**Introducing Thermochemical Equations**

***Why?***

Both chemical and physical changes involve energy changes, called the “enthalpy of reaction” or sometimes “heat of reaction.” Enthalpy, derived from the Greek *enthalpein* (to warm), is the scientific term for “heat at constant pressure.” Chemists usually study heat changes at constant pressure conditions. It is possible to write balanced equations representing chemical and physical processes that explicitly include the amount of energy involved—these equations are called thermochemical equations. States of matter must be included in thermochemical equations, as they affect the amount of heat involved. The enthalpy term, often written as H, is given in J or kJ, and the sign indicates the direction of heat flow relative to the system. In an exothermic process, heat is released to the surroundings, while in an endothermic process, heat is absorbed from the surroundings.

***Learning Objectives***

* Determine whether thermochemical equations represent endothermic or exothermic processes
* Solve mass-energy problems using thermochemical equations

***Concepts***

* Enthalpy of reaction
* Mass-energy calculations

***Prerequisites***

* Stoichiometry calculations
* Balanced chemical equations
* Intensive and extensive properties

**Model 1: Two equivalent ways to write thermochemical equations**

**Endothermic Processes**

|  |  |
| --- | --- |
| **Version 1** | **Version 2**  |
| H2O(l) + 44 kJ→ H2O(g) | H2O(l)→ H2O(g) ΔH = +44 kJ/mol |
| 2NaHCO3(s) + 129 kJ → Na2CO3(s) + H2O(l) + CO2(g) | 2NaHCO3(s) → Na2CO3(s) + H2O(l) + CO2(g) ΔH = +129 kJ/mol |

**Exothermic Processes**

|  |  |
| --- | --- |
| **Version 1** | **Version 2** |
| CH4(g) + 2O2(g) → 890 kJ + CO2(g) + 2H2O(l) | CH4(g) + 2O2(g) → CO2(g) + 2H2O(l)  ΔH = -890 kJ/mol |
| 2Na(s) + 2H2O(l) → 367.5 kJ +2 NaOH(aq) + H2(g) | 2Na(s) + 2H2O(l) → 2 NaOH(aq) + H2(g) ΔH = -367.5 kJ/mol |

***Key Questions***

1. In endothermic processes, is the energy term listed with the reactants or the products?
2. Is energy absorbed or released in an endothermic process?
3. In endothermic processes, what is the sign of ΔH?
4. In exothermic reactions, is the energy term listed with the reactants or the products?
5. In exothermic processes, what is the sign of ΔH?
6. Is energy absorbed or released in an exothermic process?
7. In 1-2 sentences, summarize how to determine if a particular thermochemical equation represents an endothermic or exothermic process.

***Problems***

1. Are the following reactions endothermic or exothermic? Explain how you arrived at your answer.
2. 3 H2(g) + N2(g) → 2709 J + 2 NH3(g)
3. 2 HCl(g) → H2(g) + Cl2(g) ΔH = +183 kJ/mol
4. 4 Fe(s) + 3 O2(g) → 2 Fe2O3(s) ΔH = -1644 kJ/mol
5. Complete the following table

|  |  |  |
| --- | --- | --- |
| Sign of ΔH | Energy as … | Endothermic or exothermic? |
|  | reactant |  |
|  - |  |  |

**Model 2 Mass-energy relationships**

 3 H2(g) + N2(g) → 2 NH3(g) ΔH = -2709 J

Mass-Energy Ratios: $\frac{-2709J}{3 mol H\_{2}}$ $\frac{3 mol H\_{2}}{-2709J}$ $\frac{-2709J}{1 mol N\_{2}} $ $\frac{1 mol N\_{2}}{-2709J}$ $\frac{-2709J}{2 mol NH\_{3}}$ $\frac{2 mol NH\_{3}}{-2709J}$

What mass of hydrogen must react with excess nitrogen to release 4500 J of energy?

 $x g H\_{2}=4500 J \frac{3 mol H\_{2}}{2709 J} \frac{2.02 g}{1 mol H\_{2}}$ = 10. g H2

*Key Questions*

1. What are you solving for in the problem above? What are the required units? Where is this written in the factor label problem?
2. What information is given to you in this problem? What units are given for this? Where is this written in the factor label problem?
3. Look at the first ratio in the factor label problem.
	1. Where do you get the information for the denominator in the ratio? What are the units?
	2. Where do you get the information for the numerator in the ratio? What are the units?
4. What happens to the unit “J” in the problem?
	* 1. What happens to the unit “mol H2” in the problem?
		2. What units are you left with at the end of the problem?

***Problems***

1. What mass of iron must react with excess oxygen in order to release 750. kJ of energy? (Note: you cannot have negative masses, so report your answer as an absolute value.)

4 Fe(s) + 3 O2(g) → 2 Fe2O3(s) ΔH = - 1644 kJ

1. What quantity of heat (in kJ) is associated with the synthesis of 92 g of NH3 according to the following equation? Report your answer with the correct sign!

 4 NO(g) + 6 H2O(l) → 4 NH3(g) + 5 O2(g) + 1170 kJ