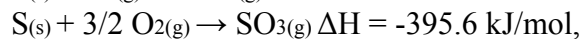
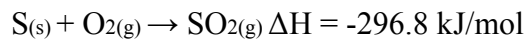


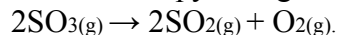
CH302: Worksheet 1c **Answer key**. Examples of Advanced Thermo listed by question type.

• **Hess's Law and combined reaction enthalpies**

1. Given that



determine the enthalpy change for the decomposition reaction



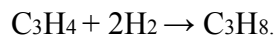
Answer: Multiply top equation by 2 and bottom equation by -2.

The answer for $\Delta H_{\text{rxn}} = (2 \times -296.8) + (-2 \times -395.6) = 197.6 \text{ kJ}$

2. Given that



determine the heat of the reaction for



Answer: Multiply the bottom equation by -1. Everything then cancels.

The answer for $\Delta H_{\text{rxn}} = (-571.6) + (-1937) + (-1 \times -2220) = -288.6 \text{ kJ}$

• **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°C and 1 atm pressure. (Hint: there is no need to use a calculator.)

Answer:

$$q = -6020 \text{ J/mol}$$

$$w = 0 \text{ (no gas involved)}$$

$$\Delta E = q + w = -6020 \text{ J/mol}$$

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 $\Delta H = -40,700 \text{ J/mol}$?

Answer: $\Delta G = \Delta H - T\Delta S$ but $\Delta G = 0$ for a phase transition so $\Delta H = T\Delta S$. Substitute $T = 373.2\text{K}$ and -40700 J/mol to find $\Delta S = -109 \text{ J/K}$ for one mole. The question is ambiguous about the quantity of alcohol 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 mole of BCl_3 that can be oriented one way
- a mole of BCl_2Br that can be oriented three ways

Answer:

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

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

• **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 $T = 0$?

- CO_2
- O_3
- HCl
- 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.

- , -, -
- , +, +

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^0 for the reaction $2N_2(g) + 3O_3(g) \rightarrow 2 N_2O_3(g)$ at $25^\circ C$

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

- 540 kJ/mol rxn
- 278.7 kJ/mol rxn
- 561 kJ/mol rxn
- 540 kJ/mol rxn
- +56 kJ/mol rxn

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