Chemistry 2720 Fall 2003 Test 1

Aids allowed: Calculator, one $8\frac{1}{2} \times 11$-inch sheet of notes

Time: 75 minutes

Total marks: 50

Useful data is given at the end of this paper.

1. The entropy of money: Suppose that someone tells you that he has a total of 10¢ in his pocket. There are a few different combinations of coins which could add up to 10¢. If we think of these different possibilities as microstates, we can calculate an entropy.

   (a) What is the entropy of 10¢? Give your answer in terms of k_B. [4 marks]

   (b) Explain what the entropy calculated in question 1a measures. [3 marks]

   (c) If you were told that one of the coins was a 5¢ piece, would the entropy increase or decrease? Why? [3 marks]

2. Prove, by a calculation based on thermodynamic principles, that a glass of water initially at 20°C with a heat capacity of 1200 J/K in a room at 20°C cannot spontaneously extract heat from the room and warm itself to 50°C. [10 marks]

3. Suppose that you pick up a bottle of water at the supermarket on a hot day where the ambient temperature is 32°C. By the time you get home, you would like to have a drink, but the water has reached ambient temperature. You pour 325 g of water into a large plastic cup with a negligible heat capacity. The ice in your freezer is at a temperature of −5°C. How much ice should you add if you want the temperature to equilibrate at 4°C? [8 marks]

4. (a) Sodium oxide ($Na_2O_{(s)}$, molar mass 61.98 g/mol) reacts with water forming sodium and hydroxide ions. Suppose that 1.3241 g of sodium oxide is reacted with 250 g of water initially at 75°C in an adiabatic enclosure at constant pressure. Describe the final state of the system. The standard enthalpy of formation of sodium oxide is $-417.98\,\mathrm{kJ/mol}$. [10 marks]

   Notes: Assume that the reaction occurs at sea level (i.e. that the atmospheric pressure is 1 atm) and neglect the variation of enthalpy with temperature in this question.

   (b) Other than the points included in the note above, name one approximation about the thermodynamics of this process made in your calculation. [2 marks]

5. The isothermal equation of state for liquid benzene at 25°C is

$$\left(\frac{\bar{V}_0}{V}\right)^a = c + bP,$$

where $\bar{V}_0 = 8.913 \times 10^{-5}\,\mathrm{m^3/mol}$ is the molar volume of benzene at 1 atm, $a = 9.269$, $b = 8.963 \times 10^{-9}\,\mathrm{Pa^{-1}}$, and $c = 0.9991$. How much work would be done (per mole) in an isothermal, reversible compression of benzene starting at 1 atm and leading to a 1% decrease in volume? [10 marks]

Notes and hints: Most of the marks in this question will go toward setting up the problem so don't panic if you don't have the time or the mathematical skill to finish it completely. The following identity may be useful: $(k/x)^a = k^a x^{-a}$.

Useful data

Specific heat capacity of liquid water: $4.184\,\mathrm{J\,K^{-1}g^{-1}}$

Specific heat capacity of ice: $2.113\,\mathrm{J\,K^{-1}g^{-1}}$

Enthalpy of melting of ice: 333.4 J/g

To convert degrees Celsius to Kelvin, add 273.15.

Standard thermodynamic data at 25°C		
Species	$\Delta\bar{H}_f^\circ$ (kJ/mol)	$\bar{C}_P$ ($\mathrm{J\,K^{-1}mol^{-1}}$)
$H_2O_{(l)}$	−285.830	75.40
$Na^+_{(aq)}$	−240.34	
$Na_2O_{(s)}$	−417.98	69.09
$OH^-_{(aq)}$	−230.015	