Announcements – 10/20/00

- ***Exam#2***
  - grading to be done later today
  - solution key will be online soon after
  - *post mortem* on Monday . . .

- ***Chapter 4***
  - assigned problems coming online soon!

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Using Enthalpies of Formation

- Hess's Law and tablulated ΔH^o_f values are a powerful tool for predicting enthalpy changes for reactions:

$$\Delta H^o = \Sigma\, \Delta H^o_f \text{ (products)} - \Sigma\, \Delta H^o_f \text{ (reactants)}$$

Example: *The Thermite Reaction*

$$8\ Al(s) + 3\ Fe_3O_4(s) \rightarrow 4\ Al_2O_3\ (s) + 9\ Fe(s)$$

We know: $\Delta H^o_f\ (Fe_3O_4) = -1120.9$ kJ

$\Delta H^o_f\ (Al_2O_3) = -1669.8$ kJ

So:

$$\Delta H^o = [4(-1669.8 \text{ kJ/mol}) + 9(0)] - [3(-1120.9 \text{ kJ/mol}) + 8(0)]$$

$\Delta H^o = (-6679.2$ kJ$) - (-3362.7) =$ ***-3316.5 kJ***

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Demo Example: Burning Mg

- The overall reaction is:

$$2\ Mg(s) + CO_2(s) \rightarrow 2\ MgO(s) + C(s)$$

ΔH^o_f : ***0*** ***??*** ***-601.70*** kJ/mol ***0***

How do we find ΔH^o_f for *SOLID* CO_2?

Use Hess's Law!

<u>We know:</u> ΔH^o_f for $CO_2(g)$ = -393.51 kJ/mol

But how do we deal with *phase changes?*

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Enthalpies of Phase Changes

- There are enthalpy changes associated with *physical processes*:

$CO_2(s) \rightarrow CO_2(l)$ ΔH_{fusion} = 6.01 kJ/mol

$CO_2(l) \rightarrow CO_2(g)$ ΔH_{vap} = 44.01 kJ/mol

So:

$CO_2(s) \rightarrow CO_2(g)$ $\Delta H_{sublimation} = \Delta H_{fusion} + \Delta H_{vap}$

$\Delta H_{sublimation}$ = 50.02 kJ/mol

We want:

$CO_2(g) \rightarrow CO_2(s)$ $\Delta H = -\Delta H_{sub}$ = -50.02 kJ/mol

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Putting it all together

- So, to get ΔH^o_f for $CO_2(g)$:

$C(s) + O_2(g) \rightarrow CO_2(g)$ ΔH^o_f = -393.51 kJ/mol
$CO_2(g) \rightarrow CO_2(s)$ ΔH = -50.02 kJ/mol

Adding gives:

$C(s) + O_2(g) \rightarrow CO_2(s)$ ΔH^o_f = -443.53 kJ/mol

And, finally:

$2\ Mg(s) + CO_2(s) \rightarrow 2\ MgO(s) + C(s)$

ΔH^o_f : ***0 -443.53 kJ/mol -601.70 kJ/mol 0***

ΔH^o_{rxn} = 2(-601.70 kJ/mol) - (-443.53 kJ/mol) = ***-759.87 kJ***

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Bond Enthalpies

- Armed with Hess's law and ΔH^o_f values, let's dissect the reaction process (i.e., the energetics of bond *making* and *breaking*):

For CH_4 (methane):

We know: $C(s) + 2\ H_2(g) \rightarrow CH_4(g)$ ΔH^o_f = -74.9 kJ/mol

- We *want* to know: the ***bond enthalpy*** for the C-H bond

So, look at the reverse reaction:

$CH_4(g) \rightarrow C(g) + 4\ H(g)$ ΔH = 4 x C-H bond enthalpy

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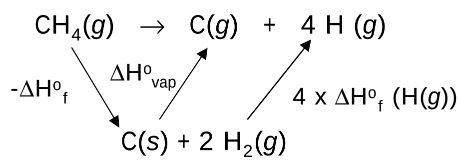
Hess's Law to the rescue

- We want to do this:

Enthalpy Cycle



$CH_4(g) \rightarrow C(s) + 2\ H_2(g)$	$-\Delta H^o_f = -(-74.9\ kJ)$
$C(s) \rightarrow C(g)$	$\Delta H^o_{vap} = 718.4\ kJ$
$2\ H_2(g) \rightarrow 4\ H(g)$	$4 \times \Delta H^o_f = 4(217.9\ kJ)$
$CH_4(g) \rightarrow C(g) + 4\ H\ (g)$	*1664.9 kJ*

So, **C-H bond enthalpy** = 1664.9 kJ/4 = ***416.2 kJ***

Bond Enthalpies: What good are they?

- They indicate how *strong* a bond is:

N≡N	946 kJ/mol
H-H	436 kJ/mol

In general: ≡ > = > -

- If we assume that bond enthalpies for a particular bond are constant in all compounds, then we can use them to estimate ΔH_{rxn}:

$\Delta H_{rxn} = \sum$ Reactant Bond Enthalpies - $\sum$ Product Bond Enthalpies

(energy added to break bonds) (energy released by making bonds)

-This works well if there are no intermolecular forces (i.e., in the gas phase!)

The Electronic Structure of Atoms

- First, we must consider the properties of

<u>Electromagnetic Radiation (EMR)</u>

Why? (flame emission movie)

•So, just what is **EMR?**

- an *oscillating* electric and magnetic field which travels through space

- a discrete series of "particles" that possess a specific energy but have no mass

BOTH!

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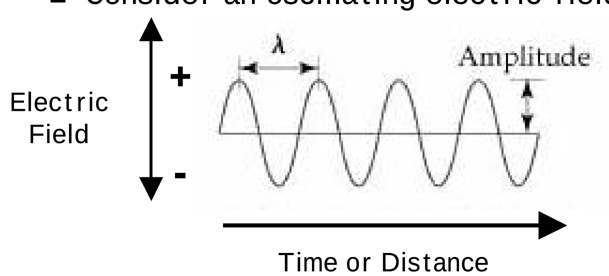
It's a Wave!

- Consider an oscillating electric field:



<u>Characterized by</u>: λ - wavelength

a - amplitude

ν - frequency

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Wave Properties of EMR

- The product of λ and ν is constant:

$$\lambda \times \nu = c$$

Since ν has units of sec^{-1} and λ has units of length, their product, c, is the *velocity* of the wave:

-in a vacuum, *all EMR* travels at a velocity of:

2.99792458 x 10⁸ m/s (= c)

("The Speed of Light")

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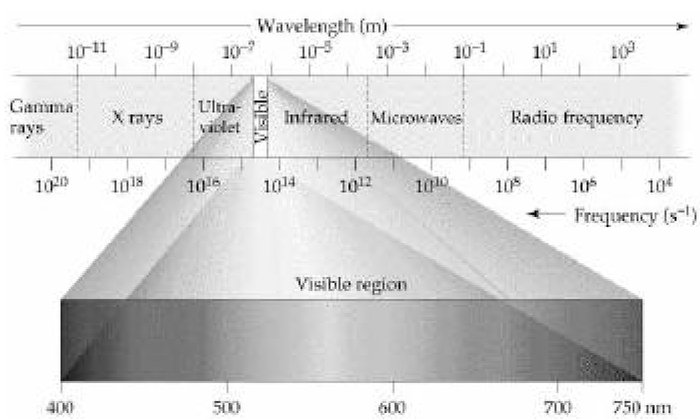
The Electromagnetic Spectrum

- The range of wavelengths and frequencies of EMR is extraordinary:



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