## Thermochemistry 1

Hess's Law
Heat of Formation
Heat of Combustion
Bond Enthalpy

## Hess's Law
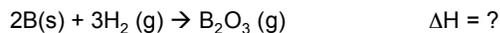
Want:
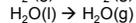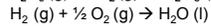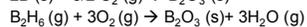
$C_{(graphite)} \rightarrow C_{(diamond)}$ $\Delta H = ?$

Given:

$C_{(graphite)} + O_2 \rightarrow CO_2$ $\Delta H = -394$ KJ
$C_{(diamond)} + O_2 \rightarrow CO_2$ $\Delta H = -396$ KJ

## Hess's Law

Want:

$2B(s) + 3H_2 (g) \rightarrow B_2O_3 (g)$ $\Delta H = ?$

Given:

$2B (s) + 3/2 O_2 (g) \rightarrow B_2O_3 (s)$ $\Delta H = -1273$ KJ
$B_2H_6 (g) + 3O_2 (g) \rightarrow B_2O_3 (s) + 3H_2O (g)$ $\Delta H = -2035$ KJ
$H_2 (g) + \frac{1}{2} O_2 (g) \rightarrow H_2O (l)$ $\Delta H = -286$ KJ
$H_2O(l) \rightarrow H_2O(g)$ $\Delta H = 44$KJ
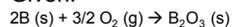
## Standard Enthalpy of Formation $(\Delta H_f)$

- **Standard _____ of Formation** - enthalpy change when one mole of a substance is formed from its elements, in their standard states, under standard conditions.

- Write equations to represent the following processes.
  - The standard enthalpy of formation of $CH_3Br$
  - The standard enthalpy of formation of $CH_3COC_2H_5$
  - The standard enthalpy of formation of $CaCO_3$

- All elements and diatomic molecules are assigned a value for enthalpy of formation equal to _____ .

- $\Delta H_f$ may be negative or positive, if the enthalpy change is negative then energy is released and the reaction is _____ , if it is positive then energy is taken in and it is _____ .

## Standard Enthalpy of Formation ($\Delta H_f$)

- What is the $\Delta H_f$ for $CuCl_2$ (s)?

- What is the $\Delta H_f$ for 2 moles of $FeCl_3$ (s)?

- Remember, these are heats of FORMATION which means that the compound is being produced. If it on the reactant side, you must _____ the sign!

## Standard Enthalpy of Formation ($\Delta H_c$)

- **Standard Enthalpy of Combustion** - enthalpy change when one mole of a substance is completely burned in oxygen under standard conditions.

- Energy is usually released in such a reaction $\Delta H_c$, so it will usually be negative.

- $\Delta H_c$ [$C_2H_6$(g)] = - 1565 kJ/mol means…

## Write the following Equations

- The standard enthalpy of combustion of $CH_4$ (g)

- The standard enthalpy of combustion of Al(s)

## Example 1 (do not use Appendix)

- Calculate the standard enthalpy of formation of ethane ($C_2H_6$), given the following combustion data…
- C(graphite) = -393 kJ/mol
- $H_2$(g) = -286 kJ/mol
- $C_2H_6$(g) = -1560 kJ/mol

## Example 2
### (do not use appendix)

- Calculate the standard enthalpy of combustion of propan-2-ol ($CH_3CH(OH)CH_3$), given the following data
- Enthalpies of combustion for C(graphite) = -393 kJ/mol and $H_2$(g) = -286 kJ/mol.
- Enthalpy of formation of propan-2-ol = -318 kJ/mol

## Examples

- Calculate the $\Delta H$ for the following reaction using the appendix
- $C_3H_8$ (g) + $5O_2$ (g) $\rightarrow$ $3CO_2$ (g) + $4H_2O$ (l)

- Is the reaction endothermic or exothermic? Why?

## Examples

- How much heat will be released from the combustion of 1.80 g of $C_6H_6$. Use the heat of formation data in the appendix.

## Example

- The Thermite reaction can be used to produce molten iron for welding railway tracks together.
- $Fe_2O_3$(s) + 2Al(s)  $Al_2O_3$(s) + 2Fe(s)
- Calculate the enthalpy change in the Thermite reaction, given the standard enthalpies of formation of iron (III) oxide and aluminum oxide are -823 and -1675 kJmol[-1], respectively.

## Bond Enthalpies

- The strength of the bond in a diatomic covalent molecule is given by the bond dissociation energy.

- For example hydrogen, $H_2$ or H-H

- $H_2(g) \rightarrow 2H(g)$          BDE= +436 kJ

## Bond Enthalpies

- In order to **break** a bond, **energy must be put in** (an **_____** process with a **_____** energy change)

- When **making** a bond, **energy is released** (an **_____** process with a **_____** energy change).

## Bond Enthalpy Example 1

- Calculate the standard enthalpy of the reaction below.
- $CH_3CH=CH_2 + H_2 \rightarrow CH_3CH_2CH_3$

## Bond Energy Data

| Bond | BET in kJmol⁻¹ |
|------|------|
| F-F | 154 |
| C=O | 743 |
| O-H | 463 |
| Br-Br | 193 |
| C-Br | 276 |
| H-Br | 366 |
| Cl-Cl | 239 |
| C-O | 360 |
| H-H | 436 |
| C-C | 348 |
| C-Cl | 339 |
| C-H | 412 |
| C=C | 612 |
| H-F | 565 |
| H-Cl | 427 |
| C-F | 485 |
| I-I | 151 |
| C-I | 238 |
| C≡C | 837 |
| C-N | 305 |
| H-I | 299 |

## Bond Enthalpy Example 2

- Calculate the enthalpy change for the reaction below.
- $CH_3CH=CH_2 + Br_2 \rightarrow CH_2BrCHBrCH_3$

## Bond Energy Data

| Bond | BET in kJmol$^{-1}$ |
|---|---|
| F-F | 154 |
| C=O | 743 |
| O-H | 463 |
| Br-Br | 193 |
| C-Br | 276 |
| H-Br | 366 |
| Cl-Cl | 239 |
| C-O | 360 |
| H-H | 436 |
| C-C | 348 |
| C-Cl | 339 |
| C-H | 412 |
| C=C | 612 |
| H-F | 565 |
| H-Cl | 427 |
| C-F | 485 |
| I-I | 151 |
| C-I | 238 |
| C≡C | 837 |
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