m_1}}$$
$$(\frac{u_1}{u_2})^2=\frac{m_2}{m_1}$$
$$m_1u^2{}_1=m_2u^2{}_2$$

38. Which of the following indicates RMS velocity of a gas ?

a) $\sqrt{\frac{2RT}{M}}$ b) $\sqrt{\frac{3P}{d}}$ c) $\sqrt{\frac{8RT}{\pi M}}$ d) $1.58\times\sqrt{\frac{T}{M}}$ ´10^4 cm/sec

A) c, d B) b, d C) a, c D) a, b

Answer:B

Solution:

$$v_{rms}=\sqrt{\frac{3RT}{M}}=\sqrt{\frac{3PV}{M}}=\sqrt{\frac{3P}{d}}$$
$$v_{rms}=\sqrt{\frac{3RT}{M}}=\sqrt{\frac{3\times 8.314\times 10^7\, ergs\times T}{M}}=1.58\times\sqrt{\frac{T}{M}}\times 10^4\, cm/\sec$$

39. Which of the following is incorrect?

A) RMS velocity depends upon molecular weight

B) RMS velocity depends upon temperature

C) RMS velocity depends upon density at a given temperature

D) The RMS velocity is used in deriving the kinetic gas equation

Answer:C

Solution:RMS velocity is independent of density at a given temperature.

Matching Type

40.**Answer:3**

Soluton:

List-I	**List-II**
A. $\sqrt{\frac{C_1^2+C_2^2+C_3^2+...+C_n^2}{n}}$	3. RMS velocity of gas molecules
B. $\frac{C_1+C_2+C_3+...+C_n}{n}$	1. Average velocity
C. $\sqrt{\frac{2P}{d}}$	4.Most probable velocity of gas molecules

1. A-1,B-2,C-3 2. A-2,B-3,C-1 3. A-3,B-1,C-4 4. A-4,B-1,C-3

Integer Type

41. Boltzmann's constant value is 1.38×10^{-X} erg K^{-1} molecule^{-1}, here X value is ____

Answer:16

Solution:The value of X in Boltzmann's constant (1.38 × 10–X erg K–1 molecule–1) is 16.

Boltzmann's constant is approximately 1.38×10^{-16} erg K^{-1} molecule^{-1}.

This is equivalent to 1.38×10^{-23} J/K in SI units. The constant relates the average kinetic energy of particles in a gas to the temperature of the gas.

KEY

				TEACHING TASK						
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
D	C	C	B	D	D	D	A	B	D	
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
C	B	B	A	C	A	D	A	B	A	
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	
C,D	A,C	D	B	D	D	A	B,C	C	4	
31										
1										
				LEARNERS TASK						
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
C	C	D	B	C	A	C	D	B	A	
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
B	B	B	D	A	A	A	D	A	B	
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	
D	D	B	C	C	B	B	B	A	B	
31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	
B	A	B,C	B,D	D	A	D	B	C	3	
41										
16										