CHEM 1311
Homework
Thermochemistry

1. (8.40) Calculate the work done in joules by a chemical reaction if the volume increases from 3.2 L to 3.4 L against a constant external pressure of 3.6 atm.

2. (8.41) The addition of H_2 to C=C double bonds is an important reaction used in the preparation of margarine from vegetable oils. 50.0 mL of H_2 reacts with 50.0 mL ethylene (C_2H_4) at 1.5 atm producing ethane (C_2H_6) with a volume of 50.0 mL. Calculate the amount of PV work done and tell the direction of the energy flow.

   $C_2H_4 + H_2 \rightarrow C_2H_6$

3. (8.42) Assume that the nutritional content of an apple (50 Cal) could be used to light a lightbulb (1 Cal = 1000cal). Calculate how many minutes would there be light for each of the following:
   a. A 100 watt incandescent bulb (1W = 1 J/s)
   b. A 23 watt compact fluorescent bulb, which provides a similar amount of light

4. (8.50) When 1.045 g of CaO is added to 50.0 mL of water at 25.0 ^oC in a calorimeter, the temperature of the water increases to 32.3 ^oC. Given a specific heat of the solution is 4.18 J/(g $\cdot$ ^oC) and that the calorimeter itself absorbs a negligible amount of heat, calculate ΔH in kilojoules for the reaction: $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2\ (aq)$

5. (8.52) When a solution containing 8.00 g of NaOH in 50.0 g of water at 25.0 ^oC is added to a solution of 8.00 g of HCl in 250.0 g of water at 25.0 ^oC in a calorimeter, the temperature of the solution increases to 33.5 ^oC. Given a specific heat for the solution of 4.18 J/(g$\cdot$ ^oC) and the calorimeter absorbs a negligible amount of heat, calculate ΔH in kilojoules for the reaction. $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

6. (8.57) Which of the following has the highest enthalpy content, and which the lowest at a given temperature: $H_2O(s)$, $H_2O(l)$, or $H_2O(g)$

7. (8.58) The enthalpy change for the reaction of 50.0 mL of ethylene with 50.0 mL of H_2 produces 50 mL of ethane at 1.5 atm is ΔH = -0.31 kJ/mol. Find the value of ΔE.

   $C_2H_4 + H_2 \rightarrow C_2H_6$ (Refer to problem #2)

8. (8.59) Assume that a particular reaction evolves 244 kJ of heat and that 35 kJ of PV work is gained by the system. What are the values of ΔE and ΔH for the system? For the surroundings?

9. (8.62) Used in welding metals, the reaction of acetylene with oxygen has a $\Delta H^o = -1256.2$ kJ/mol.

   $C_2H_2(g) + 5/2\ O_2(g) \rightarrow H_2O(g) + 2\ CO_2(g) \quad \Delta H^o = -1256.2$ kJ/mol

   Determine PV work done in kilojoules and the value of ΔE in kilojoules for the reaction of 6.50 g of acetylene at atmospheric pressure providing a volume change of -2.80 L.

10. (8.63) Ethyl chloride (C_2H_5Cl), a substance used as a topical anesthetic, is prepared by the reaction of ethylene with hydrogen chloride.

    $$C_2H_4(g) + HCl(g) \rightarrow C_2H_5Cl(g) \qquad \Delta H^o = -72.3 \text{ kJ/mol}$$

    How much PV work is done in kilojoules and what is the value of ΔE in kilojoules if 89.5 g of ethylene and 125 g HCl react at atmospheric pressure and the volume change is -71.5 L?

11. (8.64) The familiar "ether" used as an anesthetic agent is diethyl ether, C_4H_6O. Its heat of vaporization is + 26.5 kJ/mol at its boiling point. Determine the amount of energy required to convert 100mL of diethyl ether at its boiling point from liquid to vapor if its density is 0.7138 g/mL.

12. (8.65) Calculate the energy in kilojoules is required to convert 100 mL of water at its boiling point from liquid to vapor. [$\Delta H_{vap}(H_2O) = +40.7$ kJ/mol]

13. (8.66) Aluminum metal reacts with chlorine with a spectacular display of sparks:

    $2Al(s) + 3Cl_2(g) \rightarrow 2\ AlCl_3(s) \qquad \Delta H^o = -1408.4$ kJ/mol

    Calculate the amount of heat in kilojoules released by reacting 5.00 g Al.

14. (8.69) How much heat in kilojoules is evolved or absorbed in the reaction of 233.0 g of calcium oxide with enough carbon to produce calcium carbide? Is the process exothermic or endothermic?

    CaO(s) + 3 C(s) h CaC2(s) + CO(g) $\qquad \Delta H = +464.6$ kJ

15. (8.78) Sulfuric acid (H_2SO_4), the most widely produced chemical in the world, is made by a two-step oxidation of sulfur to sulfur trioxide, SO_3, followed by reaction with water. Calculate ΔH^o_f for SO_3 in kJ/mol, given the following data:

$$S(s) + O_2(g) \rightarrow SO_2(g) \qquad \Delta H^o = -296.8 kJ/mol$$

$$SO_2(g) + \tfrac{1}{2} O_2(g) \rightarrow SO_3(g) \qquad \Delta H^o = -98.9 kJ/mol$$

16. (8.79) Calculate ΔH^o_f in kJ/mol for benzene, C_6H_6, from the following data:

$$2C_6H_6(l) + 15 O_2(g) \rightarrow 12 CO_2(g) + 6 H_2O(l) \qquad \Delta H^o = -6534 kJ/mol$$

$\Delta H^o_f(CO_2) = -393.5$ kJ/mol $\qquad \Delta H^o_f(H_2O) = -285.8$ kJ/mol

17. (8.80) The standard enthalpy change for the reaction of $SO_3(g)$ with $H_2O(l)$ to yield $H_2SO_4(aq)$ is $\Delta H^o = -227.8$kJ. Using information given in problem 14, calculate ΔH^o_f for $H_2SO_4(aq)$ in kJ/mol.

[For $H_2O(l)$, $\Delta H^o_f = -285.8$ kJ/mol]

18. (8.81) Acetic acid (CH_3CO_2H), whose aqueous solutions are known as vinegar, is prepared by reaction of ethyl alcohol (CH_3CH_2OH) with oxygen:

$$CH_3CH_2OH(l) + O_2(g) \text{ h } CH_3CO_2H(l) + H_2O(l)$$

Use the following data to calculate ΔH^o in kilojoules for the reaction:

$\Delta H^o_f[CH_3CH_2OH(l)] = -277.7$ kJ/mol

$\Delta H^o_f[CH_3CO_2H(l)] = -484.5$ kJ/mol

$\Delta H^o_f[H_2O(l)] = -285.8$ kJ/mol

19. (8.83) Methyl *tert*-butyl ether (MTBE), $C_5H_{12}O$, a gasoline additive used to boost octane ratings, has $\Delta H^o_f = -313.6$ kJ/mol. Write a balanced equation for the combustion reaction and calculate the standard heat of combustion in kilojoules.

20. (8.84) Methyl *tert*-butyl ether is prepared by reaction of methanol(l) ($\Delta H^o_f = -239.2$ kJ/mol) with 2-methylpropene(*g*).

$$C_4H_8(g) + CH_3OH(l) \rightarrow C_5H_{12}O(l) \quad \Delta H^o = -57.5 kJ/mol$$

Calculate ΔH^o_f in kJ/mol for 2-methylpropene.

21. (8.85) One possible use for the cooking fat left over after making French fries is to burn it as fuel. Write a balanced equation, and use the following data to calculate the amount of energy released in kJ/mL from the combustion of cooking fat:

    Formula = $C_{51}H_{88}O_6$ Density = 0.94 g/mL ΔH^o_f = -1310 kJ/mol

22. (8.102) Tell whether reactions with the following values of ΔH and ΔS are spontaneous or nonspontaneous and whether they are exothermic or endothermic:
    a. ΔH = -48kJ; ΔS = +135 J/K @ 400 K
    b. ΔH = -48kJ; ΔS = -135 J/K @ 400 K
    c. ΔH = +48kJ; ΔS = +135 J/K @ 400 K
    d. ΔH = +48kJ; ΔS = -135 J/K @ 400 K