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Bond Enthalpy (Bond Energy)

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The **Bond Enthalpy** is the energy required to break a chemical bond. It is usually expressed in units of kJ mol^{-1}, measured at 298 K. The exact bond enthalpy of a particular chemical bond depends upon the molecular environment in which the bond exists. Therefore, bond enthalpy values given in chemical data books are averaged values.

Average Bond Enthalpies (kJ/mol)

Single Bonds

C—H	413	N—H	391	O—H	463	F—F	155
C—C	348	N—N	163	O—O	146		
C—N	293	N—O	201	O—F	190	Cl—F	253
C—O	358	N—F	272	O—Cl	203	Cl—Cl	242
C—F	485	N—Cl	200	O—I	234		
C—Cl	328	N—Br	243			Br—F	237
C—Br	276			S—H	339	Br—Cl	218
C—I	240	H—H	436	S—F	327	Br—Br	193
C—S	259	H—F	567	S—Cl	253		
		H—Cl	431	S—Br	218	I—Cl	208
Si—H	323	H—Br	366	S—S	266	I—Br	175
Si—Si	226	H—I	299			I—I	151
Si—C	301						
Si—O	368						

Multiple Bonds

C═C	614	N═N	418	O_2	495
C≡C	839	N≡N	941		
C═N	615			S═O	523
C≡N	891			S═S	418
C═O	799				
C≡O	1072				

$$\Delta H = \sum \Delta H_{(\text{bonds broken})} - \sum \Delta H_{(\text{bonds formed})}$$

This basically means that you add up all the energies of the broken bonds; add up all the energies of the bonds that are reformed and subtract one from the other.

EXAMPLE #1

Find $_{\Delta}$H° for the following reaction given the following bond energies:

$$2\,H_{2(g)} + O_{2(g)} \rightarrow 2\,H_2O_{(g)}$$

Bond	Bond Energy (kJ/mol)
H-H	436
O=O	499
O-H	463

We have to figure out which bonds are broken and which bonds are formed.

2 H-H bonds are broken.
1 O=O bond is broken
2 O-H bonds are formed per water molecule, and there are 2 water molecules formed, therefore 4 O-H bonds are formed
Now we can substitute the values given into the equation:

$$\Delta H^\circ = [\underbrace{2(436)}_{H-H} + \underbrace{499}_{O=O}] - \underbrace{4(463)}_{O-H}$$

$$\Delta H^\circ = 1371 - 1852$$

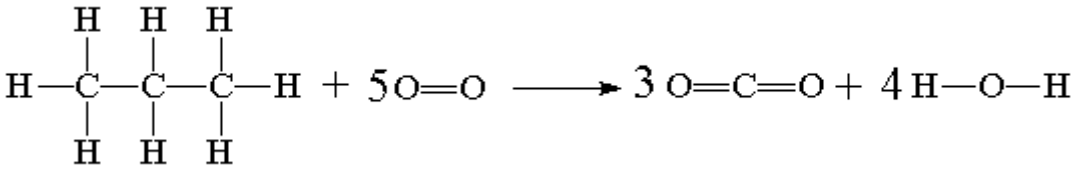
$$\boxed{\Delta H^\circ = -481\ kJ}$$

EXAMPLE #2

The complete combustion of propane can be represented by the following equation:

$$CH_3CH_2CH_3(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O$$

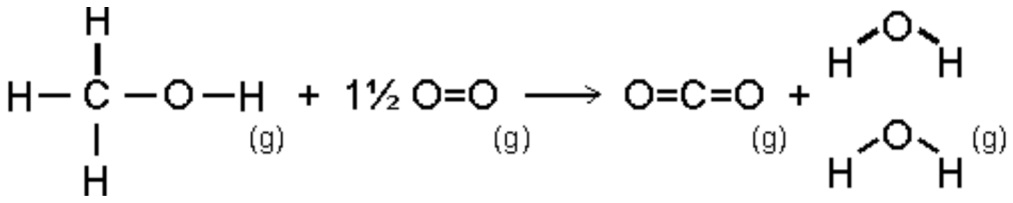
or we could redraw it to represent the bonds present:



Bond Type	Average bond enthalpy kJ/mol
C-H	+413
C-C	+347
O=O	+498
C=O	+805
H-O	+464

Total endothermic change for bond breaking:	Total exothermic change for bond forming:	
8xC-H 2xC-C 5xO=O = (8 x +413) + 2(+347) + 5(+498)	6 x C=O 8 x O-H = (6 x -805) + (8 x -464)	DH= [(8x413)+(2x347)+ (5x498)] --- [(6x805)+(8x464)]= - 2054 kJ mol^{-1}

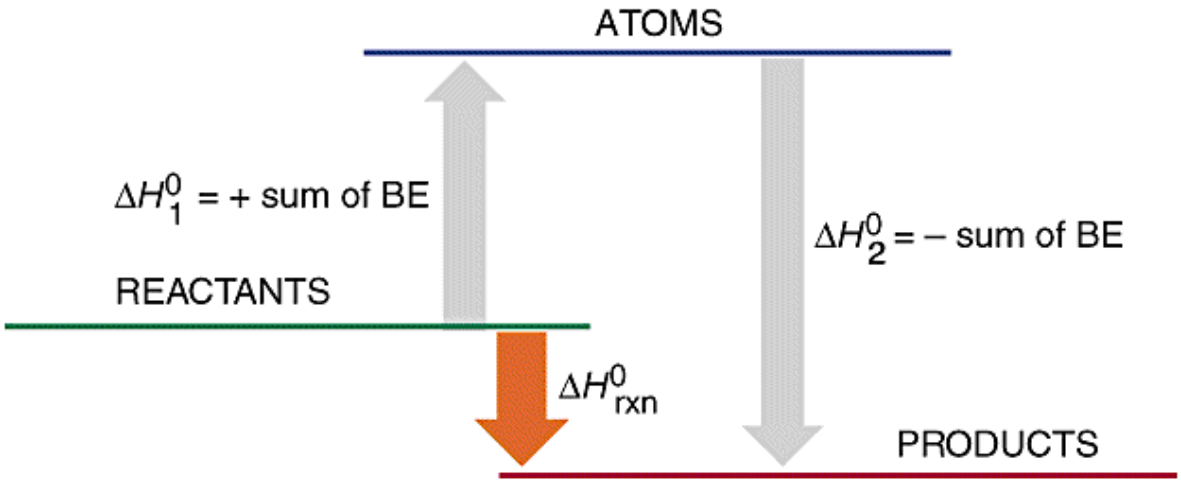
EXAMPLE #3



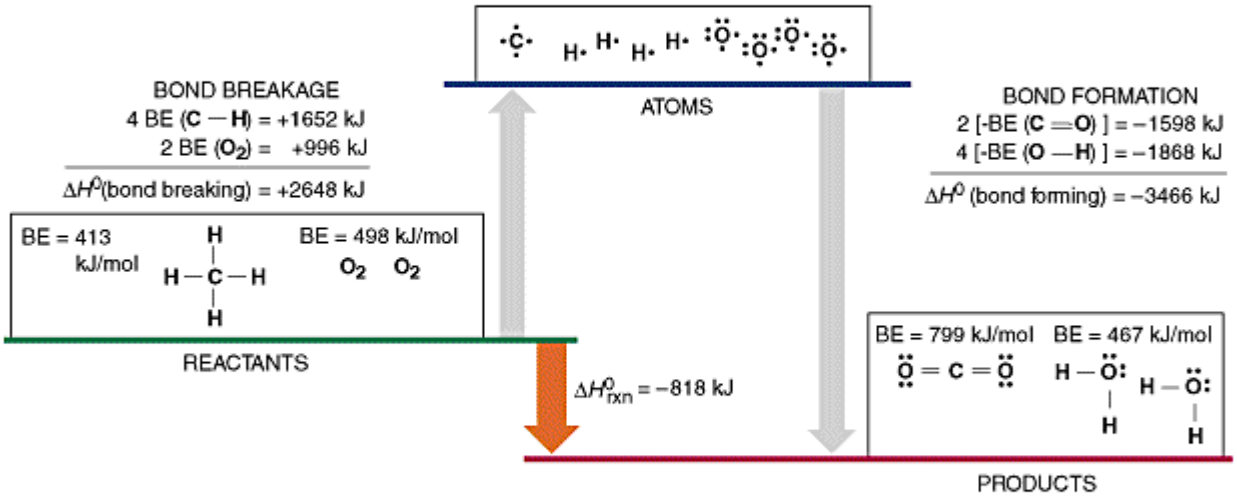
The method involves breaking chemical bonds in the reactant molecules (an endothermic process) and forming new bonds in the products (an exothermic process).

Total endothermic change for bond breaking:	**Total exothermic change for bond making:**	**Bond Enthalpies in kJ/mol**
3 x C-H 1 x C-O 1 x O-H 1½ x O=O = (3 x +413) + +336 + +464 + (1½ x +498) = +2786 kJ	2 x C=O 4 x O-H = (2 x -805) + (4 x -464) = -3466 kJ	C-H = 413 C-O = 336 O-H = 464 O=O = 498 C=O = 805
\ DH = + 2786 + - 3466 = - 680 kJ/mol		

A graphic analysis of these calculations.



A specific example can be made from our old familiar combustion of methane reaction. We calculated the enthalpy change during this transformation before from traditional thermochemcial methods. We can do this again by using the average bond enthalpies of C-H, C=O, {O=O}, and O-H bonds.



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