Thermodynamics

Topics

1st law of thermodynamics
Power
Calculating enthalpy
Bond energies
Hess's Law

1st Law of thermodynamics

- Energy can not be created nor destroyed just transferred from one form to another.
- Total energy in the universe is constant
- Heat (q) and work (w)
  - Two ways energy can enter or leave a system
  - Energy can leave a Car by either moving the car or releasing heat.

power from engines

- Total energy from an engine or piston must remain constant.
- Internal energy = total energy

$$E = q + w$$

- E = total internal energy
- q = heat

Calculating Enthalpy

- How do you mathematically calculate the amount of energy given off in a chemical reaction.

Measure the energy of each side
The difference between them is the
The energy released or absorbed

2H2 + O2 = 2H2O

P - R

Formation from elements

How do you measure absolute energy?

Not easy? Measuring relative energy is easier!

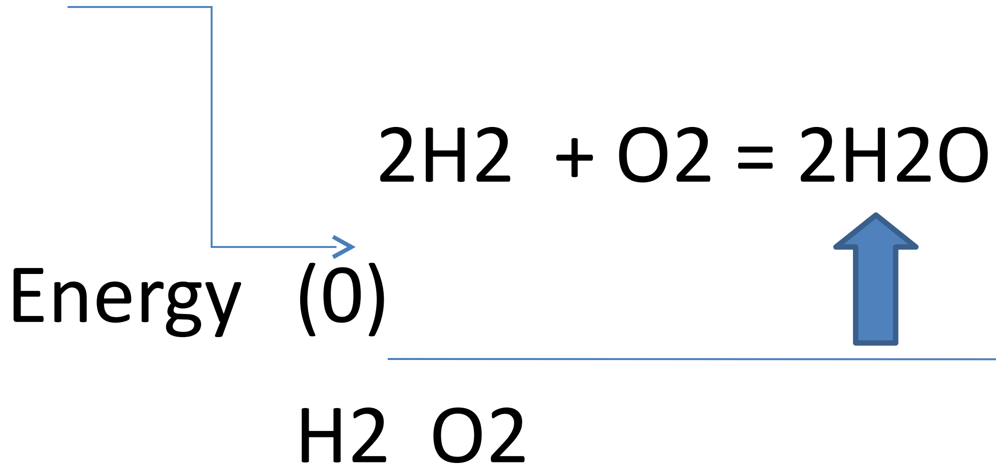
-- Determine the amount of energy needed to produce both reactants and products from elements. **Common measuring point.**

H_2 O_2

$$2H_2 + O_2 = 2H_2O$$

ΔHf

It takes zero energy to go from element to element.



- In your workbook you will find ΔHf values. Based on formation form elements.

HOW DO YOU USE THIS DATA TO CALCULATE ΔH?

State Function

- A state function is any mathmatical process were you are concerned with the start and finish only.
- Final – Initial

- This chapter contains several calculations that are state functions. The next calculation is called Entropy. Which is a state function.

Calculating ΔH

$$2H_2(g) + O_2(g) = 2H_2O(g)$$

ELEMENT	ΔHf Kj/mol
H_2	0
O_2	0
$H_2O(g)$	-228.6

$$\Delta H = \sum P - \sum R$$

$$(2)(-228.6) - (2(0) + (0)$$

$$\Delta H = -457.2KJ$$

Bond energies

- Bond formation: Releases energy
  - Forms a new lower energy state releasing energy
- Bond breakage: absorbs energy
  - Energy must be added to break bond.

- Bonds broken – Bonds formed = ΔH

Bond Energies

$2H_2 + O_2 \rightarrow 2H_2O$

Broken

2 H-H

1 O=O

Formed:

4 O-H

Bonds broken – Bonds formed = ΔH

In your workbooks look up the valued of the bonds and perform the calculation…

Bond Energies Question

- What is the energy release from 100 grams of Propane (C-C-C). Before you start determine Enthalpy using the bond energies

C3H8 + 5O2 => 3CO2 + 4H2O

C3H8	5O2	3CO2	4H2O
H–C = 99 (8)	O=O = 119(5)	C=O (CO2) = 192 (6)	H–O = 111 (8)
C–C = 83(2)			

AP Question

$$H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g)$$

Based on the information given in the table below, what is $\Delta H°$ for the above reaction?

Bond	Average Bond Energy (kJ/mol)
H–H	440
Cl–Cl	240
H–Cl	430

(A) –860 kJ
(B) –620 kJ
(C) –440 kJ
(D) –180 kJ
(E) +240 kJ

Hess’s Law

- **Hess's Law**
- ***if a reaction is carried out in a series of steps, ΔH for the reaction will be equal to the sum of the enthalpy changes for the individual steps.***

Step 1 releases “-x” energy
<u>Step 2 absorbes “+2x” energy</u>
2x + -x = x (add steps)
Overall reaction absorbes x energy

Hess's Law Example

- $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ ΔH = ?

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \quad \Delta H = -802kJ$$

$$2H_2O(g) \rightarrow 2H_2O(l) \quad \Delta H = -88kJ$$

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ = -890kJ

NOTE: Reactions must add up to overall reaction. You may need to manipulate reaction for this to happen. Addition of reaction will give overall. One could also determine ΔH of elementary step if all other steps are known.

How does manipulating a reaction affect ΔH?

- Reversing the reaction?
  - ΔH This will cause the sign on ΔH to be reversed.
  - Energy in = energy out
- Multiplying/dividing the coefficients
  - If you double all the coefficients than the ΔH will also double.
- Hint: When manipulating a reaction I always try to make sure reactants and products are on the right sides first before I start changing

Typical Hess's Law problem

- Carbon occurs in two forms: graphite and diamond. The enthalpy of combustion of graphite is -393.5 kJ, and that of diamond is -395.4 kJ
- C(graphite) + O2(g) -> CO2(g) Δ H = -393.5 kJ
- C(diamond) + O2(g) -> CO2(g) Δ H = -395.4 kJ
- Calculate ΔH for the conversion of

$$C(graphite) \rightarrow C(diamond)$$

How do you solve this problem… See next slide!!

Calculate ΔH for the conversion of graphite to diamond

C(graphite) ↔ C(diamond)

1st you must rearrange you elementary reactions so they add up to desired reaction.

Old reactions

- C(graphite) + O2(g) -> CO2(g) Δ H = -393.5 kJ
- C(diamond) + O2(g) -> CO2(g) Δ H = -395.4 kJ

Rearrange reactions… you can either flip or multiply coefficients….. Give it a try!

Answer

<u>Old reactions</u>

C(graphite) + O_2(g) -> CO_2(g) Δ H = -393.5 kJ

C(diamond) + O_2(g) -> CO_2(g) Δ H = -395.4 kJ

New reactions

C(graphite) + O_2(g) -> CO_2(g) Δ H = -393.5 kJ

1.9KJ/mol

<u>CO_2(g) -> C(diamond) + O_2(g)Δ H = +395.4 kJ</u>

C(graphite) -> C(diamond) Δ H =