CH302: Worksheet 1c Answer key. Examples of Advanced Thermo listed by question type.

• Hess's Law and combined reaction enthalpies

1. Given that

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$ $\Delta H = -296.8$ kJ/mol

$S_{(s)} + 3/2\ O_{2(g)} \rightarrow SO_{3(g)}$ $\Delta H = -395.6$ kJ/mol,

determine the enthalpy change for the decomposition reaction

$2SO_{3(g)} \rightarrow 2SO_{2(g)} + O_{2(g)}$.

Answer: Multiply top equation by 2 and bottom equation by -2.
The answer for ΔH_{rxn} = (2 x -296.8) + (-2 x -395.6) = 197.6kJ

2. Given that

$2H_2 + O_2 \rightarrow 2H_2O$ $\Delta H = -571.6$ kJ/mol

$C_3H_4 + 4O_2 \rightarrow 3CO_2 + 2H_2O$ $\Delta H = -1937$ kJ/mol

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ $\Delta H = -2220$ kJ/mol,

determine the heat of the reaction for

$C_3H_4 + 2H_2 \rightarrow C_3H_8$.

Answer: Multiply the bottom equation by -1. Everything then cancels.
The answer for ΔH_{rxn} = (-571.6) + (-1937) + (-1 x -2220) = -288.6 kJ

• Internal Energy calculations

3. The standard molar heat of freezing for water is -6020 J/mol. Calculate q, w, and ΔE for freezing 1.0 mol of water at 0^oC and 1 atm pressure. (Hint: there is no need to use a calculator.)

Answer:
q = -6020 J/mol
w = 0 (no gas involved)
$\Delta E = q + w = -6020$ J/mol

4. For a reaction in which more moles of gas are produced than are consumed (at constant pressure), ΔH is
   a) Equal to ΔE
   b) Less than ΔE
   c) Greater than ΔE correct from equation $\Delta H = \Delta E + P\Delta V$ since $P\Delta V$ will be positive

• Statistical thermodynamics: internal energy theory

5. What is the total motional contribution to the molar internal energy of CO_2? (Express your answer in amounts of RT.)

Answer: 3/2RT + 2/2RT = 5/2RT for linear molecule

6. What is the total motional contribution to the molar internal energy of NH_3? (Express your answer in Amounts of RT.)

Answer: 3/2RT + 3/2RT = 3RT for linear molecule

• Calculation of the entropy change at a phase transition

8. What is the entropy change for the freezing of 3.33 grams of an alcohol, C_2H_3OH, at 373.2K given that ΔH = -40,700 J/mol?

Answer: $\Delta G = \Delta H - T\Delta S$ but $\Delta G = 0$ for a phase transition so $\Delta H = T\Delta S$. Substitute T = 373.2K and -40700 J/mol to find ΔS = -109 J/K for one mole. The question is ambiguous about the quantity of lcohol so I am finding ΔS per mole so I don't have to do any more work.

• Statistical thermodynamics: Boltzmann formula

9. Use the Boltzmann formula to calculate the entropy at T = 0 for
   a) a mole of BCl_3 that can be oriented one way
   b) a mole of BCl_2Br that can be oriented three ways

Answer:

a) S = 0 because there is only one orientation and ln 1 will = 0 in the equation S = k ln W no matter how many molecules.

b) $S = 1.38 \times 10^{-23} \ln 3^{6.02 \times 1023} = 9.1$ J/Kmole

• Statistical thermodynamics: Third Law

10. Based on the structures of each of the following molecules, which are most likely to have a residual energy in their crystal forms at T = 0?

   a) CO_2 b) O_3 c) HCl d) Cl_2

Answer: O_3 and HCl have residual entropy because they have more than one orientation. Symmetrical CO_2 and Cl_2 do not and have S = 0.

• Entropy Change and the surrounding

11. When a sugar cube dissolves in a cup of coffee (an endothermic process), what the the signs of the entropy change for the system, surroundings and universe, respectively.

   a) -,-,-
   b) -,+,+
   c) +,-,+ correct. The system is getting more disordered and the universe must get more disordered because of second law.
   d) +,+,+
   e) none are correct

• Calculating the change in free energy

12. Calculate ΔG^o for the reaction $2N_2(g) + 3O_3(g) \rightarrow 2N_2O_3(g)$ at 25°C

	ΔH_f^o	S^o
N_2	0	191.5
O_3	0	205
N_2O_3	83.72	312.2

a) 540 kJ/mol rxn
b) 278.7 kJ/mol rxn
c) -561 kJ/mol rxn
d) -540 kJ/mol rxn
e) +56 kJ/mol rxn

Answer: Calculate ΔH = 167 kJ and $T\Delta S$ = 111kJ. So $\Delta H - T\Delta S = \Delta G$ = 56 kJ.