Thermochemistry

the study of the transfers of energy as heat that accompany chemical reactions and physical changes

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Calorimeter

a device that is used to measure the energy absorbed or released as heat in a chemical reaction or a physical change

Temperature

a measure of the average kinetic energy of the particles ina a sample of matter

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Joule

the SI unit of heat as well as all other forms of energy

Heat

the energy transferred between samples of matter because of a difference in their temperatures

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Enthalpy change

the amount of energy absorbed by a system as heat during a process at constant pressure

Enthalpy of reaction

the quantity of energy transferred as heat during a chemical reaction

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Exothermic

energy is released from the system

Endothermic

energy is absorbed by the system

Thermochemical equation

an equation that includes the quantity of energy released or absorbed

$$4H_2(g) + 2O_2(g) \longrightarrow 4H_2O(g) + 967.2kJ$$

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Molar enthalpy of formation

the enthalpy change that occurs when one mole of a compound is formed from its elements in their standard state at 298 K and 1 atm

Enthalpy of Combustion

the enthalpy that occurs during the complete combustion of one mol of a substance

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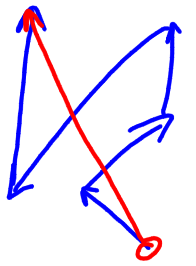
Hess's Law

the overall enthalpy change in a reaction is equal to the sum of the enthalpy changes fro the individual steps in the process



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Example of Hess's Law

$C(s) + 2H_2(g) \rightarrow CH_4(g)$ +/- H^0_f

To determine this H^0_f we can use the combustion enthalpies of C and H

$C(s) + O_2(g) \rightarrow CO_2(g)$	$H^0_c = -393.5$ kJ
$H_2(g) + 1/2\ O_2(g) \rightarrow H_2O(l)$	$H^0_c = -285.5$ kJ
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$	$H^0_c = -890.8$ kJ

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Reverse reactions will have a reverse amount of energy, as well we can multiply equations by any positive factor (such as 2). Chemical equations are additive, so we can cancel anything that is the same on both sides and add the rest together vertically.....

$C + 2H_2 \rightarrow CH_4$

$C(s) + O_2(g) \longrightarrow CO_2(g)$	$H^0_c = -393.5$ kJ
$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$	$H^0_c = 2(-285.5)$ kJ
$CO_2(g) + 2H_2O(l) \longrightarrow CH_4(g) + 2O_2(g)$	$H^0 = 890.8$ kJ
$C(s) + 2H_2(g) \longrightarrow CH_4(g)$	$H^0_f = -74.3$ kJ

Since the heat of formation of methane gas is a negative, that means energy must enter the system so it is endothermic. The energy can be written as a positive number and placed on the reactants side.

$C(s) + 2H_2(g) + 74.3\ kJ \longrightarrow CH_4(g)$

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a) $NaOH(s) + HCl(g) \text{ ----> } NaCl(s) + H_2O(g)$

b) $2\ CO(g) + O_2(g) \text{ ---> } 2\ CO_2(g)$

c) $CH_4(g) + 2\ O_2(g) \text{ ---> } CO_2(g) + 2\ H_2O(l)$

d) $2\ H_2S(g) + 3\ O_2(g) \text{ ---> } 2\ H_2O(l) + 2\ SO_2(g)$

e) $2\ NO(g) + O_2(g) \text{ ---> } 2\ NO_2(g)$

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$CH_4(g)$	-74.8	HCl(g)	-92.3
$CO_2(g)$	-393.5	$H_2O(g)$	-241.8
NaCl(s)	-411.0	$SO_2(g)$	-296.1
$H_2O(l)$	-285.8	**$NH_4Cl(s)$**	-315.4
$H_2S(g)$	-20.1	NO(g)	+90.4
$H_2SO_4(l)$	-811.3	$NO_2(g)$	+33.9
$MgSO_4(s)$	-1278.2	**$SnCl_4(l)$**	-545.2
MnO(s)	-384.9	**SnO(s)**	-286.2
$MnO_2(s)$	-519.7	**$SnO_2(s)$**	-580.7
NaCl(s)	-411.0	**$SO_2(g)$**	-296.1
NaF(s)	-569.0	**$SO_3(g)$**	-395.2
NaOH(s)	-426.7	**ZnO(s)**	-348.0
$NH_3(g)$	-46.2	**ZnS(s)**	-202.9

CO = -110.5

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NaOH(s) + HCl(g) ----> NaCl(s) + $H_2O(g)$

-426.7 kJ/mol -92.3

519 kJ

-411.0 -241.8

-652.8 kJ

H° = -133.8 kJ

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$2\ CO(g) + O_2(g) \rightarrow 2\ CO_2(g)$

$2(-110.5)$ $2(-393.5)$

221 kJ | −787 kJ

$H_c^o = -566\ kJ$

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$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)$

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$$2\ H_2S(g) + 3\ O_2(g) \rightarrow 2\ H_2O(l) + 2\ SO_2(g)$$

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

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Calculate H for the reaction

$4\ NH_3\ (g) + 5\ O_2\ (g) \rightarrow\ 4\ NO\ (g) + 6\ H_2O\ (g)$

from the following data.

$N_2\ (g) + O_2\ (g) \rightarrow 2\ NO\ (g)$	H = -180.5 kJ
$N_2\ (g) + 3\ H_2\ (g) \rightarrow 2\ NH_3\ (g)$	H = -91.8 kJ
$2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$	H = -483.6 kJ

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