9 Kinetic Theory of Gases

Boyle's Law

"For a gas having sufficiently low density, its pressure is inversly proportional to its volume, at constant temperature."

$$P \propto \frac{1}{V} \quad \Rightarrow PV = \text{constant} \qquad \text{..................} \ (1)$$

$$\Rightarrow P_1V_1 = P_2V_2$$

(A) But volume $V = \frac{m}{\rho}$

From equation (1),

$$\therefore P\left(\frac{m}{\rho}\right) = \text{constant}$$

If mass m is constant, then

$$\frac{P}{\rho} = \text{constant} \qquad \Rightarrow \frac{P_1}{\rho_1} = \frac{P_2}{\rho_2}$$

(B) Number of molecules in unit volume, $n = \frac{N}{V} \Rightarrow V = \frac{N}{n}$

from equation (1),

$$P\left(\frac{N}{n}\right) = \text{constant}$$

If N is constant then, $\frac{P}{n} = \text{constant} \Rightarrow \frac{P_1}{n_1} = \frac{P_2}{n_2} = \text{constant}$

Charle's Law

"For a gas having sufficiently low density, at constant pressure, its volume is directly proportional to its absolute temperature."

$$V \propto T \qquad \Rightarrow \frac{V}{T} = \text{constant} \qquad \Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

(A) But density $\rho = \frac{m}{V} \Rightarrow V = \frac{m}{\rho}$ $\qquad$ m = constant

So, $\frac{m}{\rho T} = \text{constant} \Rightarrow \boxed{\rho T = \text{constant}}$ $\quad \rho_1 T_1 = \rho_2 T_2$

(B) At constant pressure for a given mass of gas Volume at 0 °C is V_0 then Volume at t °C is

$$V_t = V_0\left(1 + \frac{t}{273.15}\right).$$

Gaylussac's Law

"For a gas having sufficiently low density, at constant volume, its pressure is directly proportional to its absolute temperature."

$$P \propto T \qquad \Rightarrow \frac{P}{T} = \text{constant} \qquad \Rightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

(A) At constant volume, for a given mass of gas pressure at 0 °C is P_0 then pressure at t °C is

$$P_t = P_0\left[1 + \frac{t}{273.15}\right]$$

(1) If speed of sound in air is v_s and its rms speed in air is v_{rms} then ......

(A) $v_s = v_{rms}$ (B) $v_s = v_{rms}\left(\frac{\gamma}{3}\right)^{\frac{1}{2}}$ (C) $v_{rms} = v_s\left(\frac{\gamma}{3}\right)^{\frac{1}{2}}$ (D) $v_s = v_{rms}\left(\frac{\gamma}{2}\right)^{2}$

(2) On increasing temperature of a gas filled in a closed container by 1°C, its volume increases by 0.4 %, then intial temperature of gas would be ....

(A) 250 °C (B) 150 °C (C) 250 K (D) 150 K

(3) Volume of a gas at 2 atm pressure and 746.3 K temperature for question 2 is ....

(A) 100 m^3 (B) 100 cc (C) 1 m^3 (D) 1 cc

(4) ...... = constant in Boyle's law.

(A) $\frac{P}{T}$ (B) V T (C) PV (D) $\frac{P}{V}$

(5) To double the volume of a given quantity of ideal gas at 27 °C, temperature should be ...... °C at constant pressure.

(A) 600 (B) 270 (C) 370 (D) 54

(6) On decreasing volume of a gas at constant temperature by 5 %, its pressure ......

(A) decreases by 5.26 % (B) increases by 5.26 % (C) increases by 11 % (D) decreases by 11 %

(7) 2 mole ideal gas is mixed with 3 mole diatomic rigid rotator gas. Molar specific heat at constant volume will be ......

(A) 1.2 R (B) 2.1 R (C) $\frac{3}{2}$ R (D) $\frac{5}{2}$ R

(8) A gas is filled in a closed container at temperature 250 K, on increasing its temperature by 1 K, percentange change in its pressure is ......

(A) 0.8 % (B) 0.2 % (C) 0.4 % (D) 0.1 %

(9) Two gases having equal mass are in thermal equillibrium. If their pressure are P_a and P_b and volumes are V_a and V_b respectively, then ......

(A) $P_aV_a = P_bV_b$ (B) $\frac{P_a}{V_a} = \frac{P_b}{V_b}$ (C) $P_a \neq P_b$; $V_a = V_b$ (D) $P_a = P_b$; $V_a \neq V_b$

(10) At what temperature will volume of an ideal gas becomes 3 times than that at 0 °C at constant pressure ?

(A) 819 °C (B) 646 °C (C) 546 °C (D) 182 °C

(11) 1 mol oxygen gas is filled in a container at pressure P and temperature T. In another similar container, 1 mol Helium gas is filled at temperature 2T then pressure of helium gas will be ....

(A) 8P (B) P/8 (C) P (D) 2P

(12) Volume of a gas at temperature 27 °C is V. If its temperature is increased to 327 °C at constant pressure, then its volume becomes ......

(A) V/2 (B) V (C) 2V (D) 3V

(13) At what temperature will pressure of 1 g N_2 gas be equal to pressure of 1 g O_2 gas at 15 °C ? Molecular mass of O_2 and N_2 are 32 and 28 respectively.

(A) 13 °C (B) 15 °C (C) 56.4 °C (D) –21 °C

(14) Kinetic theory of gas provides support to ......

(A) Boyle's law (B) Charle's law

(C) Boyle's and Charle's law (D) None of the laws.

(15) At constant temperature, on increasing pressure of 1200 ml gas from 70 cm-Hg to 120 cm-Hg, its volume becomes ......

(A) 400 ml (B) 500 ml (C) 600 ml (D) 700 ml

Ans. :	**1 (B), 2 (C), 3 (B), 4 (C), 5 (C), 6 (B), 7 (B), 8 (C), 9 (A), 10 (C), 11 (D), 12 (C), 13 (D), 14 (C), 15 (D)**

Avogadro's hypothesis

"For given constant temperature and pressure, number of molecules per unit volume is same for all gases."

Number of molecules in 1 mole gas is $N_A = 6.023 \times 10^{23}$

Graham's law for gas expansion

"If two different gases are mixed at constant temperature and pressure, then rate of mixing is inversely proportional to square root of density of gas."

$$r \propto \frac{1}{\sqrt{\rho}} \quad \Rightarrow \rho = \text{density}$$

$$r \propto \frac{1}{\sqrt{M}} \quad \Rightarrow M = \text{Molecular mass of gas}$$

$$\therefore \frac{r_1}{r_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{M_2}{M_1}}$$

- If volume V of gas mixes in time t then

$$r = \frac{V}{t}$$

$$\frac{r_1}{r_2} = \frac{V_1}{V_2} \times \frac{t_2}{t_1}$$

Ideal Gas Equation :

$PV = \mu RT$ for μ mole gas

$PV = \left(\frac{R}{N_A}\right)T$ for 1 mole gas

$= k_B T$ $k_B = \frac{R}{N_A} = 1.38 \times 10^{-23}\ JK^{-1}$ = Boltzmann's constant

$= Nk_B T$ for N molecules

$\Rightarrow$ $PV = \left(\frac{R}{M}\right)T$ for 1 g gas

where, r = specific Gas constant

$PV = rT$

$PV = mrT$ for m g gas.

where $r = \frac{R}{M}$ = Gas constant per unit mass.

unit of $r = Jg^{-1} k^{-1}$

Van-der-waal's correction

(A) Correction in Volume : $(V - b)$ Where $b = \frac{1}{8} \frac{RT_c}{P_c}$

(B) Correction in pressure : $\left(P + \frac{a}{V^2}\right)$ Where $a = \frac{27}{64} \frac{R^2 T_c^2}{P_c}$

Here P_c = Critical pressure, T_c = Critical temperature and V_c = Critical volume

for 1 mole gas $\left(P + \frac{a}{V^2}\right)(V - b) = RT$

for μ mole gas $\left(P + \frac{\mu^2 a}{V^2}\right)(V - \mu b) = \mu RT$

(16) In equation PV = RT value of constant R at STP, is ......

(A) 2 cal K^{-1} (B) 10 cal K^{-1} (C) 0.2 cal K^{-1} (D) 200 cal K^{-1}

(17) A gas is filled in container at temperature 27 °C. To take out (release) half the mass of gas from container, up to how much temperature should the container will be heated ?

(A) 54 °C (B) 177 °C (C) 277 °C (D) 327 °C

(18) On increasing the temperature of a gas in closed container by 1°C, its pressure increases by 0.4 %. Then initial temerature of this gas would be ......

(A) 250 K (B) 250 °C (C) 2500 k (D) 2500 °C

(19) In a metallic cylindrical container, pressure of gas at 27 °C temperature is 2 atmosphere. On making its temperature 54 °C, pressure becomes ...... atmosphere.

(A) 1 (B) 2 (C) 2.18 (D) 1/2

(20) At constant pressure, 1 litre ideal gas is heated from 27 °C to 97 °C then its final volume becomes ...... litre.

(A) 1.2 (B) 1.9 (C) 19 (D) 2.4

(21) At constant temperature, how much percentage decrease in pressure of gas should be done so as to increase its volume by 10 % keeping mass constant ?

(A) 8.1 % (B) 9.1 % (C) 10.1 % (D) 11.1 %

(22) A mixture of 8 g oxygen, 14 g Nitrogen and 22 g Carbon Dioxide at 27 °C temperature is filled in a container of 4 litre. Then pressure of mixture is ...... $N m^{-2}$.

(A) 5.79×10^5 (B) 6.79×10^5 (C) 7.79×10^3 (D) 7.79×10^5

(23) A mixture of 8 g O_2 ; 14 g N_2 and 22 g CO_2 gases at 27 °C is filled in a container of 10 litre Then pressure of mixture is ...... (Take R = 0.082 units)

(A) 1.4 atm (B) 2.5 atm (C) 3.075 atm (D) 8.7 atm

(24) Two containers of equal volume are filled with same gas at pressure P_1 and P_2 and temperature T_1 and T_2. Now when both containers are joined then their common pressure and temperature becomes P and T respectively. then ratio P/T ......

(A) $\frac{P_1T_2 + P_2T_1}{T_1\,T_2}$ (B) $\frac{P_1T_2 + P_2T_1}{T_1 + T_2}$ (C) $\frac{P_1T_2 + P_2T_1}{2\,T_1\,T_2}$ (D) $\frac{P_1T_2 + P_2T_1}{T_1 - T_2}$

(25) Main difference between ideal gas and real gas is related to .....

(A) change of state (B) temperature (C) pressure (D) mole

(26) Two different gases have pressure P, volume V and temperature T each. Now, keeping volume and temperature same, when both gases are mixed, pressure of mixture will be .....

(A) P/2 (B) P (C) 2P (D) 4P

Ans. : 16 (A), 17 (D), 18 (A), 19 (C), 20 (A), 21 (D), 22 (D), 23 (C), 24 (C), 25 (A), 26 (C)

- **Pressure of Gas :**

$PV = Nk_BT$ N = Number of molecules

$P = \frac{N}{V} k_BT$

$P = nk_BT$ Where $n = \frac{N}{V}$ = Number of molecule in unit volume.

- $PV = \mu RT$

$PV = \frac{M}{M_0} RT$ $\mu = \frac{M}{M_0} = \frac{\text{Mass of gas}}{\text{Molecular mass of gas}}$

$P = \frac{M}{V}\frac{R}{M_0} T$

$P = \frac{\rho RT}{M_0}$ where $\rho = \frac{M}{V}$ = Density of gas

- $P = \frac{1}{3} \rho \langle v^2 \rangle$ where $\langle v^2 \rangle = v_x^2 + v_y^2 + v_z^2$

$\langle v^2 \rangle = \langle v_x^2 \rangle + \langle v_x^2 \rangle + \langle v_x^2 \rangle$

$v_{rms} = \sqrt{\frac{3P}{\rho}}$ $\langle v^2 \rangle = 3\langle v_x^2 \rangle$

Where $\sqrt{\langle v^2 \rangle} = v_{rms}$

$= \sqrt{\frac{3k_BT}{m}}$ where m = mass of one molecule.

$= \sqrt{\frac{3RT}{M_0}}$ where M_0 = molecular mass

- Internal energy $E_{int} = \frac{f}{2} \mu RT$

Here f = Degrees of freedom

Monoatomic gas (He, Ne, Ar,...) $f = 3$

Diatomic gas (H_2, O_2, N_2,...) $f = 5$ (Rigid rotator)

CO_2 $f = 7$

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(27) At a given temperature, pressure of an ideal gas is proportional to ...... (Here ρ = density of gas)

(A) $\frac{1}{\rho}$ (B) $\frac{1}{\rho^2}$ (C) ρ (D) ρ^2

(28) Average kinetic energy of an ideal gas per mole is ......

(A) $\frac{1}{2}k_BT$ (B) $\frac{1}{2}$ RT (C) $\frac{3}{2}$ k_BT (D) $\frac{3}{2}$ RT

(29) At what temperature rms speed of O_2 molecule will be equal to that of H_2 molecule at 1000 K ?

(A) 160 K (B) 16 K (C) 1600 K (D) 16000 K

(30) For H_2 molecule at 300 K, $v_{rms} = 1000\ m\ s^{-1}$ then v_{rms} for O_2 molecule at 1200 K = ...

(A) 500 m s^{-1} (B) 50 m s^{-1} (C) 5000 m s^{-1} (D) 5 m s^{-1}

(31) Which of the following equation is incorrect ?

(A) $v_{rms} = \frac{3_P}{\rho}$ (B) $v_{rms} = \sqrt{\frac{3RT}{M_0}}$ (C) $v_{rms} = \sqrt{\frac{3P}{\rho}}$ (D) $v_{rms} = \sqrt{\frac{3k_BT}{m}}$

(32) Cl_2 gas is filled in a closed container. If pressure of the gas is doubled and temperature is made four times then how much times will its density become ?

(A) 2 (B) $\frac{1}{2}$ (C) 4 (D) $\frac{1}{4}$

(33) v_{rms} speed of dust particles having mass 1.38×10^{-10} kg at NTP is = ...

(A) $9.49 \times 10^{-9}\ cms^{-1}$ (B) $9.49 \times 10^{-9}\ ms^{-1}$ (C) $9.49 \times 10^{-6}\ cms^{-1}$ (D) $9.49 \times 10^{-6}\ ms^{-1}$

(34) Mean kinetic energy of a gas molecule at 127 °C temperature is 6.21×10^{-21} J. Then its kinetic energy at temperature 327 °C is ......

(A) 9.315×10^{-21} J (B) 9.315×10^{21} J (C) 9.315×10^{-23} J (D) $9.315 \times 10^{+23}$ J

(35) For Oxygen gas filled in a container, mass is 5 g, pressure is P, absolute temperature is T and volume V. Equation of state for this ideal gas would be ......

(A) PV = $\frac{5}{32}$ RT (B) PV = 5RT (C) PV = $\frac{5}{2}$ RT (D) PV = $\left(\frac{5}{16}\right)$ RT

(36) Kinetic energy of CO_2 molecule at 500 K temperature is E, then kinetic energy of CO molecule at same temperature is ....

(A) $\frac{E}{32}$ (B) 32 E (C) 16 E (D) E

(37) At a given temperature, ratio of rms speeds of molecules of H_2 and He is ......

(A) $1 : \sqrt{2}$ (B) $\sqrt{2} : 1$ (C) 1 : 2 (D) 2 : 1

(38) For 1 mole He gas, C_v = ...

(A) $\frac{3}{2}$ R (B) $\frac{7}{2}$ R (C) $\frac{1}{2}$R (D) $\frac{5}{2}$R

(39) If mole number of an ideal gas is μ and its degrees of freedom is f, then its internal energy is ......

(A) $f \mu k_B T$ (B) $\frac{f}{2}\mu k_B T$ (C) $\frac{f}{2}\mu RT$ (D) $\frac{3}{2} f\mu RT$

(40) For 1 mole Ar gas at constant pressure, molar specific heat is ......

(A) $C_v = \frac{5}{2} R$ (B) $C_P = \frac{5}{2} R$ (C) $C_v = \frac{3}{2} R$ (D) $C_P = \frac{3}{2} R$

(41) For 1 mole gas, $\frac{R}{C_v} = 0.672$ then molecules of this gas will be ......

(A) diatomic (B) triatomic (C) monoatomic (D) polyatomic

(42) If absolute temperature of a gas is made nine times, rms speed of its molecules become .... time.

(A) $\sqrt{3}$ (B) $\frac{1}{\sqrt{3}}$ (C) 3 (D) $\frac{1}{3}$

(43) Mean free path in gases is of the order of ......

(A) 1A° (B) 10 A° (C) 10^{+3} A° (D) 10^{-3} A°

(44) Length of straight path of molecules between two consecutive collisions is called ......

(A) free path (B) janpath (C) mean free path (D) Degrees of freedom

(45) If ratio of vapour density of two gases is $\frac{1}{64}$ then at constant pressure, ratio of their rms speed is ......

(A) 1 : 8 (B) 8 : 1 (C) 1 : $\sqrt{8}$ (D) $\sqrt{8}$: 1

(46) At normal temperature and pressure, number of molecule of O_2 gas per cubic meter is 2.5×10^{25}. Then mean free path of O_2 molecule is ...... (d = 3.4 A°)

(A) 8.7×10^{-8} cm (B) $8.7 \times 10^{+8}$ cm (C) 7.8×10^{-8} m (D) $7.8 \times 10^{+8}$ m

(47) Diameter of molecule of Ar gas is 3.56×10^{-10} m. Mean free path of this molecule at 27 °C temperature and 1 atm pressure is ......

(A) 7.3×10^{-6} m (B) $7.3 \times 10^{+8}$ cm (C) 7.3 A° (D) 7.3×10^{-8} m

(48) If mean free path of molecules of H_2 gas at temperature T and pressure P is d, then mean free path of molecules of H_2 gas at temperature 4T and pressure $\frac{P}{4}$ will be ......

(A) 16 d (B) $\frac{1}{16}$ d (C) 1.6 d (D) $\frac{1}{1.6}$ d

(49) Degreees of freedom of molecules of CO_2 gas is ......

(A) 3 (B) 5 (C) 7 (D) 9

(50) If for a given gas $\gamma = \frac{7}{5}$, then this gas would be ......

(A) Ne (B) Ar (C) He (D) H_2

Assertion - Reason type Question :

Instruction : Read assertion and reason carefully, select proper option from given below.

(a) Both assertion and reason are true and reason explains the assertion.

(b) Both assertion and reason are true but reason does not explain the assertion.

(c) Assertion is true but reason is false.

(d) Assertion is false and reason is true.

(51) **Assertion** : When temperature of gas is increased from 27 °C to 927 °C, rms speed of its molecules becomes four times.

Reason : $v_{rms} \propto \sqrt{T}$

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

(52) **Assertion** : Molecules of monoatomic gas (He) performs both liner motion and vibrational motion f = 3

Reason : For He gas f = 5,

For linear motion f = 3

For vibrational motion f = 2

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

(53) **Assertion** : For ideal gas (Ar), PV = constant according to Boyle's law.

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

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

(54) **Assertion** : At constant temperature, rms speed of molecules does not change with change in volume of gas.

Reason : rms speed of molecules does not depends on volume of gas.

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

(55) **Assertion** : Energy E of gas at 0 K temperature is zero.

Reason : At 0 K temperature, energy of molecules of gas is zero.

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

(56) **Assertion** : Mean free path $\bar{l}$ of gas molecules is inversely proportional to density of gas.

Reason : Mean free path is inversely proportional to pressure of gas.

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

(57) **Assertion** : Three molecules have speed 1 v, 2 v and 3 v Their v_{rms} speed is 2 v.

Reason : $v_{rms} = \sqrt{v^2}$

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

Match the columns :

(58) In column 1 and column 2, gas laws and related quantites are given. Match them appropriatly.

	Column-1 (Gas laws)		Column-2 (Quantities)
(i)	Boyle's law	P	Pressure = Constant
(ii)	Charle's law	Q	Volume = Constant
(iii)	Gaylussac's law	R	Temperature = Constant
(iv)	Equation of state	S	Quantity of gas = Constant.

(A) (i) → S (ii) → Q (iii) → P (iv) → R

(B) (i) → Q (ii) → R (iii) → R (iv) → P

(C) (i) → R (ii) → P (iii) → Q (iv) → S

(D) (i) → P (ii) → S (iii) → S (iv) → Q

(59) Match the following appropriately

	Column-1		Column-2
(i)	v_{rms} of gas	P	$\frac{1}{2}k_BT$
(ii)	Energy related to each degrees of freedom	Q	5
(iii)	Kinetic energy per mole	R	$\sqrt{\frac{3P}{\rho}}$
(iv)	Degrees of freedom of O_2 molecule	S	$\frac{3}{2}RT$

(A) (i) → R (ii) → P (iii) → S (iv) → Q

(B) (i) → P (ii) → Q (iii) → R (iv) → S

(C) (i) → Q (ii) → R (iii) → P (iv) → S

(D) (i) → S (ii) → P (iii) → Q (iv) → R

Ans. : 27 (C), 28 (D), 29 (D), 30 (A), 31 (A), 32 (B), 33 (D), 34 (A), 35 (A), 36 (D), 37 (B), 38 (A), 39 (C), 40 (B), 41 (C), 42 (C), 43 (C), 44 (A), 45 (B), 46 (C), 47 (D), 48 (A), 49 (C), 50 (D), 51 (D), 52 (D), 53 (B), 54 (C), 55 (D), 56 (A), 57 (D), 58 (C), 59 (A)

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