**Thermochemical Equations**

1. Look at the following thermochemical equations. Determine if the reaction is exothermic or endothermic.
   1. 6.01kJ + H2O(s) 🡪 H2O(l) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   2. 2Na(s) + 2H2O(l) 🡪 2NaOH(aq) + H2(g) + 367kJ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   3. 2H­2(g) + O2(g) 🡪 2H2O(l) **Δ**H = -572kJ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   4. NaHCO3(aq) + HCl(aq) 🡪 NaCl(aq) + H2O(l) **Δ**H = +11.8kJ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   5. C2H4(g) + 176kJ 🡪 H2(g) + C2H2(g) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Given that the reaction of Cdiamond + O2 🡪 CO2 (g) has a ΔH of -395.39 J, what would you predict for the ΔH for 2 Cdiamond + 2 O2 🡪 2 CO2 (g)? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. Given that the reaction of 2 C(s) + 3 H2 (g) + ½ O2 (g) 🡪 C2H2OH(l) has a ΔH of -271.96 J, what would you predict for the ΔH value of the decomposition of C2H2OH(l)? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. Given that the reaction of 2 Ti (s) + 4 Cl2 (g) 🡪 2 TiCl4 (l) has a ΔH of -1608.4 J, what would you predict to be the ΔH of the following reaction: TiCl4 (l) 🡪 Ti (s) + 2 Cl2 (g)? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. Given the following: CH4 (g) + O2 (g)🡪 CO2(g) + H2O (l) ΔH = - 890 kJ
   1. Write the balanced thermochemical equation.
   2. Is the reaction exothermic or endothermic? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   3. How much heat is given off by the reaction of 3.5 moles of CH4?
   4. How much heat is given off by the reaction of 40.0 g of O2?
   5. How many grams of CH4 are needed to release 2000 J of heat?
6. The balanced equation for the decomposition of PbO2 is

227kJ + PbO2(s) 🡪 Pb(s) + O2(g)

* 1. How much heat is required to decompose 5.0 moles of PbO2(s)?
  2. How much heat is required to decompose 55.0 grams of PbO2?

1. Given the following:

Fe + CO2 🡪 Fe2O3 + CO

ΔH = + 26.3 kJ

* 1. Write the balanced thermochemical equation.
  2. Is the reaction exothermic or endothermic? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  3. How many grams of iron will be produced when 54.0 J of heat are absorbed?
  4. How much heat is absorbed for the production of 6.5 g of iron (III) oxide?

1. Knowing that C(s) + 2H2(g) 🡪 CH4(g) + 75kJ, how many moles of C(s) must react to produce 300.0 kJ of heat energy?
2. The formation of NO(g) from N2 and O2(g) is shown below:

N2(g) + O2(g) 🡪 2NO(g) ΔH = +180 kJ

* 1. Is this an endothermic reaction or an exothermic reaction? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  2. Knowing the above, write the equation for the decomposition of **one mole** of NO(g) into its elements. Include the energy term.
  3. How much energy is released during the decomposition of 312 g of NO?

**Heat of Solution Problems**

Remember, making a solution is not a chemical reaction, but heat is still involved! Here is some data

you will need to solve these problems:

|  |  |
| --- | --- |
| **Compound** | **Enthalpy of Solution (ΔHsoln) in kJ/mole** |
| NaOH | -445.1 |
| NH4NO3 | +25.7 |
| CaCl2 | -82.8 |

1. How much heat is released when 0.677 moles of NaOH(s) is dissolved in water? Write the equation for the dissociation of NaOH(s) and then do the math.
2. How many moles of NH4NO3(s) must be dissolved in water if 88.0 kJ of heat are to be removed from the water? Write the equation for the dissociation of NH4NO3(s) and then do the math.
3. A. I want to raise the temperature of 100.0 grams of water by 10.0 ˚C. How much heat is required?

B. How many grams of NaOH would have to be added to the water to produce this temperature change?

1. How many grams of CaCl2(s) were added to 50.0 g of water if the temperature of the water went up by 2.0 ˚C? Write the dissociation equation and then do the math.

**Enthalpy of Formation and Hess’s Law**

**Part 1.** Balance the following equations. Then use the heats of formation and Hess’s Law to find the enthalpy of the reaction. Classify each reaction as endothermic or exothermic.

1. NH3(g) + HCl(g) 🡪 NH4Cl(s)
2. K(s) + H2O(l) 🡪 KOH(aq) + H2(g)
3. NO(g) + O2(g) 🡪 NO2(g)
4. NH3(g) + O2(g) 🡪 NO2(g) + H2O(g)

**Part 2.** Solve the following problems using enthalpy of formation, Hess’s Law and stoichiometry.

1. How much heat is released from the combustion of 1.00 gram of methane gas (CH4)?
2. How much heat is evolved when 8.00 grams of oxygen reacts with an excess of C2H4?
3. Calculate the heat produced when 15.0 grams of solid calcium hydroxide forms from the reaction of solid calcium oxide and liquid water.
4. Carbon monoxide gas reacts with solid iron (III) oxide to produce solid iron and carbon dioxide. How much heat is involved when 56.0 grams of carbon monoxide react with excess iron (III) oxide? Is the reaction endothermic or exothermic?

**Part 3.** Use the thermochemical reactions provided to find the enthalpy of the designated reaction. This

is also an application of Hess' Law.

1. Calculate H for the reaction: C2H4 (g) + H2 (g) --> C2H6 (g), from the following thermochemical data.

|  |  |
| --- | --- |
| C2H4 (g) + 3 O2 (g) --> 2 CO2 (g) + 2 H2O (l) | H = -1411. kJ |
| C2H6 (g) + 3½ O2 (g) --> 2 CO2 (g) + 3 H2O (l) | H = -1560. kJ |
| H2 (g) + ½ O2 (g) --> H2O (l) | H = -285.8 kJ |

1. Calculate H for the reaction 4 NH3 (g) + 5 O2 (g) --> 4 NO (g) + 6 H2O (g), from the following thermochemical data.

|  |  |
| --- | --- |
| N2 (g) + O2 (g) --> 2 NO (g) | H = -180.5 kJ |
| N2 (g) + 3 H2 (g) --> 2 NH3 (g) | H = -91.8 kJ |
| 2 H2 (g) + O2 (g) --> 2 H2O (g) | H = -483.6 kJ |

1. Find H for the reaction 2H2(g) + 2C(s) + O2(g) --> C2H5OH(l), using the following thermochemical data.

|  |  |
| --- | --- |
| C2H5OH (l) + 2 O2 (g) --> 2 CO2 (g) + 2 H2O (l) | H = -875. kJ |
| C (s) + O2 (g) --> CO2 (g) | H = -394.51kJ |
| H2 (g) + ½ O2 (g) --> H2O (l) | H = -285.8 kJ |

1. Calculate H for the reaction CH4 (g) + NH3 (g) --> HCN (g) + 3 H2 (g), given: (Hint: You can multiply by a fraction like ½ )

|  |  |
| --- | --- |
| N2 (g) + 3 H2 (g) --> 2 NH3 (g) | H = -91.8 kJ |
| C (s) + 2 H2 (g) --> CH4 (g) | H = -74.9 kJ |
| H2 (g) + 2 C (s) + N2 (g) --> 2 HCN (g) | H = +270.3 kJ |

1. Calculate H for the reaction 2 Al (s) + 3 Cl2 (g) --> 2 AlCl3 (s) from the data. (Hint: pay attention to states of matter)

|  |  |
| --- | --- |
| 2 Al (s) + 6 HCl (aq) --> 2 AlCl3 (aq) + 3 H2 (g) | H = -1049. kJ |
| HCl (g) --> HCl (aq) | H = -74.8 kJ |
| H2 (g) + Cl2 (g) --> 2 HCl (g) | H = -1845. kJ |
| AlCl3 (s) --> AlCl3 (aq) | H = -323. kJ |

More Hess’s Law Practice (if you need it!)

(1)  Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:  
PCl5(g)  →  PCl3(g)  +  Cl2(g)

P4(s)  +  6Cl2(g)  →  4PCl3(g)            ΔH = -2439 kJ  
4PCl5(g)  →  P4(s)  +  10Cl2(g)         ΔH = 3438 kJ  
answer = 249.8 kJ

(2)  Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:  
2CO2(g)  +  H2O(g)  →  C2H2(g) +  5/2O2(g)

C2H2(g) + 2H2(g)  →  C2H6(g)                              ΔH  =-94.5 kJ  
H2O(g)  →  H2(g) + 1/2O2 (g)                               ΔH  =71.2 kJ  
C2H6(g) +  7/2O2(g)  →  2CO2(g)  +  3H2O(g)     ΔH  =-283 kJ  
answer = 235 kJ

(3)  Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:  
N2H4(l)  +  H2(g)  →  2NH3(g)

N2H4(l)  +  CH4O(l)  →  CH2O(g)  +  N2(g)  +  3H2 (g)         ΔH = -37 kJ  
N2(g)  +  3H2(g)  →  2NH3(g)                                                ΔH = -46 kJ  
CH4O(l)  →  CH2O(g) +  H2(g)                                              ΔH = -65 kJ  
answer = -18 kJ

(4)  Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:  
H2SO4(l)  →  SO3(g)  +  H2O(g)

H2S(g)  +  2O2(g)  →  H2SO4(l)                                  ΔH = -235.5 kJ  
H2S(g)  +  2O2(g)  →  SO3(g)  +  H2O(l)                    ΔH = -207 kJ  
H2O(l)  →  H2O(g)                                                      ΔH = 44 kJ  
answer = 72 kJ

(5)  Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:  
2C2H4O(l) + 2H2O(l)  →  2C2H6O(l) +  O2(g)

C2H6O(l)  +  3O2(g)  →  2CO2(g)  +  3H2O(l)            ΔH = -685.5 kJ  
C2H4O(l)  +  5/2O2(g)  →  2CO2(g)  +  2H2O(l)         ΔH = -583.5 kJ  
answer = 204.0 kJ

(6)  Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:  
N2(g) +  2O2(g)  →  2NO2(g)

N2(g)  +  3H2(g)  →  2NH3(g)                                  ΔH = -115 kJ  
2NH3(g)  +  4H2O(l)  →  2NO2(g)  +  7H2(g)          ΔH = -142.5 kJ  
H2O(l)  →  H2(g)  +  1/2O2(g)                                 ΔH = -43.7 kJ  
answer = -83 kJ

(7)  Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:  
CO2(g)  →  C(s) +  O2(g)

H2O(l)  →  H2(g)  +  1/2O2(g)                                    ΔH = 643 kJ  
C2H6(g)  →  2C(s) +  3H2(g)                                     ΔH = 190.6 kJ  
2CO2(g) +  3H2O(l)  →  C2H6(g) + 7/2O2(g)            ΔH = 3511.1 kJ  
answer = 886 kJ

(8)  Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:  
N2H4(l)  +  CH4O(l)  →  CH2O(g)  +  N2(g)  +  3H2 (g)

2NH3(g)  →  N2H4(l)  +  H2(g)                 ΔH = 22.5 kJ  
2NH3(g)  →  N2(g)  +  3H2(g)                 ΔH = 57.5 kJ  
CH2O(g) +  H2(g)  →  CH4O(l)               ΔH = 81.2 kJ  
answer = -46.2 kJ