36 Dimensional analysis

Answers to additional problems

36.1 The label should be completely dimensionless and without a factor. We treat the data as an equation. For example, we start with the equation Applied pressure $p = 1 \times 10^5$ Pa. We divide both sides by the unit Pa and multiply both sides by the inverse of $\times 10^5$ which is clearly 10^{-5}. This yields 10^{-5} Applied pressure p /Pa = 1. If this statement is correct for one datum, it will be correct for a column heading.

36.2 We start with pressure p because the variable is pressure. Because the unit of pressure in this example is the bar, we write, pressure, p /bar. This way, the label is completely dimensionless.

36.3 Inserting known units, [J mol^{-1}] = [J mol^{-1}] – [K] [$\Delta S^{\ominus}$].
To be dimensionally correct, each of these three terms must be dimensionally identical. Therefore, [K] [$\Delta S^{\ominus}$] is dimensionally equivalent to [J mol^{-1}], K $\times$ $\Delta S^{\ominus}$ = J mol^{-1}. Dividing both sides by K yields, $\Delta S^{\ominus}$ = J K^{-1} mol^{-1}.

36.4 **1.** One atm $= \dfrac{101\,325}{10^5}$ bar = 1.013 2 bar (to 4 s.f.)

2. One bar $= \dfrac{10^5}{101\,325}$ atm = 0.986 9 atm (to 4 s.f.)

36.5 Current $I = dQ/dt$, where Q is charge in coulombs and t is time. Rearranging yields $dQ = I \times dt$. Inserting units, [C] = [A] [s] so a Coulomb has the compound unit, A s.

36.6 The chemist should start by defining molar mass, saying,

$$\text{mass} \div \text{amount of material}, \ m \div n$$

Inserting units, $M = \dfrac{[\text{kg}]}{[\text{mol}]}$ so molar mass has the units of kg mol^{-1}.
Chemists are permitted to deviate from the SI system of units and almost always cite a molar mass in g mol^{-1}.

36.7 The Nernst equation is, $E = E^{\ominus} + \dfrac{RT}{nF} \ln \left(\dfrac{[\text{O}]}{[\text{R}]}\right)$

Inserting units, $$[\text{V}] = [\text{V}] + \frac{[\text{J K}^{-1}\ \text{mol}^{-1}] \times [\text{K}]}{[1]\,[\text{C mol}^{-1}]} \times [1]$$

Cancelling yields, [V] = [J C^{-1}]. The definition of an Ampère A is a coulomb C per second (see the answer to Additional Problem 36.5). A coulomb has the units of A s and C^{-1} has the units A^{-1} s^{-1} or (A s)$^{-1}$.
The compound unit of the joule is kg m^2 s^{-2} (see Table 36.2). Substituting yields, [V] = [kg m^2 s^{-2}] [A^{-1} s^{-1}]. The SI units of potential are therefore [kg m^2 s^{-3} A^{-1}].

36.8 Rearranging the equation, $k_B = R \div N_A$. Inserting units, $[k_B] = \dfrac{[\text{J K}^{-1}\text{mol}^{-1}]}{[\text{mol}^{-1}]}$. Cancelling yields k_B in [J K^{-1}].

36.9 The Clapeyron equation is, $\frac{\mathrm{d}p}{\mathrm{d}T}=\frac{\Delta H}{T\,\Delta V_{\mathrm{m}}}$. The subscripted m on ΔV means molar volume so m^{-1}. Rearranging to make dp the subject yields, $\mathrm{d}p=\frac{\mathrm{d}T\,\Delta H}{T\,\Delta V_{\mathrm{m}}}$.

Inserting unit terms, $[\mathrm{d}p]=\frac{[\mathrm{K}]\ [\mathrm{J\,mol^{-1}}]}{[\mathrm{K}]\ [\mathrm{m^3\ mol^{-1}}]}$. Cancelling yields, $[\mathrm{J\,m^{-3}}]$. From Table 36.2, the SI units of the joule are, $\mathrm{kg\,m^2\,s^{-2}}$.

Substituting for J gives $[\mathrm{Pa}] = [\mathrm{kg\,m^2\,s^{-2}}]\ [\mathrm{m^{-3}}] = [\mathrm{kg\,m^{-1}\,s^{-2}}]$ which is the same as that in Table 36.2.

36.10 Inserting units, $[C_p] = \frac{[\mathrm{J\,mol^{-1}}]}{[\mathrm{K}]} = [\mathrm{J\,K^{-1}\,mol^{-1}}]$. The joule (in the SI system) is $[\mathrm{kg\,m^2\,s^{-2}}]$. Therefore, $[C_p] = [\mathrm{kg\,m^2\,s^{-2}\,K^{-1}\,mol^{-1}}]$.