

5.3: Enthalpy and Bond Energy

Table 1 Average Bond Energies (kJ/mol)

Single bonds			Multiple bonds
H-H 432	N-H 391	I-H 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		
C-I 240	F-Cl 253		
C-S 259	F-Br 237		
	Cl-Cl 239		
	Cl-Br 218		
	Br-Br 193		

*C=O in CO₂(g) = 799

Process

Energy Required (kJ/mol)

CH ₄ (g) → CH ₃ (g) + H(g)	435
CH ₃ (g) → CH ₂ (g) + H(g)	453
CH ₂ (g) → CH(g) + H(g)	425
CH(g) → C(g) + H(g)	339

Total = 1652

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

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 Energy:

$$\Delta H = \begin{array}{l} \text{sum of energies required} \\ \text{to break old bonds} \\ \text{(positive values)} \end{array} + \begin{array}{l} \text{sum of energies released in} \\ \text{the formation of new bonds} \\ \text{(negative values)} \end{array}$$

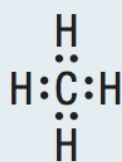
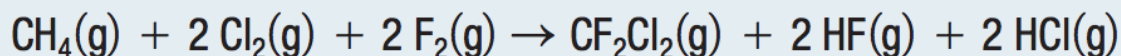
This leads to the equation

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

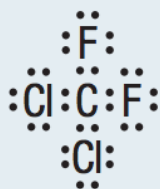
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Sample Problem 2: Using Bond Energies and Lewis Diagrams to Estimate ΔH

Using the bond energies in Table 1, calculate the enthalpy change for the reaction in which methane gas, $\text{CH}_4(\text{g})$, is combined with chlorine gas and fluorine gas to produce Freon-12 gas, $\text{CF}_2\text{Cl}_2(\text{g})$. **Figure 2** shows the Lewis structures of methane and Freon-12. The balanced chemical equation for the formation of 1 mol of Freon-12 is



methane



Freon-12

Sample Problem 3: Using Bond Energies and Chemical Structures to Estimate ΔH

Using bond energies from Table 1, determine whether the complete combustion of ethyne gas (acetylene), $\text{C}_2\text{H}_2(\text{g})$, to carbon dioxide gas and liquid water is exothermic or endothermic.