Name _____ **Chemistry** **__/__/__**

Heats of Reaction

Heat changes often accompany chemical reactions. If heat is absorbed in a chemical reaction (**endothermic change**), the products will have more energy than the reactants and ΔH will have a positive value. If heat is released in a chemical reaction (**exothermic change**), the products will have less energy than the reactants and ΔH will have a negative value. Regardless of whether a chemical reaction is endothermic or exothermic, all reactions require activation energy in order to begin. **Activation energy(E_a)** is defined as the amount of energy needed to start a chemical reaction. A **catalyst** is sometimes used to reduce the amount of activation energy needed to start a reaction. Catalysts are used to speed up reactions but are not used up in the reaction.

To calculate the change in enthalpy (ΔH) for a reaction you must find the difference between the **heats of formation** of the reactants and the products. **$\Delta H = H_f$(products) – H_f(reactants)**

For example: Calculate the change in enthalpy for the following reaction:

$Ca\ (s) + H_2O\ (l) \rightarrow Ca(OH)_2\ (s) + H_2\ (g)$

First balance the equation:

$Ca\ (s) + \mathbf{2}\ H_2O\ (l) \rightarrow Ca(OH)_2\ (s) + H_2\ (g)$

Determine the enthalpy for the products and the reactants:

$Ca\ (s) + \mathbf{2}\ H_2O\ (l) \rightarrow Ca(OH)_2\ (s) + H_2\ (g)$

$0 + \mathbf{2}\ (-286) \rightarrow -986.6 + 0$

$-572 \rightarrow -986.6$

Substance	$H_{formation}$ (kJ/mol)
Ca (s)	0.0
H_2O (l)	-286
$Ca(OH)_2$ (s)	-986.6
H_2 (g)	0

Calculate the ΔH for the reaction using the formula from above:

$\Delta H = H_f$(products) – H_f(reactants)

ΔH = -986.6 – (-572)

ΔH = -414.6 kJ; this is an exothermic reaction

The change in enthalpy (ΔH) for a reaction can be written **at the end of an equation** or **as part of the equation**. Look below how the same reaction can be represented two different ways.

$C_6H_{12}O_6\ (s) \rightarrow 2\ C_2H_5OH\ (l) + 2\ CO_2\ (g)\ \ \Delta H = 67.0\ kJ$ or $C_6H_{12}O_6\ (s) + 67.0\ kJ \rightarrow 2\ C_2H_5OH\ (l) + 2\ CO_2\ (g)$

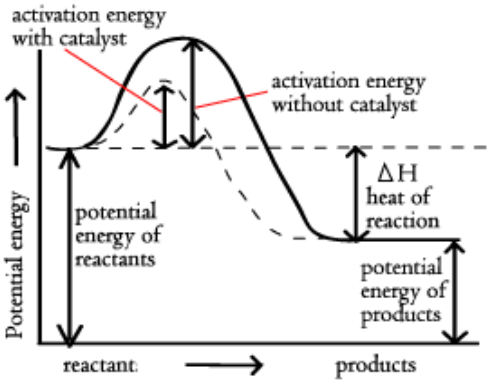
If a reaction is **endothermic**, the **ΔH** will be **positive** in value and the energy value can be written as a **reactant**, as seen above. If a reaction is **exothermic**, the **ΔH** value will be **negative** and the energy value can be written as part of the **product** as seen here**:** $C + O_2(g) \rightarrow CO_2(g)\ \ \Delta H = -394\ kJ$ or $C + O_2(g) \rightarrow CO_2(g) + 394\ kJ$

Energy Diagrams

Energy diagrams are used to give a graphic representation of a chemical reaction. The energy diagrams for endothermic and exothermic reactions are shown below.

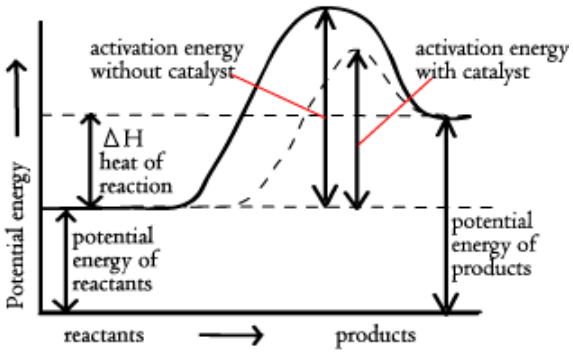
EXOTHERMIC

A + B --> C + D + heat
ΔH = negative



ENDOTHERMIC

A + B + heat --> C + D
ΔH = positive



In Summary:

ΔH Value	Endothermic/Exothermic	Higher Enthalpy	In Equation, write ΔH value as a:	Example
Positive (+)	Endothermic	Products	Reactant	X + Y + ΔH → Z
Negative (-)	Exothermic	Reactant	Product	X + Y → Z + ΔH

Homework:

1. Define activation energy –

2. Define catalyst –

3. Rewrite the following equations with energy included. Indicate if the reaction is **endothermic or exothermic**.

a. $2NO + O_2 \rightarrow 2NO_2 \quad \Delta H = -27$ kcal

endothermic or exothermic

b. $CH_4 + O_2 \rightarrow CO_2 + H_2O \quad \Delta H = -890$ kJ

endothermic or exothermic

c. $2H_2O \rightarrow 2H_2 + O_2 \quad \Delta H = 571.6$ kJ

endothermic or exothermic

d. $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 \quad \Delta H = 2870$ kJ

endothermic or exothermic

e. $2K + 2H_2O \rightarrow 2KOH + H_2 \quad \Delta H = -393$ kJ

endothermic or exothermic

f. $TiO_2 + 2Cl_2 \rightarrow TiCl_4 + O_2 \quad \Delta H = 140.5$ kJ

endothermic or exothermic

4. The heat of formation for Cu_2S is -79.5 kJ/mol, for S its 0 kJ/mol and for CuS its -53.1 kJ/mol.

$Cu_2S + S \rightarrow 2CuS$

a. What is the change in enthalpy for this reaction?_____
b. Is this reaction exothermic or endothermic ? Circle One.
c. Draw an energy diagram for this reaction. Label potential energy of the reactants, potential energy of the products, ΔH, and activation energy.

d. Which has higher enthalpy, the reactants or the products of this reaction? Circle One.
e. Re-write the equation from above with the ΔH value as a reactant or product, which ever is correct.

5. Determine the heat of reaction for the following reaction as water vapor cools to form liquid water. The heat of formation for H_2O (g) is 241.82 kJ/mol and for H_2O (l) it is -285.83 kJ/mol.

H_2O (g) $\rightarrow$ H_2O (l)

a. What is the change in enthalpy for this reaction?_____
b. Is this reaction exothermic or endothermic ? Circle One.
c. Draw an energy diagram for this reaction. Label potential energy of the reactants, potential energy of the products, ΔH, and activation energy.

d. Which has higher enthalpy, the reactants or the products of this reaction? Circle One.
e. Re-write the equation from above with the ΔH value as a reactant or product, which ever is correct.

6. The heat of formation of H_2O_2 is –187.6 kJ/mol, the heat of formation of H_2O is -285.83 kJ/mol, and the heat of formation of O_2 is 0 kJ/mol. Determine the heat of reaction for the decomposition of H_2O_2. Draw an energy diagram for this reaction.

$2H_2O_2 \rightarrow 2H_2O + O_2$

a. What is the change in enthalpy for this reaction?_____
b. Is this reaction exothermic or endothermic ? Circle One.
c. Draw an energy diagram for this reaction. Label potential energy of the reactants, potential energy of the products, ΔH, and activation energy.

d. Which has higher enthalpy, the reactants or the products of this reaction? Circle One.
e. Re-write the equation from above with the ΔH value as a reactant or product, which ever is correct.

7. In the engine of your car, nitrogen and oxygen combine to form nitrogen oxides, chemicals that contribute to pollution. Below is a reaction that produces nitrogen dioxide from previously formed nitrogen monoxide. Determine the ΔH value for this reaction using the heats of formation given. Draw an energy diagram for this reaction.

$2NO_2\ (g) \rightarrow 2NO\ (g) + O_2\ (g)$

Substance	ΔH_f (kJ/mol)
NO_2 (g)	+33.2
NO (g)	+90.2
O_2 (g)	0

a. What is the change in enthalpy for this reaction? _____
b. Is this reaction exothermic or endothermic ? Circle One.
c. Draw an energy diagram for this reaction. Label potential energy of the reactants, potential energy of the products, ΔH, and activation energy.

d. Which has higher enthalpy, the reactants or the products of this reaction? Circle One.
e. Re-write the equation from above with the ΔH value as a reactant or product, which ever is correct.

8. Pentane, the smallest hydrocarbon found in gasoline, can be synthesized from 2-pentanol and hydrogen gas in a multi-step process. Determine the ΔH for this reaction using the heats of formation given for the equation below. Draw an energy diagram for this reaction.

$C_5H_{11}OH\ (l) + H_2\ (g) \rightarrow C_5H_{12}\ (l) + H_2O\ (l)$

Substance	ΔH_f (kJ/mol)
$C_5H_{11}OH$ (l)	-365.2
H_2 (g)	0
C_5H_{12} (l)	-173.5
H_2O (l)	-285.83

a. What is the change in enthalpy for this reaction? _____
b. Is this reaction exothermic or endothermic ? Circle One.
c. Draw an energy diagram for this reaction. Label potential energy of the reactants, potential energy of the products, ΔH, and activation energy.

d. Which has higher enthalpy, the reactants or the products of this reaction? Circle One.
e. Re-write the equation from above with the ΔH value as a reactant or product, which ever is correct.