Chemistry 2740 Spring 2008 Test 1

Time: 50 min	**Questions:** 7	**Marks:** 48
Aids permitted: calculator, one 8.5×11-inch formula sheet		
See reverse for useful data.		

1. Under what condition(s) is ΔU equal to the heat transferred to a system? [2 marks]

2. State whether each of the following statements is true or false, and explain the basis for your decision in a few words: [2 marks each]

   (a) $\Delta_f \bar{H}^\circ = 0$ for an aqueous proton.

   (b) $\Delta S > 0$ for any spontaneous process.

   (c) It is impossible for a system to reach absolute zero.

3. Explain briefly why the internal energy of an ideal gas only depends on its temperature, and not on the volume in which the gas is held. [4 marks]

4. For the reaction

   $$\text{glycerol} + \text{P}_\text{i} \rightarrow \text{3-phosphoglycerate} + \text{H}_2\text{O}$$

   in aqueous solution at 25°C, $\Delta_r \bar{G}^{\circ\prime} = 10.0\,\text{kJ/mol}$, where P_i represents "inorganic" phosphate and $\Delta_r \bar{G}^{\circ\prime}$ is the standard free energy change in the biochemists' standard state.

   (a) Is this reaction spontaneous if [glycerol] = 1.0 mmol/L, [P_i] = 18 mmol/L and [3-phosphoglycerate] = 0.35 mmol/L? [5 marks]

   (b) Thinking about the definition of the biochemists' standard state, explain why we write P_i instead of (e.g.) PO_4^{3-}. [2 marks]

5. Major thermodynamic reference tables often don't give the standard free energy of formation. Instead, they give the standard enthalpy of formation and standard entropy. The standard enthalpy of formation of $UO^{2+}_{2(aq)}$ is $-1019.0\,\text{kJ/mol}$. Calculate the standard free energy of formation of $UO^{2+}_{2(aq)}$. [6 marks]

6. Random numbers have important applications in many fields of computer science, including cryptography. Unfortunately, it is difficult to generate truly random numbers. In cryptography, insufficiently random numbers can result in codes which are easy to break. Some physical devices like zener diodes do appear to generate true random numbers. Suppose that such a device is used to generate three-bit (bit = binary digit, i.e. a digit which can only take the values 0 or 1) random numbers.

   (a) What is the entropy of this random number generator? Give your answer as a multiple of $k_B \ln 2$. [4 marks]

   Hint: How many possible values are there for each bit?

   (b) What would be the entropy of an n-bit random number generator? [2 marks]

   (c) Entropy is an extensive property. Explain how your last result is consistent with this statement. [2 marks]

7. Some humidifiers work by creating a fine mist. Very small droplets of water evaporate very quickly, even at room temperature. The molar mass of water is 18.0153 g/mol.

   (a) An industrial humidifier vaporizes 5 kg of water per hour as described above. Assume that the droplets are formed and evaporate at 25°C. How much heat does this remove from the air? Express your final answer in watts. [10 marks]

   (b) To put the above number in perspective, suppose that we operate the humidifier in a closed, well insulated room of dimensions $10 \times 10 \times 4$ m. The air pressure in the room is 100 kPa when the temperature is 18°C. Ignoring all other possible sources of heat and treating the air as an ideal gas, what effect would the operation of the humidifier have on the temperature in the room over the course of an hour? Take the heat capacity of air to be approximately $29\,\mathrm{J\,K^{-1}mol^{-1}}$. [5 marks]

Useful data

$R = 8.314\,472\,\mathrm{J\,K^{-1}mol^{-1}}$
To convert degrees Celsius to Kelvin, add 273.15.
For water, $\tilde{C}_p = 4.184\,\mathrm{J\,K^{-1}g^{-1}}$.

Standard thermodynamic data at 1 bar and 25°C

Species	$\frac{\Delta_f H^\circ}{\mathrm{kJ\,mol^{-1}}}$	$\frac{\Delta_f G^\circ}{\mathrm{kJ\,mol^{-1}}}$	$\frac{C_p}{\mathrm{J\,K^{-1}mol^{-1}}}$
$H_2O_{(l)}$	−285.830	−237.140	75.40
$H_2O_{(g)}$	−241.826	−228.582	33.58

Species	$\frac{S^\circ}{\mathrm{J\,K^{-1}mol^{-1}}}$
$H_{2(g)}$	130.680
$O_{2(g)}$	205.152
$U_{(s)}$	50.20
$UO_{2(aq)}^{2+}$	−98.2