**Enthalpy** - H

Energy of a system which is open to the atmosphere.

$$\mathbf{H = E + PV}$$

We are concerned with changes in enthalpy.

$$\Delta H = \Delta E + \Delta(PV)$$

If a reaction is carried out in an open container the external pressure on the system is constant:

$$\Delta H = \Delta E + P\Delta V$$

Recall:

$\Delta E = q + w$

$\Delta E = q - P\Delta V$

$q = E + P\Delta V$

Therefore: $\Delta H = q$

Whenever a reaction is carried out against constant pressure, i.e. in an open container.

**Calorimetry -**

The science of measuring the quantities of heat that are involved with chemical or physical changes.

**Heat Capacity** - ( C )

The amount of heat needed to raise the temp. of an object by 1°C.

$$C = \frac{Heat\_Absorbed}{Increase\_in\_Temperature}$$

**Specific Heat Capacity -**

Amount of heat needeed to raise the temp. of 1g of a substance 1°C.

Specific Heat of water: $\frac{4.184J}{g\text{-}^\circ C}$

**Molar Heat Capacity -**

The amount of heat needed to raise the temp. of one mole of a substance 1°C.

**Bomb Calorimeter-**

A device used to carry out experiments at constant volume.

$\Delta E = q + w$

$\Delta E = q - P\Delta V$

In a bomb calorimeter $\Delta V$ is zero,

$\Delta E = q$ (V = constant)

**Hess's Law** - (heat summation)

For any rxn that can be written as a series of steps, $\Delta H$ for the rxn is equal to the sum of the $\Delta H$'s of the steps.

The chief use of Hess's law is to calculate the enthalpy change for a reaction for which data cannot be determined experimentally or are otherwise unavailable.

**Thermochemical Equations** include the value of $\Delta H$.

The **standard heat of reaction** is the value of $\Delta H$ for a reaction occurriing under standard conditions (1 atm, 25°C) and involving the actual number of moles specified by the coefficients of the equation.

$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$ $\Delta H = -92.38kJ$

$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)} + 92.38\ kJ$

The above two thermochemical equations are for the **exothermic** reaction between nitrogen and hydrogen to form ammonia.

Rules for manipulating thermochemical equations:

1. When an equation is reversed (written in the opposite direction), the sign of $\Delta H$ must also be reversed.

   $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -394\ kJ$

   $CO_{2(g)} \rightarrow C_{(s)} + O_{2(g)}$ $\Delta H = +394\ kJ$

2. Formulas canceled from both sides of an equation must be for the substance in identical physical states.

3. If all the coeffecients if an equation are

- multiplied or divided by the same factor, the value of $\Delta H°$ must likewise be changed.

Carbon monoxide is used in metallurgy to remove oxygen from metal oxides and thereby give the free metal. Given the following two thermochemical equations:

$Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 2Fe_{(s)} + 3CO_{2(g)}$ $\quad \Delta H° = -26.7$ kJ

$CO_{(g)} + 1/2\ O_{2(g)} \rightarrow CO_{2(g)}$ $\quad \Delta H° = -283.0$ kJ

Determine $\Delta H°$ for the reaction:

$2Fe_{(s)} + 3/2\ O_{2(g)} \rightarrow Fe_2O_{3(s)}$

$2Fe_{(s)} + 3CO_{2(g)} \rightarrow Fe_2O_{3(s)} + 3CO_{(g)}$ $\quad \Delta H° = +26.7$ kJ

$3CO_{(g)} = 3/2\ O_{2(g)} \rightarrow 3CO_{2(g)}$ $\quad \Delta H° = -849.0$ kJ

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$Fe_{(s)} + 3/2\ O_{2(g)} \rightarrow Fe_2O_{3(s)}$ $\quad \Delta H° = -822.3$ kJ

## Standard Enthalpy of Formation-

The change in enthalpy that accompanies the formation of 1 mole of a compound from its elements with all substances in their standard states at 25°C.

Standard state is 1 atm, 25°C. (1 M for solutions)

The enthalpy change for a given reaction can be calculated by subtracting the enthalpies of formation of the reactants from the enthalpies of formation of the products.

$$\Delta H_{rxn} = \sum \Delta H_{(products)} - \sum \Delta H_{(reactants)}$$

The enthalpy of formation of elements is zero.

examples