Week 9 Worksheet

Chem 11100-2: Section 33

Nov. 30, 2021

Remarks: The following information might be useful

	ΔG° [kJ/mol]
HNO_3 (aq)	-110.9
NO (g)	87.6
NO_2 (g)	51.3
H_2O (l)	-237.1

1. The heat of fusion for ice is 333 J/g
2. The specific heat capacity of water is 4.184 J/g·°C

***Problem* 1:** When two solids are mixed in a closed container, the temperature inside the container drops and a gas is produced. What are the correct signs for $\Delta G, \Delta H$, and ΔS for this process?

***Problem* 2:** Which of the following is true for any substance undergoing the process

$$\text{X (s)} \rightleftharpoons \text{X (l)}$$

at is normal melting point?

i) $\Delta S < 0$

ii) $\Delta H = 0$

iii) $\Delta H = T\Delta G$

iv) $T\Delta S = 0$

v) $\Delta H = T\Delta S$

***Problem* 3:** Is there an increase or decrease in the entropy of the universe as a result of the following reaction? Explain.

$$2\,HNO_3\,(aq) + NO\,(g) \longrightarrow 3\,NO_2\,(g) + H_2O\,(l)$$

***Problem* 4:** Calculate ΔS°_{surr} for the following reaction at 298 K, given that $\Delta S^\circ_{rxn} = 162.7$ J/mol·K and $\Delta G^\circ_{rxn} = -23.27$ kJ/mol.

$$CH_4\,(g) + 2\,H_2S\,(g) \rightleftharpoons CS_2\,(g) + 4\,H_2\,(g)$$

***Problem* 5:** During the discussion of heat capacities in lecture, we had that 'C, the heat capacity is the amount of heat required to raise the temperature of a system by 1K; defined either at constant pressure C_p or constant volume C_V.' We can write this more formally as

$$C_p = \left(\frac{đQ}{dT}\right)_p \tag{1}$$

where the $()_p$ denotes that pressure is being held constant (or similarly for volume v). Then, the specific heat capacities at constant pressure is given by

$$c_p = \frac{1}{m} C_p = \frac{1}{m}\left(\frac{đQ}{dT}\right)_p \tag{2}$$

Using this, derive the relationship

$$S(T_b) - S(T_a) = mc_p \ln \frac{T_b}{T_a} \tag{3}$$

Assume that c_p is independent of temperature.

***Problem* 6:** Given 2 systems A and B with constant specific heats of c_A and c_B initially at temperatures T_A and T_B are brought into thermal constant with each other. We consider the final combined system of $A + B$ to be thermally isolated so only heat exchange occurs between the 2 systems. After the systems come to equilibrium, the reach a common final temperature T_f. What is the entropy change of the entire system $(A + B)$ in this process? Denote the mass of system A as m_A and B as m_B.

Bonus: The second law of thermodynamics requires that the entropy change of an isolated system to never be negative. Show that the entropy change derived above does not violate the second law.

***Problem* 7:** The heat absorbed by a mole of ideal gas in a quasi-static process in which the temperature T changes by dT and its volume V by dV is given by

$$đQ = cdT + pdV$$

where c is its constant molar specific heat at constant volume and p is the pressure $p = RT/V$. Find an expression for the change of entropy of this gas in a quasi-static process which takes it from initial values of temperature T_i and volume V_i to the final values T_f and V_f. Does your answer depend on the process involved in going from the initial to the final state?

***Problem* 8:** A 750-g copper calorimeter can containing 200 g of water is in equilibrium at a temperature of 20°C. An experimenter now places 30-g of ice at 0°C in the calorimeter and encloses the latter with a heat-insulating shield. That is, consider the copper + water + ice system completely isolated (only heat transfer between these 3 subsystems)

a) When all the ice has melted and equilibrium has been reached, what will be the temperature of the water? (The specific heat of copper is 0.418 J/g·°C)

b) Compute the total entropy change resulting from the process of part (a).