Thermochemistry - Problem Set One

Vocabulary

1. Define the following terms:

a. enthalpy ⇒ $\Delta H = -q$ (The thermodynamic potential of a system)
heat given off or absorbed at constant pressure

b. exothermic A property of a chemical rxn that releases he to the surroundings. (e.g. hot pack)

c. calorimetry The measure of heat and heat transfer.

d. standard enthalpy of formation - Reference values of enthalpy used to construct theoretical ΔH values.

e. endothermic A property of a chemical rxn that absorbs heat from the surroundings (e.g. cold pack)

f. heat vs. temperature heat is a form of energy with units joules, calories, etc. temperature is a measure of the average kinetic energy of the molecules a substance.

Concept

State the first law of thermodynamics.

The change in internal energy of a system, ΔU, is equal to the heat added to the system, q, minus the work done by the system, w.

Problems

$m_m S_8 = 8 \times 32.06 = 256.48 g/m$

$m_m SO_2 = 64.06 g/mol$

2. For the reaction:

$S_{8(s)} + 8O_{2(g)} \rightarrow 8SO_{2(g)} \quad \Delta H = -2368 kJ$

Apply stoichiometry to enthalpy of rxn ΔH

a. How much heat is evolved when 25.0 moles of sulfur is burned in excess oxygen?

$25.0 mol\ S_8 \times \frac{-2368 kJ}{1 S_8} = -59.2 MJ$ (M = mega = 1000 K)

b. How much heat is evolved when 275 grams of sulfur is burned in excess oxygen?

$275 g\ S_8 \times \frac{1 mol}{256.48} \times \frac{-2368 kJ}{1 S_8} = -2.54 MJ$

c. How much heat is evolved when 150.0 grams of sulfur dioxide are produced?

$150.0 g\ SO_2 \times \frac{1 mol}{64.06 g} \times \frac{-2368 kJ}{8 SO_2} = -693.1 kJ$

3. It takes 78.2 J to raise the temperature of 45.6 grams of lead by 13.3 °C. Calculate the specific heat capacity and molar heat capacity of lead.

$S.H. = q/\Delta T \cdot m = \frac{78.2 J}{13.3^\circ \cdot 45.6 g} = 0.129 J/g^\circ \times \frac{207.2 g}{mol} = 26.7 J/mol^\circ$

unknown specific heat

4. A 15.0 gram sample of nickel metal is heated to 100.0 °C and dropped into 55.0 grams of water, initially at 23.0 °C. Assuming that all the heat lost by the nickel is absorbed by the water, calculate the final temperature of the nickel and water. (The specific heat of nickel is 0.444 J/g °C)

heat transfer problem

nickel water

$(15g)(100 - Tf)(0.444) = (55.0g)(Tf - 23)(4.184)$

$6.66(100 - Tf) = 230.12(Tf - 23)$

$666 - 6.66Tf = 230.12Tf - 5292.76$

$5958.76 = 236.78Tf$

$Tf = 25.2^\circ C$

5. Using the standard enthalpies of formation given to you in a table, calculate the standard enthalpy change for the overall reaction that occurs when ammonia is burned in air to form nitrogen dioxide gas and liquid water. Is this reaction endothermic or exothermic?

$2NH_{3(g)} + \frac{7}{2}O_{2(g)} \xrightarrow{\Delta} 2NO_{2(g)} + 3H_2O_{(\ell)}$ $\quad = \frac{-349.7\,KJ}{mol\ NH_3}$

$-45.9 \qquad \emptyset \qquad 33.1 \qquad -285.83$

$[3\cdot(-285.83) + 2(33.1)] - 2(-45.9) = -791.29 + 91.8 = \frac{-699.5\,KJ}{2NH_3}$

6. Two forms of carbon are graphite, the soft, black, slippery material used in "lead" pencils and as a lubricant for locks, and diamond, the brilliant, hard gemstone. Using the standard enthalpy table determine the ΔH for this conversion. Is this an endothermic or an exothermic process?

$C_{graphite} \longrightarrow C_{diamond}$ $\quad \Delta H = 1.8 - \emptyset = 1.8KJ$

$\emptyset \qquad 1.8$ $\quad$ endothermic

7. Diborane (B_2H_6) is a highly reactive boron hydride, which was once considered as a possible rocket fuel for the United States space program. Calculate the ΔH for the synthesis of diborane from its elements, according to the equation:

$2B_{(s)} + 3H_{2(g)} \rightarrow B_2H_{6(g)}$

using the following data.

$2B(s) + \frac{3}{2}O_2(g) \rightarrow B_2O_3(s)$

$3H_2O(g) + B_2O_3(s) \rightarrow B_2H_6(g) + 3O_2(g)$

$3H_2O(\ell) \rightarrow 3H_2O(g)$

$3H_2(g) + \frac{3}{2}O_2(g) \rightarrow 3H_2O(\ell)$

Reaction	ΔH (kJ)	
$2B(s) + 3/2\ O_2(g) \longrightarrow B_2O_3(s)$	−1273	
$B_2H_6(g) - 3\ O_2(g) \longrightarrow B_2O_3(s) - 3\ H_2O(g)$	−2035	reverse
$H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O\ (l)$	−286	x 3
$H_2O(l) \longrightarrow H_2O(g)$	44	x 3

$-1273 + 2035 - 858 + 132 = 36KJ$

8. Given the following data:

Reaction	ΔH (kJ)	
$H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(l)$	−285.5	x 2 (reverse)
$N_2O_5(g) + H_2O(l) \longrightarrow 2\ HNO_3(l)$	−76.6	x 2 (reverse)
$1/2\ N_2(g) + 3/2\ O_2\ (g) + 1/2\ H_2(g) \longrightarrow HNO_3(l)$	−174.1	X 4

$571 + 153.2 - 696.4$

calculate the ΔH for the reaction:

$2N_{2(g)} + 5O_{2(g)} \rightarrow 2N_2O_{5(g)}$ $\quad \Delta H = +27.8$

$2(2HNO_3(\ell) \rightarrow N_2O_5(g) + H_2O(\ell))$

$2N_2(g) + 6O_2(g) + 2H_2(g) \rightarrow 4HNO_3(\ell)$

$2H_2O(\ell) \rightarrow 2H_2 + O_2(g)$