Chemistry 2740 Spring 2011 Test 1 Solutions

1. **Intensive:** temperature, pressure

   Extensive: mass, number of moles, volume, internal energy, enthalpy, entropy

2. (a) mass of sample and temperature change

   (b) to obtain the calorimeter's heat capacity

   (c) the specific (or molar) internal energy change

3. Some possible examples:

   - Heat flowing spontaneously from a cold to a hot body
   - Gases unmixing
   - Water cooling to 0 °C and forming ice in a room at 20 °C (or any temperature above 0 °C) by spontaneously transferring heat from a glass of water to the room
   - Conversion of heat into work with perfect efficiency

4. (a) We first need to convert the molar entropy change to a per residue basis:

$$\begin{aligned}
\Delta S &= \frac{52\,\mathrm{J\,K^{-1}mol^{-1}}}{6.022\,142\,0 \times 10^{23}\,\mathrm{mol^{-1}}} = 8.6 \times 10^{-23}\,\mathrm{J/K} \\
&= k_B \ln \Omega_f - k_B \ln \Omega_i \\
&= k_B \ln \Omega_f - k_B \ln 1 = k_B \ln \Omega_f \\
\therefore \ln \Omega_f &= \frac{\Delta S}{k_B} = \frac{8.6 \times 10^{-23}\,\mathrm{J/K}}{1.380\,650\,3 \times 10^{-23}\,\mathrm{J/K}} = 6.3 \\
\therefore \Omega &= e^{6.3} = 520\,\text{conformations per residue}
\end{aligned}$$

   (b) $k_B \ln \Omega_i > 0$ and $k_B \ln \Omega_f = \Delta S + k_B \ln \Omega_i$, therefore we would calculate a larger number of conformations for the unfolded state.

5. (a) In one minute, the person generates

$$q = (-100\,\mathrm{J/s})(60\,\mathrm{s}) = -6000\,\mathrm{J}$$

   of heat. The oxidation reaction is

$$C_6H_{12}O_{6(aq)} + 6O_{2(aq)} \rightarrow 6CO_{2(aq)} + 6H_2O_{(l)}.$$

   The enthalpy of reaction is

$$\begin{aligned}
\Delta_r H^\circ_m &= 6\Delta_f H^\circ(\mathrm{CO_2, aq}) + 6\Delta_f H^\circ(\mathrm{H_2O, l}) - [\Delta_f H^\circ(\mathrm{C_6H_{12}O_6, aq}) + 6\Delta_f H^\circ(\mathrm{O_2, aq})] \\
&= 6(-413.26) + 6(-285.830) - [-1263.06 + 6(-12.09)]\ \mathrm{kJ/mol} \\
&= -2858.94\,\mathrm{kJ/mol} \\
\therefore n_{C_6H_{12}O_6} &= \frac{-6.00\mathrm{kJ}}{-2858.94\,\mathrm{kJ/mol}} = 0.002\,10\,\mathrm{mol}.
\end{aligned}$$

(b) $n_{O_2} = 6n_{C_6H_{12}O_6} = 0.0126\,\text{mol}$.

(c) The number of moles of gas per breath is calculated from the ideal gas law:

$$V = (0.5\,\text{L})/(1000\,\text{L/m}^3) = 5\times10^{-4}\,\text{m}^3.$$
$$n = \frac{pV}{RT} = \frac{(101\,325\,\text{Pa})(5\times10^{-4}\,\text{m}^3)}{(8.314\,472\,\text{J}\,\text{K}^{-1}\text{mol}^{-1})(293.15\,\text{K})}$$
$$= 0.0208\,\text{mol}.$$

Of this amount, 21% is oxygen, so the amount of oxygen in each breath is 4.36×10^{-3} mol. 25% of the latter amount is actually absorbed, so the amount of oxygen absorbed per breath is 1.09×10^{-3} mol/breath. To take in 0.0126 mol of oxygen in a minute, we must therefore take

$$\frac{0.0126\,\text{mol}}{1.09\times10^{-3}\,\text{mol/breath}} = 11.5\,\text{breaths per minute}.$$

(d) Work of expansion against a constant external pressure: $w = -p_{\text{ext}}\Delta V$.

Each breath expands the chest by 0.5 L, so 11.5 breaths expands the chest by a total of 5.77 L, or $5.77\times10^{-3}\,\text{m}^3$. Thus,

$$w = -(101\,325\,\text{Pa})(5.77\times10^{-3}\,\text{m}^3) = -585\,\text{J}.$$