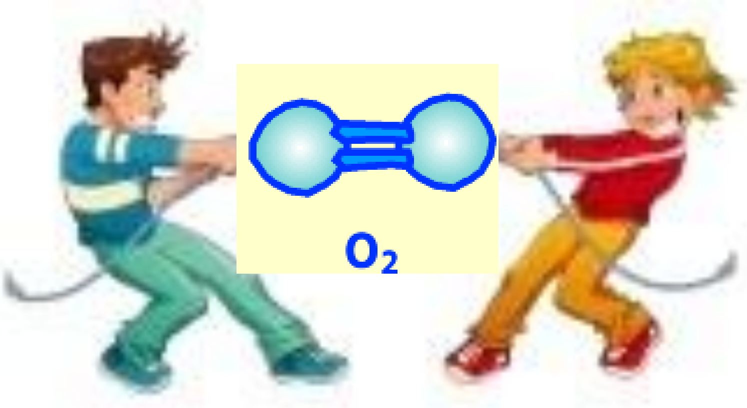
Bond Energies

Chapter 5.3

Bonds and Energy

- Breaking chemical bonds *requires* energy



- Forming chemical bonds *releases* energy

- The amount of energy required or released for a chemical process depends on the **number** and **types** of bonds that are formed and broken

Bond Dissociation Energy

- **Bond dissociation energy** is the energy required to break a given chemical bond
- The bond dissociation energy of a given bond is complex as it depends on the types of atoms and bonds in the same molecule

Process	Energy Required (kJ/mol)
$CH_4(g) \rightarrow CH_3(g) + H(g)$	435
$CH_3(g) \rightarrow CH_2(g) + H(g)$	453
$CH_2(g) \rightarrow CH(g) + H(g)$	425
$CH(g) \rightarrow C(g) + H(g)$	339
	Total = 1652

- For this reason, the use of an **average bond energy** is more convenient for predicting enthlapy changes in chemical reactions

$$\text{Average} = \frac{1652}{4} = 413$$

- The units for average bond energy are kJ/mol, so this tells us that if we want to break one mole of C-H bonds into one mole of C atoms and one mole of H atoms it would take 413kJ of energy

Average Bond Energies

Table 1 Average Bond Energies (kJ/mol)

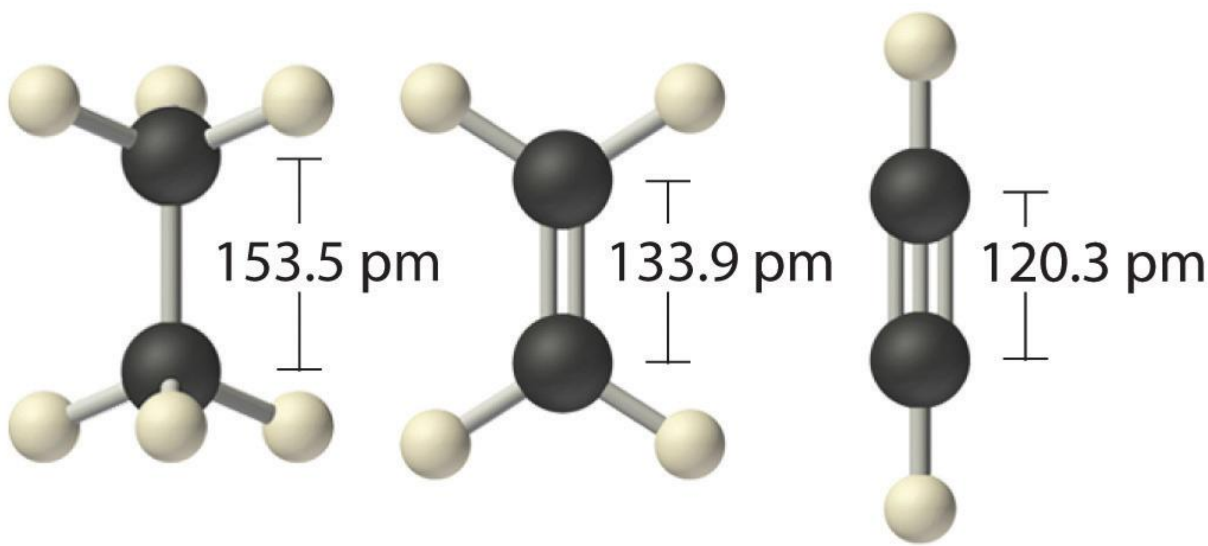
Single bonds			Multiple bonds
H–H 432	N–H 391	I–I 149	C=C 614
H–F 565	N–N 160	I–Cl 208	C≡C 839
H–Cl 427	N–F 272	I–Br 175	O=O 495
H–Br 363	N–Cl 200	S–H 347	C=O* 745
H–I 295	N–Br 243	S–F 327	C≡O 1072
C–H 413	N–O 201	S–Cl 253	N=O 607
C–C 347	O–H 467	S–Br 218	N=N 418
C–N 305	O–O 146	S–S 266	N≡N 941
C–O 358	O–F 190	Si–Si 340	C≡N 891
C–F 485	O–Cl 203	Si–H 393	C=N 615
C–Cl 339	O–I 234	Si–C 360	
C–Br 276	F–F 154	Si–O 452	
C–I 240	F–Cl 253		
C–S 259	F–Br 237		
	Cl–Cl 239		
	Cl–Br 218		
	Br–Br 193		

*C=O in $CO_2(g)$=799

- Average bond energies are published in tables like the one on page 307 of your textbook

Multiple Bonds

- Multiple bonds tend to be shorter and stronger than single bonds



C_2H_6 C_2H_4 C_2H_2

Multiple Bonds

Table 2 Bond Lengths of Some Common Bonds

Bond	Bond type	Bond length (pm)	Bond energy (kJ/mol)
C–C	single	154	347
C=C	double	134	614
C≡C	triple	120	839
C–O	single	143	358
C=O	double	123	745
C–N	single	143	305
C=N	double	138	615
C≡N	triple	116	891

Enthalpy and Bond Energies

$$\Delta H = \left[\text{Sum of bond energies of all bonds in reactants}\right] - \left[\text{Sum of bond energies of all bonds in products}\right]$$

$$\Delta H = \underbrace{\Sigma n \times D \text{ (bonds broken)}}_{\text{energy required}} - \underbrace{\Sigma n \times D \text{ (bonds formed)}}_{\text{energy released}}$$

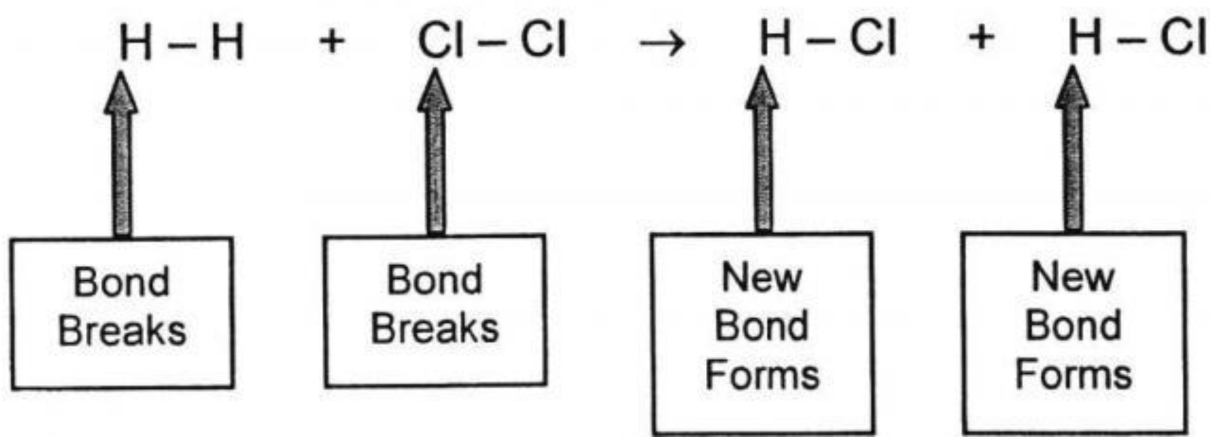
Σ means ‘sum of’
n is the amount (in moles) of a particular bond type
D is the bond energy per mole of bonds (it is always + and looked up in a table

Practice

Using bond energies, calculate the enthalpy change for the following reaction and determine whether it is exothermic or endothermic.

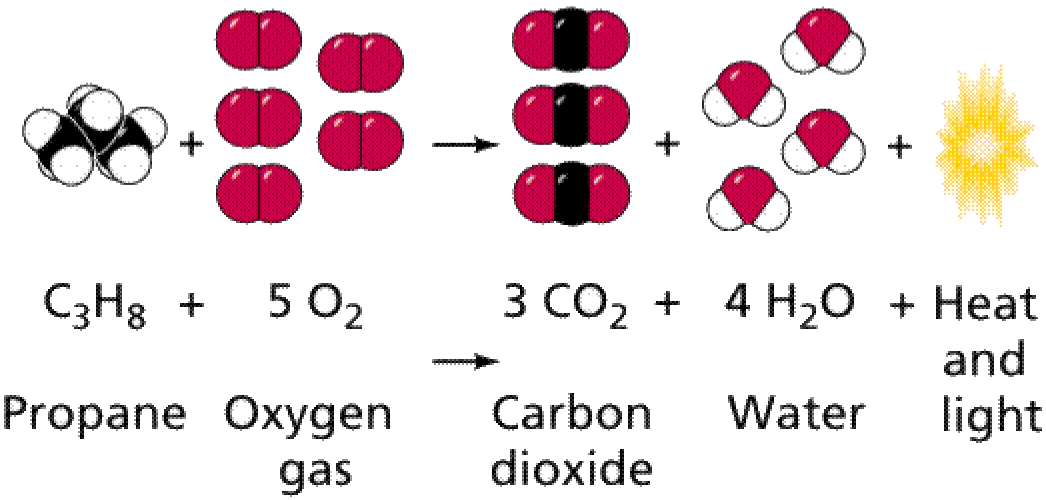
hydrogen + chlorine → hydrogen chloride

$$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$$



More Practice

Using bond energies, calculate the enthalpy change for the following reaction.



Practice Makes Perfect!

- Calculate the enthalpy change that would result from the complete combustion of pentane.

HOMEWORK

Required Reading:

p. 307-313

(remember to supplement your notes!)

Questions:

p. 312 #1-4

p. 313 #1-13