2.3 An ideal gas originally at 0.85 atm and 66°C was allowed to expand until its final volume, pressure, and temperature were 94 mL, 0.60 atm, and 45°C, respectively. What was its initial volume?

Because n is kept constant, the ideal gas equation $PV = nRT$ can be rewritten as

$$\frac{PV}{T} = \text{constant}$$

or

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Therefore,

$$V_1 = \frac{P_2V_2}{T_2}\frac{T_1}{P_1} = \frac{(0.60\ \text{atm})\ (94\ \text{mL})}{(273 + 45)\ \text{K}}\frac{(273 + 66)\ \text{K}}{0.85\ \text{atm}} = 71\ \text{mL}$$

2.35 A healthy adult exhales about 5.0×10^2 mL of a gaseous mixture with every breath. Calculate the number of molecules present in this volume at 37°C and 1.1 atm. List the major components of this gaseous mixture.

First calculate the number of moles of molecules, from which the number of molecules can be obtained.

$$n = \frac{PV}{RT} = \frac{(1.1\ \text{atm})\ (5.0 \times 10^2\ \text{mL})\left(\frac{1\ \text{L}}{1000\ \text{mL}}\right)}{(0.08206\ \text{L atm K}^{-1}\ \text{mol}^{-1})\ (273 + 37)\ \text{K}} = 0.0216\ \text{mol}$$

$$\text{Number of molecules} = (0.0216\ \text{mol})\left(\frac{6.022 \times 10^{23}\ \text{molecules}}{1\ \text{mol}}\right) = 1.3 \times 10^{22}\ \text{molecules}$$

The major components of exhaled air are CO_2, O_2, N_2, and H_2O.

3.3 Show that 1 L atm = 101.3 J.

The units conversion can be performed using R expressed in L atm and J, respectively.

$$R = 0.08206\ \text{L atm K}^{-1}\ \text{mol}^{-1} = 8.314\ \text{J K}^{-1}\ \text{mol}^{-1}$$

$$1\ \text{L atm} = \frac{8.314\ \text{J}}{0.08206} = 101.3\ \text{J}$$

3.17 At 373.15 K and 1 atm, the molar volume of liquid water and steam are 1.88×10^{-5} m^3 and 3.06×10^{-2} m^3, respectively. Given that the heat of vaporization of water is 40.79 kJ mol^{-1}, calculate the values of ΔH and ΔU for 1 mole in the following process:

$$H_2O(l, 373.15\ K, 1\ atm) \rightarrow H_2O(g, 373.15\ K, 1\ atm)$$

ΔH for the above process is the heat of vaporization, that is, $\Delta H = 40.79$ kJ for 1 mole of water.

It is necessary to calculate w and q before determining ΔU. Since the process occurs at constant pressure, $q = \Delta H = 40.79$ kJ when 1 mol liquid H_2O vaporizes. In the same process,

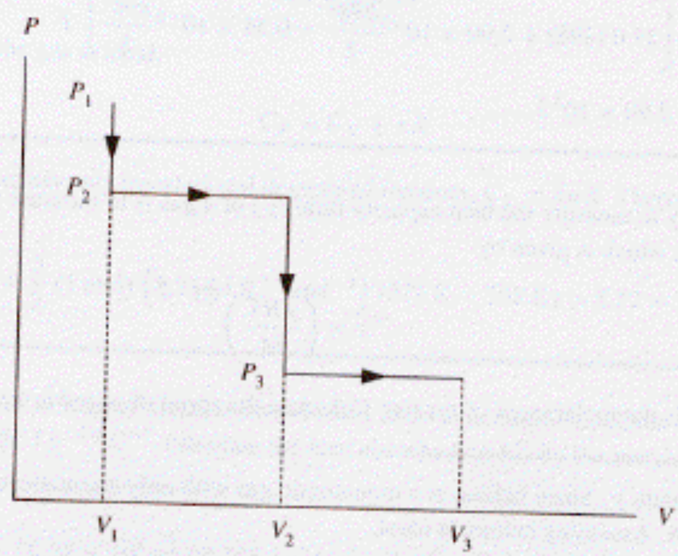
$$\begin{aligned} w &= -P_{ex}\Delta V \\ &= -(1.00\ \text{atm})\left(3.06 \times 10^{-2}\ \text{m}^3 - 1.88 \times 10^{-5}\ \text{m}^3\right)\left(\frac{1000\ \text{L}}{1\ \text{m}^3}\right)\left(\frac{101.3\ \text{J}}{1\ \text{L atm}}\right) \\ &= -3.098 \times 10^3\ \text{J} \end{aligned}$$

Note that we could have safely ignored the volume of liquid H_2O, since it is negligible compared with that of gaseous H_2O above.

Using the first law,

$$\Delta U = q + w = 40.79\ \text{kJ} - 3.098\ \text{kJ} = 37.69\ \text{kJ}$$

3.31 The following diagram represents the P–V changes of a gas. Write an expression for the total work done.



The total work done is the sum of the work done against the constant external pressure P_2 when the system expands from V_1 to V_2, and that against the constant external pressure P_3 when the system expands from V_2 to V_3:

$$w = -P_2(V_2 - V_1) - P_3(V_3 - V_2)$$