Chapter 18 In-Class Solutions

Ex. 3

A cylindrical tank has a tight-fitting piston . . . .

$V_i = 0.110\ m^3$ $\quad P_i = 0.355$ atm

$V_f = 0.390\ m^3$ $\quad P_f = ?$ $\qquad PV = nRT$

$P_i V_i = P_f V_f = \underbrace{nRT}_{\text{constant}}$ $\qquad P_f = P_i \dfrac{V_i}{V_f} = 0.355\text{ atm}\left(\dfrac{0.110\ m^3}{0.390\ m^3}\right)$

$\boxed{P_f = 0.1001\text{ atm.}}$ Constant temperature

Ex. 9

A large cylindrical tank contains $0.750\ m^3$ of N_2 gas at 27 °C and 7.50×10^3 Pa (absolute pressure).

$P_i = 7.50 \times 10^3$ Pa $\quad V_i = 0.750\ m^3$ $\quad T_i = 27\ °C$

$P_f = ?$ $\quad V_f = 0.410\ m^3$ $\quad T_f = 157\ °C$

$\dfrac{P_1 V_1}{T_1} = \dfrac{P_2 V_2}{T_2} = \underbrace{nR}_{\text{constant}}$ $\qquad P_f = P_2 = P_1\left(\dfrac{V_1}{V_2}\right)\left(\dfrac{T_2}{T_1}\right)$

$P_f = 7.50 \times 10^3\text{ Pa}\left(\dfrac{0.750}{0.410}\right)\left(\dfrac{157+273}{27+273}\right) = \boxed{1.97 \times 10^4\text{ Pa}}$

Ex. 23

How close together are gas molecules? Consider an ideal gas at 27 °C and 1.00 atm.

a.) $PV = nRT = \dfrac{N}{N_A} RT$ $\qquad \dfrac{V}{N}$ = volume per molecule $= \dfrac{RT}{P N_A}$

$\dfrac{V}{N} = \dfrac{\left(8.31 \frac{J}{mol \cdot K}\right) 300\text{ K}}{1.013 \times 10^5\text{ Pa}\left(6.022 \times 10^{23} \frac{\text{molecules}}{\text{mole}}\right)} = 4.0867 \times 10^{-26}\ \dfrac{m^3}{\text{molecule}}$

a = the length of the side of a cube $= \sqrt[3]{V/N} = \boxed{3.44\text{ nm}}$

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b.) How does "a" compare with the diameter of a typical molecule?

d = diameter ~0.3 nm

$\Rightarrow$ d is approximately $\frac{1}{10}$ a

c.) Once again the spacing of atoms in a solid (~0.3 nm) is approximately $\frac{1}{10}$ a.

Ex. 29

A deuteron ^2_1H is the nucleus of a hydrogen isotope and consists of one proton and one neutron.

a.) $T = 300\times10^6$ K $V_{rms} = ?$ $V_{rms} = \sqrt{\frac{3k_BT}{m}}$

m = mass of ^2_1H conversion

$$m = 2\text{ amu}\left(\frac{1.6605\times10^{-27}\text{ kg}}{1\text{ amu}}\right) = 3.32\times10^{-27}\text{ kg}$$

$$V = \sqrt{\frac{3(1.38\times10^{-23}\text{ J/K})(3\times10^8\text{ K})}{3.32\times10^{-27}\text{ kg}}} = \boxed{1.93\times10^6\text{ m/s}}$$

$$\frac{V_{rms}}{c} = \frac{1.93\times10^6\text{ m/s}}{3.00\times10^8\text{ m/s}} = 0.0064 \text{ or } \boxed{0.64\%}$$ ... still relatively small

b.) T = ? if $V_{rms} = 0.1c$ $V_{rms}^2 = \frac{3k_BT}{m}$

$$T = \frac{mV_{rms}^2}{3k_B} = \frac{(3.32\times10^{-27}\text{ kg})(3.00\times10^7\text{ m/s})^2}{3(1.38\times10^{-23}\text{ J/K})} = \boxed{7.22\times10^{10}\text{ K}}$$

Ex. 36

A rigid container hold 4.00 moles of a monatomic ideal gas at 300 K. $Q = 6{,}000$ J $Q = nC_V\Delta T$ $C_V = \frac{3}{2}R$ (monatomic)

$$\Delta T = \frac{Q}{nC_v} = \frac{6{,}000\text{ J}}{4.00\text{ mol}\ \frac{3}{2}(8.31\text{ J/mol}\cdot\text{K})}$$ $\Delta T = 120.3\ C^\circ$

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Ex.36 cont'd

$T_i = 300\ K$ $P_i = 6.00 \times 10^4\ Pa$

$T_f = 420\ K$ $P_f = ??$ $PV = nRT$

a constant

$$\frac{P_i}{T_i} = \frac{P_f}{T_f} = \left(\frac{nR}{V}\right) \qquad P_f = P_i\left(\frac{T_f}{T_i}\right) = 6.00 \times 10^4\ Pa\left(\frac{420}{300}\right)$$

$$\boxed{P_f = 8.40 \times 10^4\ Pa}$$

Ex, 41

For polyatomic carbon dioxide gas (CO_2, $M = 44\ g/mol$) at $T = 300\ K$ ...

$k_B = R/N_A$ $N_A m = M$

a.) $$V_{mp} = \sqrt{\frac{2k_BT}{m}} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2(8.31)300}{44 \times 10^{-3}\ kg/mol}}$$

$$\boxed{V_{mp} = 337\ m/s}$$

b.) $$V_{Av} = \sqrt{\frac{8k_BT}{\pi m}} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8(8.31\ J/mol \cdot K)300\ K}{\pi(44 \times 10^{-3}\ kg/mol)}}$$

$$\boxed{V_{Av} = 380\ m/s}$$

c.) $$V_{rms} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3(8.31\ J/mol \cdot K)\ 300\ K}{44 \times 10^{-3}\ kg/mol}}$$

$$\boxed{V_{rms} = 412\ m/s}$$