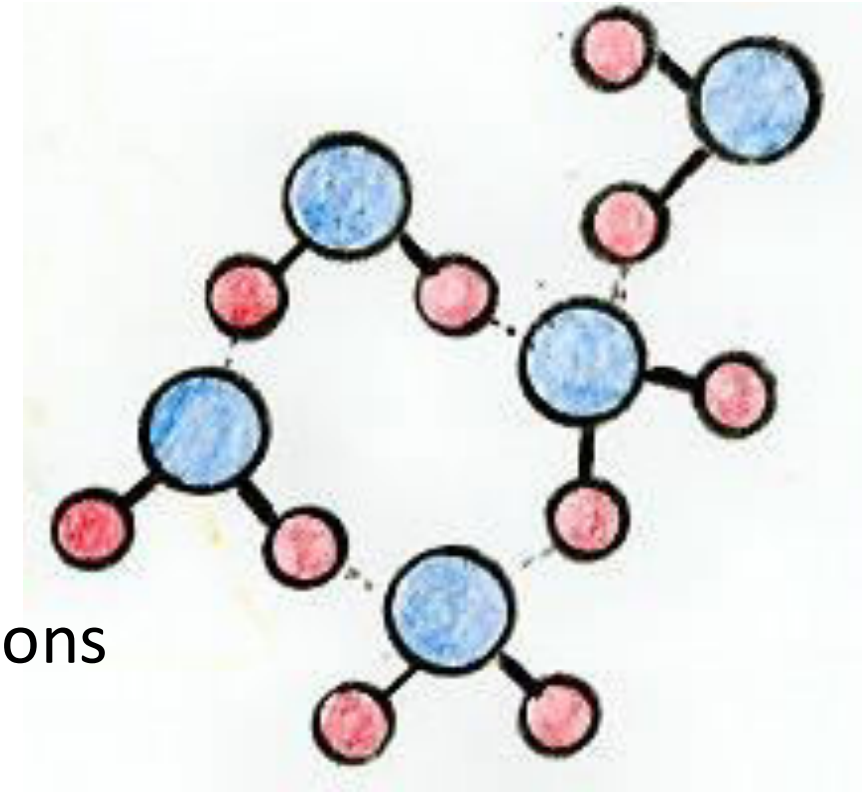
ENTHALPY AND HESS' LAW

ENTHALPY AND HESS' LAW

Chemical energy is stored in:

- moving electrons
- vibration of chemical bonds
- rotation and translation of molecules



- stored nuclear energy of protons & neutrons
- energy stored in chemical bonds

ENTHALPY AND HESS' LAW

Enthalpy

enthalpy (H) – total kinetic and potential energy of a system at a constant pressure

change in enthalpy (ΔH) – change in heat of a system

$$\Delta H = H_{final} - H_{initial}$$

$$\Delta H = H_{products} - H_{reactants}$$

ENTHALPY AND HESS' LAW

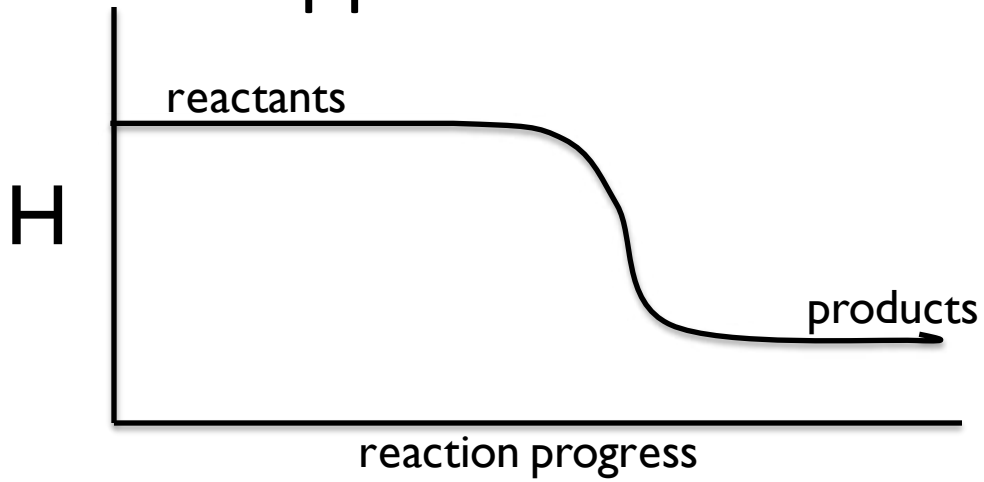
Enthalpy

For an exothermic reaction:

$$H_{products} \square H_{reactants}$$

$$\therefore \Delta H \text{ is negative}$$

Describe what has happened.



ENTHALPY AND HESS' LAW

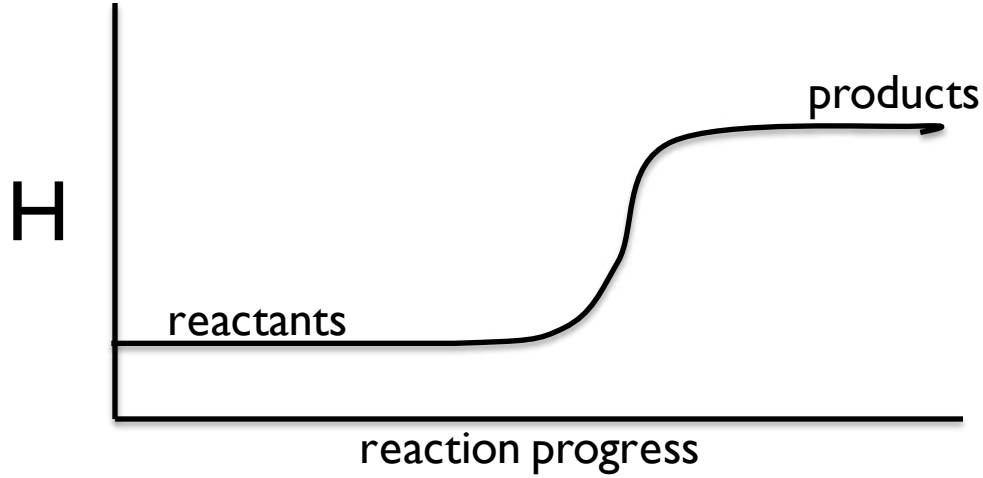
Enthalpy

For an endothermic reaction:

$$H_{products} \square H_{reactants}$$

$$\therefore \Delta H \text{ is positive}$$

Describe what has happened.



ENTHALPY AND HESS' LAW

Enthalpy

How does enthalpy relate to heat with respect to an isolated system?

$\Delta H = q$

when using a calorimeter.

What is the formula for q?

ENTHALPY AND HESS' LAW

Enthalpy

What is the formula for q?

$q =$ ☐

Since $q = \Delta H$

$\Delta H =$ ☐

ENTHALPY AND HESS' LAW

Enthalpy

How are enthalpy and heat related?

$\Delta H_{system} = -q$ _____ reaction

$\Delta H_{system} = +q$ _____ reaction

This is only true at constant pressure, which is always the case in a calorimeter.

Standard conditions for enthalpy changes: temperature at 298K (25ºC) and 100kPa

ENTHALPY AND HESS' LAW

Enthalpy

The enthalpy change for a balanced chemical reaction is constant.

This is called a thermochemical equation

e.g. $2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(g)}$ $\Delta H° = -483.6$ kJ

$\Delta H°$ – standard enthalpy of a reaction

– must be a balanced chemical equation

Read as - 483.6 kJ per 2 mol of H_2 being reacted.

ENTHALPY AND HESS' LAW

Enthalpy

$\Delta H°$ values are proportional to coefficient changes of a chemical equation.

$$N_2O_{4\,(g)} \rightarrow 2\,NO_{2\,(g)} \quad \Delta H° = +57.93\ kJ$$

$3\,N_2O_{4\,(g)} \rightarrow 6\,NO_{2\,(g)}$ $\Delta H° =$ ____

$\frac{1}{2}\,N_2O_{4\,(g)} \rightarrow NO_{2\,(g)}$ $\Delta H° =$ ____

ENTHALPY AND HESS' LAW

Enthalpy

$N_2O_{4\,(g)} \rightarrow 2\,NO_{2\,(g)}$ $\Delta H° = +57.93$ kJ

$2\,NO_{2\,(g)} \rightarrow N_2O_{4\,(g)}$ $\Delta H° =$ ____

Reversing a chemical reaction causes a sign change in front of the $\Delta H°$ value.

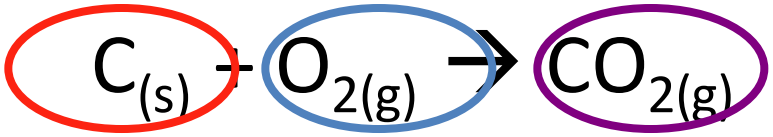
ENTHALPY AND HESS' LAW

Enthalpy

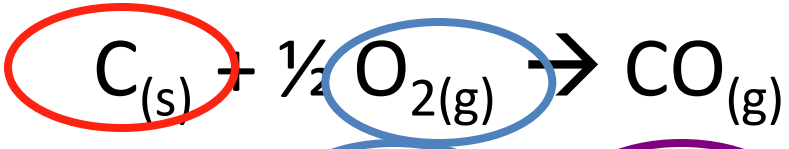
$\Delta H°$ values of unknown reactions can be solved when other known reactions are given.

ENTHALPY AND HESS' LAW

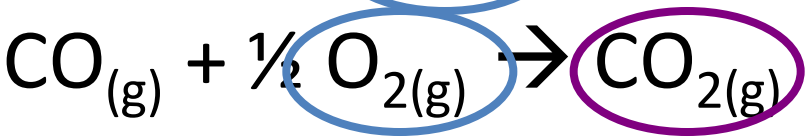
Example #1



$\Delta H° = ?$



$\Delta H° = -110.5$ kJ



$\Delta H° = -283.0$ kJ

What parts of the above reactions are the same as the first reaction?

ENTHALPY AND HESS' LAW

Rules for solving thermochemical equation questions:

For any reaction that can be written in steps, the $\Delta H°$ is the same as the sum of the values of the $\Delta H°$ for each individual step.

Hess's Law of Summation

ENTHALPY AND HESS' LAW

$\Delta H°$ Rules

1. If all the coefficients of an eq^n are multiplied or divided by a common factor, the $\Delta H°$ must be changed likewise.

$N_2O_{4\,(g)} \rightarrow 2\ NO_{2\,(g)}$ $\quad \Delta H° = +57.93$ kJ

$3\ N_2O_{4\,(g)} \rightarrow 6\ NO_{2\,(g)}$ $\quad \Delta H° = +57.93\text{kJ} \times 3$

$= +173.79$ kJ

$\frac{1}{2}\ N_2O_{4\,(g)} \rightarrow NO_{2\,(g)}$ $\quad \Delta H° = +57.93\text{kJ} \div 2$

$= +28.96$ kJ

$\Delta H°$ Rules

2. When a reaction is reversed, the sign of $\Delta H°$ must also be reversed.

$$N_2O_{4\,(g)} \rightarrow 2\,NO_{2\,(g)} \quad \Delta H° = +57.93\ kJ$$

$$2\,NO_{2\,(g)} \rightarrow N_2O_{4\,(g)} \qquad \Delta H° = -57.93\ kJ$$

ENTHALPY AND HESS' LAW

ΔH° Rules

3. When canceling compounds for Hess's Law, the state of the compounds is important.

$H_{2(g)} + ½\ O_{2(g)} \rightarrow H_2O_{(g)}$ $\Delta H° = +57.93\ kJ$

$K_2SO_{4(s)} + 2H_2O_{(l)} \rightarrow H_2SO_{4(aq)} + 2KOH_{(s)}$ $\Delta H° = +342.4kJ$

These two CANNOT cancel each other out

ENTHALPY AND HESS' LAW

Ex #1

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

$C_{(s)} + \frac{1}{2} O_{2(g)} \rightarrow \cancel{CO_{(g)}}$ $\Delta H° = -110.5$ kJ

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

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H° = -393.5$ kJ

The enthalpies are added together

Therefore the enthalpy is -393.5 kJ

ENTHALPY AND HESS' LAW

Ex #2

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

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

(2) $CO_{(g)} + ½\ O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H° = -283.0$ kJ

This is not as easy to do!

STEP 1: Number each given thermochemical equation.

ENTHALPY AND HESS' LAW

Ex #2

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

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

(2) $CO_{(g)} + ½\ O_{2(g)} \rightarrow CO_{2(g)} \quad \Delta H° = -283.0\ kJ$

- (1) $2\ Fe_{(s)} + 3\ CO_{2(g)} \rightarrow Fe_2O_{3(s)} + 3\ CO_{(g)} \quad \Delta H° = +26.7\ kJ$

(2) $CO_{(g)} + ½\ O_{2(g)} \rightarrow CO_{2(g)} \quad \Delta H° = -283.0\ kJ$

STEP 2: Arrange the equations so that your desired reactants are on the left side, and your desired products are on the right side

ENTHALPY AND HESS' LAW

Ex #2

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

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

(2) $CO_{(g)} + ½\ O_{2(g)} \rightarrow CO_{2(g)}\quad \Delta H° = -283.0\ kJ$

$-$ (1) $2\ Fe_{(s)} + 3\ CO_{2(g)} \rightarrow Fe_2O_{3(s)} + 3\ CO_{(g)}\quad \Delta H° = +26.7\ kJ$

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

STEP 3: Multiply the equations by factors such that they may match your desired equation. *Remember to multiply the enthalpy by the same factor.*

ENTHALPY AND HESS' LAW

Ex #2

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

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

(2) $CO_{(g)} + ½\ O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H° = -283.0$ kJ

- (1) $2\ Fe_{(s)} + 3\ CO_{2(g)} \rightarrow Fe_2O_{3(s)} + 3\ CO_{(g)}$ $\Delta H° = +26.7$ kJ

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

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

STEP 4: Add the two equations and enthalpies together. Remember to cancel repeating chemicals.

ENTHALPY AND HESS' LAW

Enthalpy

$H_2O_{(s)} \rightarrow H_2O_{(l)}$

What is happening?

Is a $\Delta H°$ value involved? Why or why not?

Heat is absorbed by the ice in order to melt.
$\Delta H°$ is positive, because heat is required

Enthalpy

Enthalpy is also involved in physical changes.