

NAME _____

BE.011/2.772
Exam 2
19 March 2004

Conversions & Constants

$$k \text{ (boltzman constant)} = 1.38017 \times 10^{-23} \text{ J/K}$$

$$\text{Gas Constant } R = Nk = 8.3144 \text{ J/K-mol}$$

$$\text{Avagadro's Number} = 6.022 \times 10^{23}$$

$$1 \text{ atm} = 101,325 \text{ N/m}^2$$

$$1 \text{ N} = 1 \text{ J/m}$$

$$1 \text{ J} = 0.23901 \text{ cal}$$

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 cm³ of compressed CO₂ is placed in a holder and screwed onto the charger/dispensing apparatus, piercing a metal membrane on the CO₂ canister and releasing CO₂ into the bottle, where approx 50cm³ 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 CO₂ into a new volume of 60 cm³. The constant pressure heat capacity of CO₂ at the starting temperature, room temperature (25C) 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 (25C) to -10C and form ~ 1 gm (~ 0.05 mols) of ice if the heat capacity of the canister (mass \times C_p) is 4300J/k and the heat of fusion of ice $\Delta H_{\text{melt}} \sim 6000\text{ J/mol}$ (you can neglect the heat associated with cooling the water vapor to -10C). 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 C_p 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 $U = -\epsilon$ 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.
- 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.
 - Can you generalize your answer for larger N ?



