Contents

1 Chapter 18 - Thermal Properties of Matter **1**
- 1.1 The Ideal Gas Law . . . 1
  - 1.1.1 Question . . . 1
  - 1.1.2 18.3 . . . 2
  - 1.1.3 18.4 . . . 2
  - 1.1.4 18.7 . . . 3
  - 1.1.5 18.13 . . . 3
  - 1.1.6 18.16 . . . 3
  - 1.1.7 18.18 . . . 4
  - 1.1.8 Question . . . 5

1 Chapter 18 - Thermal Properties of Matter

Avogadro's number

$$N_A = 6.02 \times 10^{23}\,\mathrm{mol} \tag{1}$$

1.1 The Ideal Gas Law

Ideal gas: a collection of atoms or molecules that move randomly and exert no long-range forces on each other.

Number of moles

$$n = \frac{N}{N_A} = \frac{m_{particle}N}{m_{particle}N_A} = \frac{m}{M} \tag{2}$$

The **molar mass** M **(molecular weight)** is the mass per mole. The total mass of n moles is $m_{total} = nM$.

Ideal-gas equation

$$pV = nRT \tag{3}$$

Universal gas constant

$$R = 8.31\,\mathrm{J\,mol^{-1}\,K^{-1}} = 0.0821\,\mathrm{L\,atm\,mol^{-1}\,K^{-1}} \tag{4}$$

The volume occupied by 1 mol of any ideal gas at atmospheric pressure and at 0 °C is 22.4 L.

1.1.1 Question

$$\begin{aligned} V &= 22.4 \times 10^{-3}\,\mathrm{L} \\ T &= 273.15\,\mathrm{K} \\ p &= 1.013 \times 10^{5}\,\mathrm{Pa} = 1.0\,\mathrm{atm} \\ n &= ? \end{aligned}$$

$$\begin{aligned}
pV &= nRT \\
n &= \frac{pV}{RT} \\
n &= \frac{(1.0\ \text{atm})(22.4\,\text{L})}{(0.0821\,\text{L}\,\text{atm}\,\text{mol}^{-1}\,\text{K}^{-1})(273.15\,\text{K})} \\
n &= 1.000\,\text{mol}
\end{aligned}$$

1.1.2 18.3

$$\begin{aligned}
V_0 &= 0.110\,\text{m}^3 \\
p_0 &= 0.355\,\text{atm} \\
V_1 &= 0.390\,\text{m}^3 \\
T &= \text{constant} \\
p_1 &= ?
\end{aligned}$$

$$\begin{aligned}
p_0V_0 &= p_1V_1 \\
p_1 &= \frac{p_0V_0}{V_1} \\
p_1 &= \frac{(0.355\,\text{atm})(0.110\,\text{m}^3)}{0.390\,\text{m}^3} \\
p_1 &= 0.1001\,\text{atm}
\end{aligned}$$

1.1.3 18.4

$$\begin{aligned}
V_0 &= 3.00\,\text{L} \\
p_0 &= 3.00\,\text{atm} \\
T_0 &= 20.0\,^\circ\text{C} = 293\,\text{K} \\
p_1 &= 1.00\,\text{atm}
\end{aligned}$$

(a)

$$\begin{aligned}
pV &= nRT \\
\frac{p}{T} &= \frac{nR}{V} \\
\frac{p_0}{T_0} &= \frac{p_1}{T_1} \\
T_1 &= \frac{p_1T_0}{p_0} \\
T_1 &= \frac{(1.00\,\text{atm})(293\,\text{K})}{3.00\,\text{atm}} \\
T_1 &= 97.7\,\text{K} = -175.3\,^\circ\text{C}
\end{aligned}$$

1.1.4 18.7

$$
\begin{aligned}
V_0 &= 499\,\mathrm{cm}^3 = 499 \times 10^{-6}\,\mathrm{m}^3 \\
p_0 &= 1.01 \times 10^5\,\mathrm{Pa} \\
T_0 &= 27.0\,^\circ\mathrm{C} = 300\,\mathrm{K} \\
V_1 &= 46.2\,\mathrm{cm}^3 = 46.2 \times 10^{-6}\,\mathrm{m}^3 \\
p_1 &= 2.72 \times 10^6\,\mathrm{Pa} + 1\,\mathrm{atm} = 2.821 \times 10^6\,\mathrm{Pa} \\
T_1 &= ?
\end{aligned}
$$

$$
\begin{aligned}
pV &= nR\Delta T \\
\frac{p_0V_0}{T_0} &= \frac{p_1V_1}{T_1} \\
T_1 &= \frac{T_0p_1V_1}{p_0V_0} \\
T_1 &= \frac{(300\,\mathrm{K})(2.821 \times 10^6\,\mathrm{Pa})(46.2 \times 10^{-6}\,\mathrm{m}^3)}{(1.01 \times 10^5\,\mathrm{Pa})(499 \times 10^{-6}\,\mathrm{m}^3)} \\
T_1 &= 755.79\,\mathrm{K}
\end{aligned}
$$

1.1.5 18.13

$$
\begin{aligned}
p_0 &= 1\,\mathrm{atm} V_0 && = V_{earth} \\
V_1 &= V_{venus} \\
T_1 &= 1003\,^\circ\mathrm{C} = 1276\,\mathrm{K} \\
p_1 &= 92\,\mathrm{atm} \\
T_0 &= 273\,\mathrm{K}
\end{aligned}
$$

$$
\begin{aligned}
pV &= nR\Delta T \\
\frac{p_0V_0}{T_0} &= \frac{p_1V_1}{T_1} \\
V_1 &= \frac{T_1p_0}{T_0p_1}V_0 \\
V_1 &= \frac{(1276\,\mathrm{K})(1\,\mathrm{atm})}{(273\,\mathrm{K})(92\,\mathrm{atm}} \\
V_1 &= (0.051)V_0
\end{aligned}
$$

1.1.6 18.16

$$
\begin{aligned}
n &= 3\,\mathrm{mol} \\
l &= 0.300\,\mathrm{m}
\end{aligned}
$$

(a)

$$T = 20.0\,^\circ\mathrm{C} = 293\,\mathrm{K}$$

$$\begin{aligned}
F &= pA \\
F &= \frac{nRTA}{V} \\
F &= \frac{(3\,\mathrm{mol})(8.31\,\mathrm{J\,mol^{-1}\,K^{-1}})(293\,\mathrm{K})(0.300\,\mathrm{m})^2}{(0.300\,\mathrm{m})^3} \\
F &= 24\,348.3\,\mathrm{N} = 2.43 \times 10^4\,\mathrm{N}
\end{aligned}$$

(b)

$$T = 100.0\,^\circ\mathrm{C} = 373\,\mathrm{K}$$

$$\begin{aligned}
F &= \frac{nRTA}{V} \\
F &= \frac{(3\,\mathrm{mol})(8.31\,\mathrm{J\,mol^{-1}\,K^{-1}})(373\,\mathrm{K})(0.300\,\mathrm{m})^2}{(0.300\,\mathrm{m})^3} \\
F &= 30\,996.3\,\mathrm{N} = 3.10 \times 10^4\,\mathrm{N}
\end{aligned}$$

1.1.7 18.18

$$\begin{aligned}
\Delta y &= 11\,000\,\mathrm{m} \\
T &= -56.5\,^\circ\mathrm{C} = 216.5\,\mathrm{K} \\
\rho &= 0.364\,\mathrm{kg\,m^{-3}} \\
p &= ?
\end{aligned}$$

$$\begin{aligned}
\rho &= \frac{m}{V} \\
m &= \rho V \\
n &= \frac{m}{M} \\
n &= \frac{\rho V}{M}
\end{aligned}$$

$$\begin{aligned}
pV &= nRT \\
pV &= \left(\frac{\rho V}{M}\right) RT \\
p &= \frac{\rho RT}{M} \\
p &= \frac{(0.364\,\mathrm{kg\,m^{-3}})(8.314\,\mathrm{J\,mol^{-1}\,K^{-1}})(216.5\,\mathrm{K})}{28.8 \times 10^{-3}\,\mathrm{kg\,mol^{-1}}} \\
p &= 22\,749.8\,\mathrm{Pa} = 2.27 \times 10^4\,\mathrm{Pa}
\end{aligned}$$

1.1.8 Question

$$T = 0.00\,^{\circ}\mathrm{C} = 273\,\mathrm{K}$$
$$g = 9.80\,\mathrm{m\,s^{-2}}$$

$$\begin{aligned}
\frac{dp}{dy} &= -\rho g \\
p &= \rho R T \\
\rho &= \frac{p}{RT} \\
\frac{dp}{dy} &= -\left(\frac{p}{RT}\right) g \\
\frac{dp}{dy} &= -\frac{pg}{RT} \\
p' &= -p \cdot \frac{g}{RT} \\
\mathcal{L}\left\{p'\right\} + \mathcal{L}\left\{p\right\} &= \frac{g}{RT} \\
sF(s) - f(0) + F(s) &= \frac{g}{RT} \\
F(s)(s-1) &= \frac{g}{RT} \\
F(s) &= \frac{g}{RT} \cdot \frac{1}{s-1} \\
s &= \frac{ge^{t}}{RT}
\end{aligned}$$