Chapter 19.

1. In a student experiment, a constant-volume gas thermometer is calibrated in dry ice (−78.5°C) and in boiling ethyl alcohol (78.0°C). The separate pressures are 0.900 atm and 1.635 atm. (a) What value of absolute zero in degrees Celsius does the calibration yield? What pressures would be found at (b) the freezing and (c) the boiling points of water? *Hint*: Use the linear relationship $P = A + BT$, where A and B are constants.

Ans:

Since we have a linear graph, we know that the pressure is related to the temperature as $P = A + BT_C$, where A and B are constants. To find A and B, we use the given data:

$$0.900 \text{ atm} = A + B(-78.5°\text{C}) \qquad \textbf{[1]}$$

And

$$1.635 \text{ atm} = A + B(78.0°\text{C}) \qquad \textbf{[2]}$$

Solving Equations [1] and [2] simultaneously, we find:

$$A = 1.27 \text{ atm and } B = 4.70 \times 10^{-3} \text{ atm/°C}$$

Therefore,

$$P = 1.27 \text{ atm} + (4.70 \times 10^{-3} \text{ atm/°C})T_C$$

(a) At absolute zero the gas exerts zero pressure ($P = 0$), so

$$T_C = \frac{-1.27 \text{ atm}}{4.70 \times 10^{-3} \text{ atm/°C}} = \boxed{-270°\text{C}}$$

(b) At the freezing point of water, $T_C = 0$ and

$$P = 1.27 \text{ atm} + 0 = \boxed{1.27 \text{ atm}}$$

At the boiling point of water, $TC = 100°\text{C}$, so

$$P = 1.27 \text{ atm} + (4.70 \times 10^{-3} \text{ atm/°C})(100°\text{C}) = \boxed{1.74 \text{ atm}}$$

2. A copper telephone wire has essentially no sag between poles 35.0 m apart on a winter day when the temperature is −20.0°C. How much longer is the wire on a summer day when the temperature is 35.0°C?

Ans:

The wire is 35.0 m long when $T_C = -20.0°\text{C}$.

$$\Delta L = L_i \bar{\alpha}\left(T - T_i\right)$$

Since for $\bar{\alpha} = \alpha\left(20.0°\text{C}\right) = 1.70 \times 10^{-5}\left(°\text{C}\right)^{-1}$ Cu,

$$\Delta L = (35.0 \text{ m})[1.70 \times 10^{-5} (°\text{C})^{-1}][35.0°\text{C} - (-20.0°\text{C})] = \boxed{+3.27 \text{ cm}}$$

3. A sample of lead has a mass of 20.0 kg and a density of 11.3×10^3 kg/m^3 at 0°C. (a) What is the density of lead at 90.0°C? (b) What is the mass of the sample of lead at 90.0°C?

Ans:

(a) The density of a sample of lead of mass m = 20.0 kg, volume V_0, at temperature T_0 is

$$\rho_0 = \frac{m}{V_0} = 11.3\times10^3 \text{ kg/m}^3$$

For a temperature change $\Delta T = T - T_0$, the same mass m occupies a larger volume $V = V_0 (1 + \beta\Delta T)$; therefore, the density is

$$\rho = \frac{m}{V_0(1+\beta\Delta T)} = \frac{\rho}{(1+\beta\Delta T)}$$

where $\beta = 3\alpha$, and $\alpha = 29 \times 10^{-6}$ (°C)$^{-1}$.

For a temperature change of from 0.00°C to 90.0°C,

$$\rho = \frac{\rho_0}{(1+\beta\Delta T)} = \frac{11.3\times10^3 \text{ kg/m}^3}{1+3\left(29\times10^{-6}\,(°\text{C})^{-1}\right)(90.0°\text{C})}$$

$$= \boxed{11.2\times10^3 \text{ kg/m}^3}$$

(b) The mass is still the same, $\boxed{20.0 \text{ kg}}$, because a temperature change would not change the mass.

4. A container in the shape of a cube 10.0 cm on each edge contains air (with equivalent molar mass 28.9 g/mol) at atmospheric pressure and temperature 300 K. Find (a) the mass of the gas, (b) the gravitational force exerted on it, and (c) the force it exerts on each face of the cube. (d) Why does such a small sample exert such a great force?

Ans:

(a) From $PV = nRT$, we obtain $n = \dfrac{PV}{RT}$ Then

$$m = nM = \frac{PVM}{RT}$$

$$= \frac{(1.013\times10^5 \text{ Pa})(0.100\,\text{m})^3(28.9\times10^{-3}\text{ kg/mol})}{(8.314\,\text{J/mol}\cdot\text{K})(300\,\text{K})}$$

$$= \boxed{1.17\times10^{-3}\text{ kg}}$$

(b) $F_g = mg = (1.17 \times 10^{-3}\text{ kg})(9.80 \text{ m/s}^2) = \boxed{11.5 \text{ mN}}$

(c) $F = PA = (1.013 \times 10^5 \text{ N/m}^2)(0.100 \text{ m})^2 = \boxed{1.01 \text{ kN}}$

(d) The $\boxed{\text{molecules must be moving very fast}}$ to hit the walls hard.

5. A popular brand of cola contains 6.50 g of carbon dioxide dissolved in 1.00 L of soft drink. If the evaporating carbon dioxide is trapped in a cylinder at 1.00 atm and 20.0°C, what volume does the gas occupy?

Ans:

The CO_2 is far from liquefaction, so after it comes out of solution it behaves as an ideal gas. Its molar mass is M = 12.0 g/mol + 2(16.0 g/mol) = 44.0 g/mol. The quantity of gas in the cylinder is

$$n = \frac{m_{\text{sample}}}{M} = \frac{6.50\,\text{g}}{44.0\,\text{g/mol}} = 0.148\,\text{mol}$$

Then $PV = nRT$ gives

$$\begin{aligned} V &= \frac{nRT}{P} \\ &= \frac{0.148\,\text{mol}(8.314\,\text{J/mol}\cdot\text{K})(273.15\,\text{K} + 20°\text{C})}{1.013\times10^5\ \text{N/m}^2} \\ &\qquad \times\left(\frac{1\,\text{N}\cdot\text{m}}{1\,\text{J}}\right)\left(\frac{10^3\ \text{L}}{1\,\text{m}^3}\right) \\ &= \boxed{3.55\,\text{L}} \end{aligned}$$