Conversions & Constants

\( k \) (boltzmann constant) = 1.38017 x 10^{-23} J/K
Gas Constant \( R = Nk = 8.3144\text{J/K-mol} \)
Avagadro’s Number = 6.022 x 10^{23}
1 atm = 101,325 N/m^2
1 N = 1 J/m
1 J = 0.23901 cal

1. Home soda seltzer makers were popular in the Czech Republic during the early-mid 20th century, and can now be purchased from various high-end purveyors of kitchenware. To make seltzer, a heavy-duty bottle (to withstand pressure) is filled with water, leaving a little air space on top. A charger/dispensing apparatus is screwed on to make a tight seal. A metal canister containing 10 cm^3 of compressed CO\(_2\) is placed in a holder and screwed onto the charger/dispensing apparatus, piercing a metal membrane on the CO\(_2\) canister and releasing CO\(_2\) into the bottle, where approx 50cm^3 air space is available.

a. **If the process occurs adiabatically, as expansion of the gas into the new volume, what is the temperature of the gas at the end of the process?** You may consider that the air initially present in the bottle does not contribute to the final state; i.e., you may consider this adiabatic expansion of the CO\(_2\) into a new volume of 60 cm^3. The constant pressure heat capacity of CO\(_2\) at the starting temperature, room temperature (25°C) is \( C_p = 37.4\text{ J/mol-K} \). You can assume this is an ideal gas, for which the molar heat capacity \( C_v = C_p - R \).
b. Frost forms on the metal canister. What does this indicate about the assumption that the process is adiabatic? How much energy would be required to cool the canister from room temperature (25°C) to –10°C and form ~1 gm (~0.05 mols) of ice if the heat capacity of the canister (mass x Cp) is 4300 J/k and the heat of fusion of ice $\Delta H_{\text{melt}} \sim 6000$ J/mol (you can neglect the heat associated with cooling the water vapor to –10°C). How does that compare to what the enthalpy change would be for cooling CO$_2$ from room temperature to the temperature you calculated in part a, if the cooling were done at constant pressure and the total number of moles of CO$_2$ is 0.2?

2. For the time being, it is still legal to “Supersize” your meal at MacDonald’s. You order, and eat, the following SuperSize meal (data obtained from the MacDonald’s web site)

“Double Quarter Pounder® with Cheese, 770 calories  
Super Size® French Fries, 610 calories  
Chocolate Triple Thick® Shake (32 fl oz cup), 1150 calories  
Baked Apple Pie, 260 calories  
**total calories 2790**”

Through a freak accident, as soon as you finish the last morsel, you suddenly become an adiabatic system. How much does your body temperature rise if all of the calories in the meal are converted to heat? Note that what is reported as “calories” are actually kcal (i.e., the total heat generated from the meal is 2790 kcal). For the calculation, estimate your weight as 60 kg, and your average heat capacity Cp as 1.0 kcal/kg/K.
3. Consider again the text example we discussed in class of collapse of a 4-mer polymer chain in a poor solvent. In that example, a simple 2-D lattice model was used to build an expression for the free energy of the collapsed and open state, where the adjacent monomers interact with energy $U = -\varepsilon$ per monomer-monomer interaction. Free energy arguments were then used to define the temperature $T_0$ where half the chains are in the collapsed state and half in the open state.

a. Does a 6-mer chain (see figure for possible open and collapsed configurations) made of the same monomers have a higher or lower value of $T_0$? Provide convincing evidence of your answer, but you do not need to calculate the precise value of $T_0$. For these purpose, we can define a “collapsed” chain as having one or more monomer-monomer interactions. We emphasize that you do not need to provide the precise value, just convincing evidence for whether $T_0$ is higher or lower for the 6-mer chain compared to the 4-mer.

b. Can you generalize your answer for larger $N$?
4. Chymotrypsinogen, secreted by the pancreas, is the precursor to chymotrypsin, a digestive enzyme that acts in the small intestine (and is thus necessary for completion of the activity described in problem 2). At 25°C and pH 3, the enthalpy of denaturation of chymotrypsinogen is $\Delta H = 39$ kcal/mol. At body temperature (37°C), the denaturation $\Delta H = 8$ kcal/mol (also at pH 3). What is the change in heat capacity of the protein upon denaturation? You may presume that all experiments were conducted at 1 atm pressure.

5. Ice at 1 atm and 0°C has a density of 0.917 gm/cm³. Water at the same T and P has a density of 0.9998 gm/cm³. At 1 atm and 0°C, $\Delta H_{\text{melt}} = 5.9176$ kJ/mol.
   a. What is the entropy change on melting?
   b. What is $\Delta U$ during melting?