ΔH ASSIGNMENT

1. The reaction of 2 mol of gaseous hydrogen with 1 mol of gaseous oxygen to form 2 mol of liquid water releases 517.8 kJ, provided that all reactants and products are brought to 25°C and 1 atm. Write a thermochemical equation for the formation of 1 mol of liquid water.

2. Ethanol, C_2H_5OH, is made industrially by the reaction of water with ethylene, C_2H_4. Calculate the value of ΔH° for the reaction $C_2H_4(g) + H_2O(l) \rightarrow C_2H_5OH(l)$ given the following thermochemical equations:
   $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$ ΔH° = -1411 kJ
   $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ ΔH° = -1367.1 kJ

3. Calculate the ΔH° for the following reactions:
   a. $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$
   b. $NaOH(s) + HCl(g) \rightarrow NaCl(s) + H_2O(g)$

4. Write out the thermochemical equation for the combustion of 1 mol of sucrose, $C_{12}H_{22}O_{11}$, which released 5640.9 kJ of energy. Calculate the *standard heat of formation* of sucrose.

5. Nitric acid reacts with potassium hydroxide as follows: $HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(l)$. In one experiment a student placed 55.0 mL of 1.3 mol/L nitric acid in a coffee cup calorimeter and noted that the temperature was 23.5°C. The student added 55.0 mL of 1.3 mol/L KOH also at 23.5°C. After quickly stirring the mixture with a thermometer, its temperature was seen to rise to 31.8°C. Calculate the heat of this reaction. Assume that the specific heats of all solutions were 4.184 J/g°C and that the densities of all solutions were 1 g/mL. Calculate the heat of reaction per mole of acid.

6. Aluminum and iron (III) oxide react and form aluminum oxide and iron. For each mole of aluminum used, 426.9 kJ of energy is released under standard conditions. Write the thermochemical equation that shows the consumption of 4 mol of Al. (All substances are solids).

7. The following equation represents the dehydration of calcium hydroxide to make quick lime, CaO, a substance present in cement: $Ca(OH)_2(s) \rightarrow CaO(s) + H_2O(l)$ ΔH° = +65.3 kJ. One of the reactions when cement is mixed with water is the reverse of this reaction. Write the thermochemical equation for the reaction of 10 mol of quick lime with water under standard conditions.

8. Show how the equations: $N_2O_4(g) \rightarrow 2NO_2(g)$ ΔH° = +57.93 kJ and $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ ΔH° = -113.14 kJ can be manipulated to give the value of ΔH° for the following reaction: $2NO(g) + O_2(g) \rightarrow N_2O_4(g)$.

9. We can generate hydrogen chloride by heating a mixture of sulfuric acid and potassium chloride according to the reaction: $2KCl(s) + H_2SO_4(l) \rightarrow 2HCl(g) + K_2SO_4(s)$. Calculate the $\Delta H°$ for this reaction from the following thermochemical equations.

$HCl(g) + KOH(s) \rightarrow KCl(s) + H_2O(l)$	$\Delta H° = -203.6$ kJ
$H_2SO_4(l) + 2KOH(s) \rightarrow K_2SO_4(s) + 2H_2O(l)$	$\Delta H° = -342.4$ kJ

10. Calculate $\Delta H°$ for the following reaction, which describes the preparation of an unstable nitrous acid. $HCl(g) + NaNO_2(s) \rightarrow HNO_2(l) + NaCl(s)$. Use the following thermochemical equations.

$2NaCl(s) + H_2O(l) \rightarrow 2HCl(g) + Na_2O(s)$	$\Delta H° = +507.31$ kJ
$NO(g) + NO_2(g) + Na_2O(s) \rightarrow 2NaNO_2(s)$	$\Delta H° = -427.14$ kJ
$NO(g) + NO_2(g) \rightarrow N_2O(g) + O_2(g)$	$\Delta H° = -42.68$ kJ
$2HNO_2(l) \rightarrow N_2O(g) + O_2(g) + H_2O(l)$	$\Delta H° = +34.35$ kJ

11. What is the value for $\Delta H°$ for the neutralization of lithium hydroxide by hydrochloric acid? $LiOH(aq) + HCl(aq) \rightarrow LiCl(aq) + H_2O(l)$. The following thermochemical equations can be used in addition to any others you make up.

$Li(s) + ½O_2(g) + ½H_2(g) \rightarrow LiOH(s)$	$\Delta H° = -487.0$ kJ
$2Li(s) + Cl_2(g) \rightarrow 2LiCl(s)$	$\Delta H° = -815.0$ kJ
$LiOH(s) \rightarrow LiOH(aq)$	$\Delta H° = -19.2$ kJ
$HCl(g) \rightarrow HCl(aq)$	$\Delta H° = -77.0$ kJ
$LiCl(s) \rightarrow LiCl(aq)$	$\Delta H° = -36.0$ kJ

12. Write the thermochemical equations that would be used in connection with values of $\Delta H°_f$ for each of the following compounds. Obtain values for $\Delta H°$ from your data table.
    a. Acetic acid
    b. Sodium bicarbonate (sodium hydrogen carbonate)
    c. Gypsum ($CaSO_4*2H_2O$)
    d. Plaster of Paris ($CaSO_4*$ ½H_2O)
    e. Methanol

13. Nitrogen dioxide, an air pollutant, combines with water to make nitric acid, a corrosive acid, and nitrogen monoxide (NO). What is the $\Delta H°$ for the following reaction:
    $3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(l) + NO(g)$

14. We can remove carbon dioxide from air by passing the air through solid granules of sodium hydroxide. What is the $\Delta H°$ for the following reaction:
    $CO_2(g) + NaOH(s) \rightarrow NaHCO_3(s)$

15. From $\Delta H°_f$ data for the formation of carbon dioxide and water and the thermochemical equation for the combustion of glucose, $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$. $\Delta H°_{combustion}° = -2820$ kJ/mol, calculate the $\Delta H°_f$ for glucose.

16. Phosphorus burns in air to give tetraphosphorus decaoxide: $4P(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$ $\Delta H° = -3062$ kJ. The product combines with water to give phosphoric acid: $P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(l)$ $\Delta H° = -257.2$ kJ. Using these equations and some others from this unit as needed, write the thermochemical equation for the formation of 1 mol of phosphoric acid from its elements, including the value for $\Delta H°_f$.

17. Calculate the $\Delta H°$ for: $CO(g) + Fe_3O_4(s) \rightarrow CO_2(g) + Fe(s)$