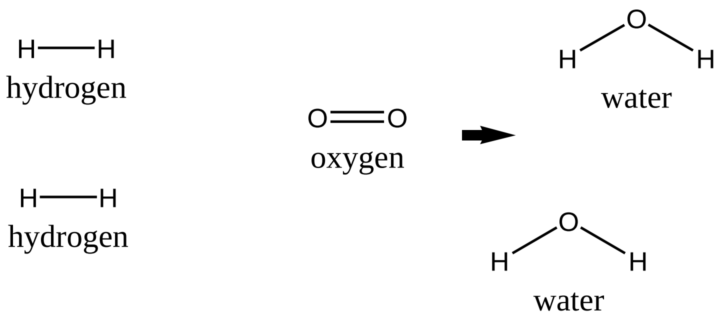
<u>Exercises</u>

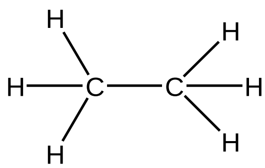
1. Estimate ΔH for each of the following using the given table of bond energies:

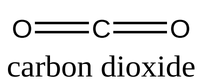
   a) $2H_2 + O_2 \rightarrow 2\ H_2O$



ΔH_{bb}	ΔH_{bf}	$\Delta H = \Delta H_{bb} + \Delta H_{bf}$
2(436)+498 = 1370 kJ	2(2)(-464)= -1856	1370 kJ-1856kJ= -490 kJ

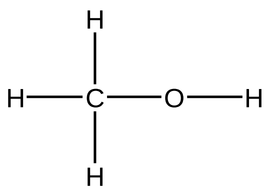
   b) $C_2H_6 + 3.5\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$





ΔH_{bb}	ΔH_{bf}	$\Delta H = \Delta H_{bb} + \Delta H_{bf}$
6(414)+1(347) +3.5(499)=	2(2)(-745)+3(2)(-464)=	= - 1204KJ

c) $2\ CH_3OH + 3\ O_2 \rightarrow 2\ CO_2 + 4\ H_2O$



ΔH_{bb}	ΔH_{bf}	$\Delta H = \Delta H_{bb} + \Delta H_{bf}$
2(3)C—H + 2(O---C) + 2(O---H)+3 O=O =2(3)(414)+(2) (335) +2(464) +3(494)	2(2)(-745) +4(2)(-464)=	-1128kJ

2. *a) Without* consulting a table of bond energies, find the bond energy of

   H--Cl *on a per mole basis* if H_2's and Cl_2's bond energies are 436 kJ/mole and 243 kJ/mole, respectively, and the ΔH for the following reaction is -185 kJ/mole of H_2

   $H_2 + Cl_2 \rightarrow 2\ HCl$

   $\Delta H = \Delta H_{bb} + \Delta H_{bf}$ =436+243+2(-x)=-185, where x = bond energy of 1 mole of HCl

   x = 432 kJ/mole HCl

   b) Convert H_2 's bond energy to kJ/g

   436 kJ/mole H_2 , but 1 mole of H_2 = 2.02 g =436 kJ/2.02 g = 216 kJ/g

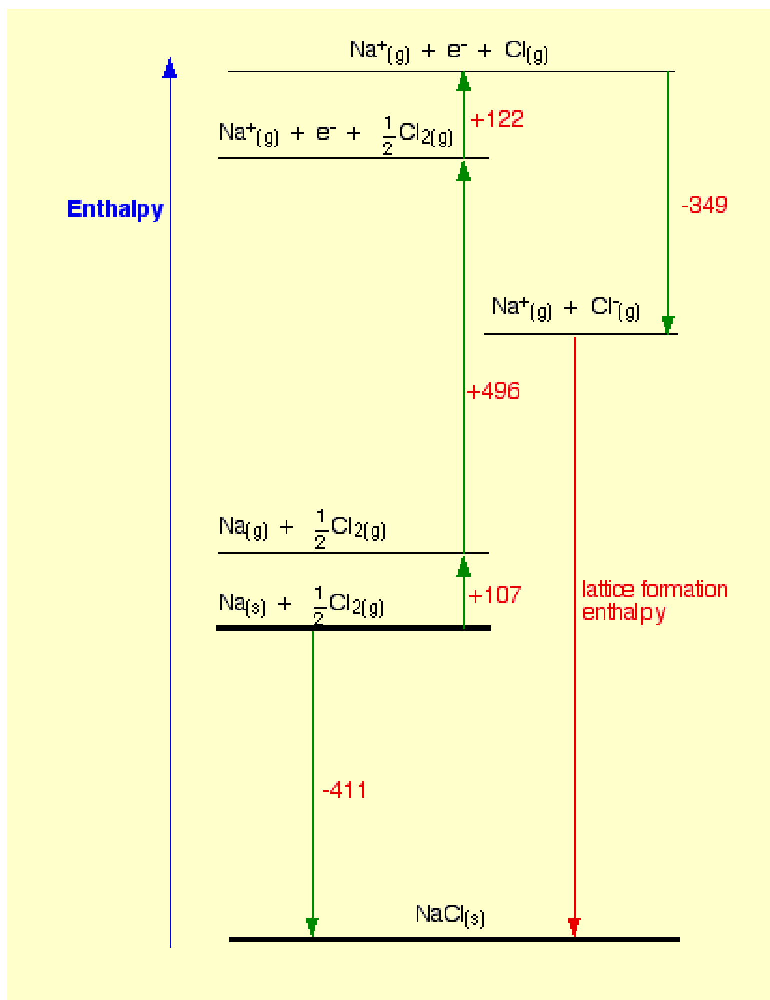
c) Show an energy- reaction profile (energy diagram) for $H_2 + Cl_2 \rightarrow 2HCl$

in terms of ΔH_{bb} and ΔH_{bf}

3. Why is H---Cl 's bond energy greater than that of H---Br?

   Hint: periodic trends.

Since Cl is more electronegative than Br, it will pull electrons from the bonded H closer to itself, which lowers its potential energy. Just like it takes more energy to raise something from a relatively lower shelf(compared to HBr) to a higher shelf, it will take more energy to then separate the H from the Cl. Hence HCl's bond energy is higher then HBr's.

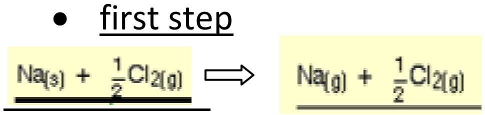


4. a) Explain why the first 3 steps of the salt-producing reaction are endothermic.
   b) Why are the last two steps are exothermic?

   c) Use algebra to show that the overall reaction is indeed $Na_{(s)} + ½\ Cl_{2(g)} \rightarrow NaCl_{(s)}$

A)

- first step



The Na is sublimating; endo

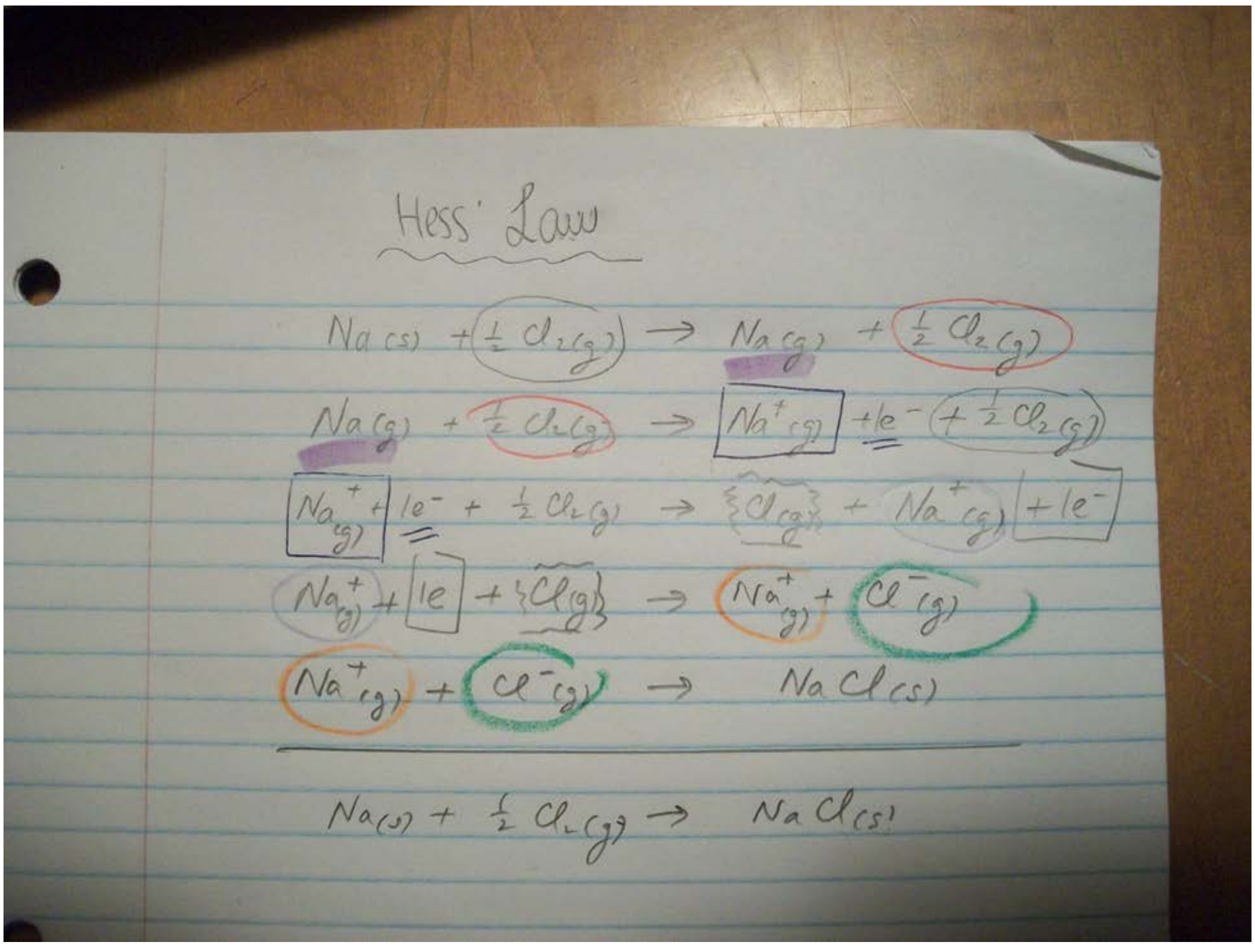
- The second step: the sodium gas is getting ionized. The electron is being separated from the atom. (like ionization energy)

- Third step: Cl_2 's bond is being broken.

b)

- Fourth step: electron is being captured by chlorine (similar to bonding and opposite of ionization)
- Fifth step: the sodium and chloride ions are coming closer together and bonding

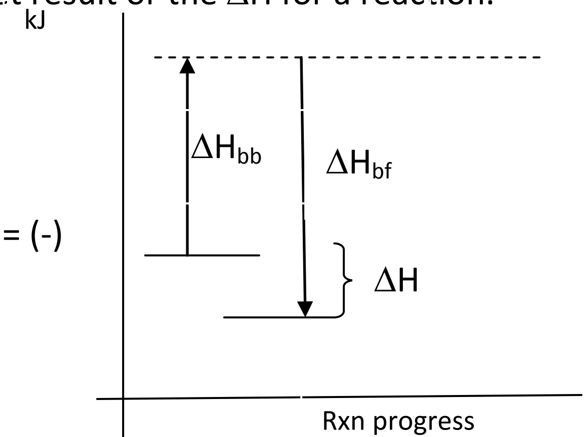
c)



Notes:

Estimating ΔH From Bond Energies

It takes energy to break old bonds but energy is released when new bonds are formed. If we could do the chemical accounting and sum up what's invested and what the returns are, we could estimate the net result or the ΔH for a reaction.



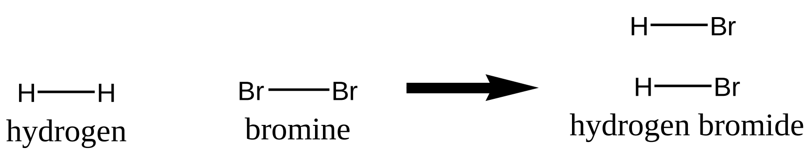
Important reminder:

Energy invested to break bonds; ΔH_{bb} = (+)

Energy released when bonds are formed; ΔH_{bf} = (-)

Example 1: Estimate the ΔH per mole of H_2 for the following reaction:

$H_2 + Br_2 \rightarrow 2\,HBr$



progress

ΔH_{bb}	ΔH_{bf}	$\Delta H = \Delta H_{bb} + \Delta H_{bf}$
436 kJ + 193 kJ = 629 kJ	-366kJ*2 = -732 kJ	-732 kJ + 629 kJ= -103 kJ

Table of Bond Energies to consult:

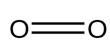
Average bond energies, kJ/mol:

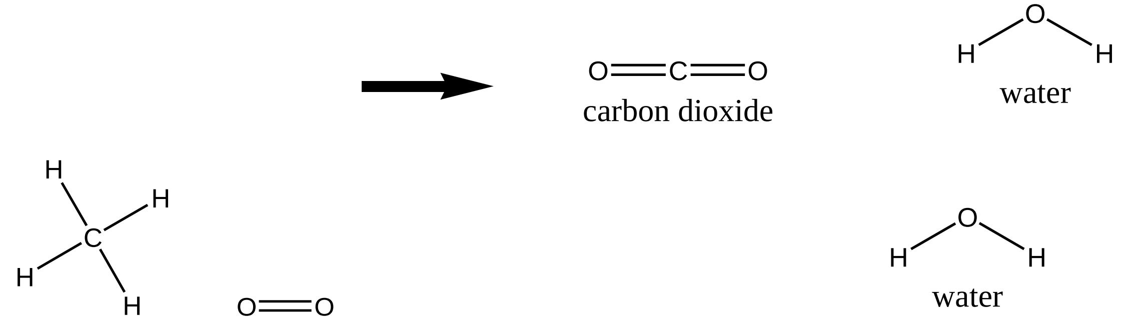
H—H	436	C—H	414	N—N	159	P—H	318
H—F	570	C—O	335	N=N	418	P—Cl	326
H—Cl	432	C=O	745	N≡N	941	S—H	339
H—Br	366	C≡O	1075	N—F	270	Cl—Cl	243
H—I	298	C—F	485	N—Cl	201	Br—Br	193
C—C	347	C—Cl	326	O—O	138	Br—Cl	218
C=C	619	C—Br	285	O=O	494	I—I	151
C≡C	812	C—I	239	O—H	464		
C—N	293	N—H	389	F—F	159		
C=N	515	N—O	175	F—Cl	256		
C≡N	891	N=O	590				

Example 2: Estimate the ΔH for the following reaction. Again consult the bond energies table on the previous page:

$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

Lewis Structures





ΔH_{bb}	ΔH_{bf}	$\Delta H = \Delta H_{bb} + \Delta H_{bf}$
4(413)+2(498) = 2648 kJ	2(-745)+4(-460)= -3330 kJ	2648 kJ-3330 kJ = -680 kJ

<u>Example 3</u> Show an energy- reaction profile(energy diagram) for an endothermic reaction in terms of ΔH_{bb} and ΔH_{bf}

Dalton's Law of Partial Pressures

If there are two or more gases in a container, the total pressure is the sum of the individual pressures of the various gases:

$P_T = P_1 + P_2 + \ldots$

Consider two gases A and B in a container at the same temperature.

> $P_T = P_A + P_B$ where P_A is the partial pressure of gas A(partial pressure is the gas' individual contribution to the total pressure)

If we know n_A and $n_{B,}$ is there a way we could calculate P_A from P_T, n_A and n_B?

$$P_A = (n_A/n_T)(P_T)$$

Use PV = nRT to derive this formula.

$P_AV = n_ART$

$P_TV = n_TRT$

Divide these two equations, simplify and isolate P_A:

$$\frac{P_AV}{P_TV} = \frac{n_ART}{n_TRT}$$

$$\frac{P_A}{P_T} = \frac{n_A}{n_T}$$

$$P_A = \frac{n_A}{n_T}P_T$$

Example 1 While kept at a constant temperature, a gas mixture contains the following:

n	gas
0.340	H_2
5.55	He
2.10	Ar

The manometer attached to the container containing the mixture reads 233 kPa. Find the partial pressure of each gas.

$$P_A = \frac{n_A}{n_T} P_T$$

$$P_{H2} = \frac{n_{H2}}{n_T} P_T$$

$$P_{H2} = \left[\frac{0.34}{0.34 + 5.55 + 2.10}\right] 233\ kPa$$

=9.9 kPa

Repeat for other gases; P_{He} = 162 kPa; P_{Ar} = 61 kPa

Example 2 Since equal volumes of ideal gases contain the same number of moles under the same conditions of P and T, % volumes of gases are directly proportional to mole fractions.

With this in mind, find the partial pressure of oxygen in air at STP.

Air is 21% O_2 by volume.

n_{O2} = 0.21

P_T = 101. 3 kPa at STP

$$P_A = \frac{n_A}{n_T} P_T$$

$$P_{O2} = \frac{n_{O2}}{n_T} P_T = \frac{0.21}{1} 101.3 = 21\ kPa$$

Exercises

1. A balloon contains 0.100 moles of oxygen and 0.400 moles of nitrogen. If the balloon is at standard temperature and pressure, what is the partial pressure of the nitrogen?

$$P_{N2} = \frac{n_{N2}}{n_T} P_T = \frac{0.400}{0.100 + 0.400} 101.3 = 81.0\ \ kPa$$

2. The pressure of a mixture of nitrogen, carbon dioxide, and oxygen is 150.0 kPa. What is the partial pressure of oxygen if the partial pressures of the nitrogen and carbon dioxide are 100.0 kPa and 24.0 kPa, respectively?

$$P_T = P_{N2} + P_{O2} + P_{CO2}$$
$$150.0 = 100.0 + 24.0 + P_{CO2}$$
$$P_{CO2} = 26.0\ kPa$$

3. A gaseous mixture made from 10.0 g of oxygen and 15.0 g of argon is placed in a 8.00 L vessel at 25.2^oC. What is the partial pressure of each gas, and what is the total pressure in the vessel?

10.0 g O_2/(32.0g/mole)= 0.3125 mole O_2

15.0 g Ar/(39.9g/mole)= 0.376 mole Ar

$P_TV = n_TRT$

P_T(8.00)= (0.3125+0.376)*8.31(273+25.2)

P_T = 213 kPa

$$P_{O2} = \frac{0.3125}{0.376} 213.26 = 96.8\ kPa$$

$P_{Ar=}P_T - P_{O2=}$213 - 96.8= 116 kPa

4. a) 0. 888 L of “wet”oxygen (this implies that it’s mixed with water vapour) are collected at a temperature of 25.0 ^oC. The total pressure of the gases is 99.8 kPa. What is the partial pressure of the dry O_2? The partial pressure of water at 25.0^o C is 3.17 kPa.

   b) How many grams of water are in the 0. 888 L mixture?

a) $P_{O2=}\ P_T - P_{H2O=}$99.8 – 3.17= 96.6 kPa

   b) $P_TV = n_TRT$

   99.8(0.888) = n_T(8.31)(25+273)

   $n_{T=}$ 0.03578 moles

$$P_{H2O} = \frac{n_{H2O}}{n_T} P_T$$

$$3.17 = \frac{n_{H2O}}{0.03578} 99.8$$

n = 0.001136 moles of water(18g/mole) = 0.0204 g of water