BYJU'S EXAM PREP

Important Questions On Gaseous State

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Important Questions on Gaseous State

1. Determine the pressure at which the mean free path of argon (g) at 25°C becomes comparable to the size of a 1.0 litre vessel that contains it? Assume that $\sigma = 0.36\ nm^2$.

A. 6.1×10^{-4} Torr

B. 4.8×10^{-4} Torr

C. 6.1×10^{-3} Torr

D. 4.8×10^{-3} Torr

2. It is given that the speed of sound in a gas is $c_s = (\gamma RT/M)^{1/2}$ where $\gamma = C_p/C_v$. Calculate the speed of sound in helium at room temperature.

A. 2.45 km/s

B. 3.02 km/s

C. 1.02 km/s

D. None of the above

3. Determine the atmospheric pressure at Shimla whose height above the sea level is 2250 m if the pressure at the ground level is 1 atm and temperature is 25°C if there exist no complications such as turbulence or temperature gradients ($M = 29\ g\ mol^{-1}$).

A. 0.7725 atm

B. 0.8975 atm

C. 0.6754 atm

D. 0.7943 atm

4. Calculate the pressure exerted by one mole of carbon dioxide gas in a $1.32\ dm^3$ vessel at 48°C using the van der Waals equation. The van der Waals constants are $a=3.59\ dm^6\ atm\ mol^{-2}$ and $b=0.0427\ dm^3\ mol^{-1}$.

A. 20.03 atm

B. 12.95 atm

C. 18.56 atm

D. 22.56 atm

5. Determine the Boyle temperature T_B for CO_2 gas, assuming it to be a van der Waals gas. The van der Waals constants are $a=3.59\ dm^6\ atm\ mol^{-2}$ and $b=0.0427\ dm^3\ mol^{-1}$.

A. 2032 K

B. 1026 K

C. 1256 K

D. 2445 K

6. Determine the critical temperature of a van der Waals gas for which P_c is 100 atm and b is $50\ cm^3\ mol^{-1}$.

A. 487.2 K

B. 357.4 K

C. 278.9 K

D. 254.6 K

7. Calculate the pressure exerted by one mole of CO_2 gas at 40°C, confined to a volume of 0.107 dm^3, using the law of corresponding states, given that the critical constant of the gas $V_{m,c}$ = 0.0957 $dm^{3,}$ T_C = 304 K and P_C = 73.0 atm.

A. 78.23 atm

B. 81.03 atm

C. 67.23 atm

D. 54.32 atm

8. Determine the temperature at which the average velocity of oxygen equals that of hydrogen at 20 K.

A. 420 K

B. 300 K

C. 320 K

D. 500 K

9. For hydrogen gas, calculate the root mean square velocity $<c^2>^{1/2}$ at 0°C.

A. 1.84×10^3 m/s

B. 1.84×10^4 m/s

C. 3.84×10^3 m/s

D. 3.84×10^4 m/s

10. Calculate the average translational kinetic energy of an ideal gas per molecule (ε) at 25°C.

A. 6.17×10^{-21} J per molecule

B. 6.17×10^{-23} J per molecule

C. 6.17×10^{-24} J per molecule

D. 6.17×10^{-25} J per molecule

ANSWER KEY

1. A	2. C	3. A	4. C	5. B	6. A
7. B	8. C	9. A	10. A		

SOLUTIONS

Solution 1. The formula to calculate pressure (P) is:

$$P = \frac{kT}{\sqrt{2}\sigma\lambda}$$

Now,

$\lambda \approx (1000\ cm^3)^{1/3} = 10\ cm = 0.10\ m$

$$\therefore\ P = \frac{(1.38\times10^{-23}\,JK^{-1})(298K)}{\sqrt{2}(0.36\times10^{-18}m^2)(0.10m)} = 0.081\ N\ m^{-2} = 0.081\ Pa$$

$$= \frac{0.081\ Pa}{1.01325\times10^5\ Pa/atm} = 8.0\times10^{-7}\ atm = 6.1\times10^{-4}\ Torr\ (1\ atm = 760\ Torr)$$

Solution 2. For helium,

$\gamma = C_p/C_v = 5/3$ and $M = 4.0\ g\ mol^{-1} = 4.0\times10^{-3}\ kg\ mol^{-1}$

$$\therefore\ c_s = \left[\frac{\gamma RT}{M}\right]^{1/2} = \left\{\frac{5\times(8.314\,JK^{-1}mol^{-1})(298K)}{3\times4.0\times10^{-3}kg\,mol^{-1}}\right\}^{1/2}$$

$= (1.03\times10^6\ s^{-2})^{1/2} =$ **$1.02\ km\ s^{-1}$** $[\because J = kg\ m^2\ s^{-1}]$

Solution 3. The barometric formula is:

$$\ln\frac{P_0}{P} = \frac{Mgx}{RT}$$

Substituting the given values in above equation as:

$$\therefore\ \log\left(\frac{l}{P}\right) = \frac{(29\times10^{-3}kgmol^{-1})(9.81ms^{-2})(2250m)}{2.303\times(8.314JK^{-1}mol^{-1})(298K)} = 0.1121\ \ (J = kg\ m^2\ s^{-2})$$

$\log P = -0.1121 = \bar{1}.8879$

On solving,

$P = 0.7725\ atm$

Solution 4. For a van der Waals gas, the expression is:

$$P = \frac{nRT}{V-nb} - \frac{n^2a}{V^2}$$

$$= \frac{(1mol)(0.08206\,dm^3dm^3atm\,K^{-1}mol^{-1})(321K)}{(1.32\,dm^3)-(1mol)(0.0427\,dm^3\,mol^{-1})} - \frac{(1mol)^2(3.59\,dm^6\,atm\,mol^{-2})}{(1.32\ dm^3)^2}$$

$= 20.62\ atm - 2.06\ atm = 18.56\ atm$

Solution 5. The formula to calculate Boyle temperature is:

$$T_B = \frac{a}{bR} = \frac{3.59\,dm^6 atm\,mol^{-2}}{\left(0.0427\ dm^3\,mol^{-1}\right)\left(0.08206\,dm^3 atm\,K^{-1} mol^{-1}\right)} = 1026K$$

Solution 6. The expression to calculate P_c in terms of a and b is:

$a = P_c\,27\,b^2$

Also,

$$T_c = \frac{8a}{27\ Rb} = \frac{(8)\left(P_c 27 b^2\right)}{27\ Rb} = \frac{8P_c b}{R} = \frac{(8)(100\ atm)\left(0.050\ dm^2 mol^{-1}\right)}{0.08206\ dm^3\ atm\ K^{-1}\,mol^{-1}} = 487.2\ K$$

Solution 7. $P_r = \frac{8T_r}{3V_r - 1} - \frac{3}{V_r^2} = \frac{8(T/T_C)}{3(V_m/V_{m,c}) - 1} - \frac{3}{\left(V_m/V_{m,c}\right)^2}$

$$= \frac{8(313/304)}{3(0.107/0.0957) - 1} - \frac{3}{(0.107/0.0957)^2}$$

$$= \frac{(8)(1.03)}{3\times1.18 - 1} - \frac{3}{(1.1)^2} = 3.51 - 2.40 = 1.11$$

$$P = P_r P_C = 1.11 \times 73.0\ atm = 81.03\ atm$$

Solution 8. The expression to calculate average velocity is:

$\langle c\rangle = (8RT/\pi M)^{1/2}$, i.e., $\langle c\rangle \propto (T/M)^{1/2}$

Let $\langle c\rangle_1$ and $\langle c\rangle_2$ be the average velocities of O_2 and H_2, respectively.

$$\frac{\langle c\rangle_1}{\langle c\rangle_2} = \left(\frac{T_1/M_1}{T_2/M_2}\right)^{1/2} = 1 \text{ so that } T_1/M_1 = T_2/M_2$$

$T_1/32\ g\ mol^{-1} = T_2/2\ g\ mol^{-1}$

$\therefore T_1 = (32/2)T_2 = 16 \times 20\ K = 320\ K$

Solution 9. The molar mass M of H_2 = 2.016 g mol^{-1} = 2.016 × 10^{-3} kg mol^{-1}

The formula to calculate root mean square velocity is:

$$\langle c^2\rangle^{1/2} = \left(\frac{3RT}{M}\right)^{1/2} = \left(\frac{(3)(8.314\,JK^{-1}mol^{-1})(273.15K)}{2.016\times10^{-3}kgmol^{-1}}\right)^{1/2}$$

$\langle c\rangle^{1/2} = 1.84 \times 10^3\ m\ s^{-1}$

Solution 10. The formula to calculate average translational kinetic energy is:

$\varepsilon = \frac{3}{2}$ kT = 3/2 (1.38 × 10^{-23} J K^{-1}) (298 K) = 6.17× 10^{-21} J per molecule