Strength of the Covalent Bond

Covalent Bond Strength

- Most simply, the strength of a bond is measured by determining how much energy is required to break the bond.
- This is the **bond enthalpy**.
- The bond enthalpy for a Cl—Cl bond, *D* (Cl— Cl), is measured to be 242 kJ/mol.

Average Bond Enthalpies

- Table 8.4 lists the average bond enthalpies for many different types of bonds.
- Average bond enthalpies are positive (+), because bond breaking is an endothermic process.

TABLE 8.4 • 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						
Si—Cl	464						

Multiple Bonds

C=C	614	N=N	418	O_2	495
C≡C	839	N≡N	941		
C=N	615	N=O	607	S=O	523
C≡N	891			S=S	418
C=O	799				
C≡O	1072				

Basic Concepts of Chemical Bonding

Average Bond Enthalpies

Note: These are *average* bond enthalpies, not absolute bond enthalpies; the C—H bonds in methane, CH_4, will be a bit different than the C—H bond in chloroform, $CHCl_3$.

TABLE 8.4 • 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
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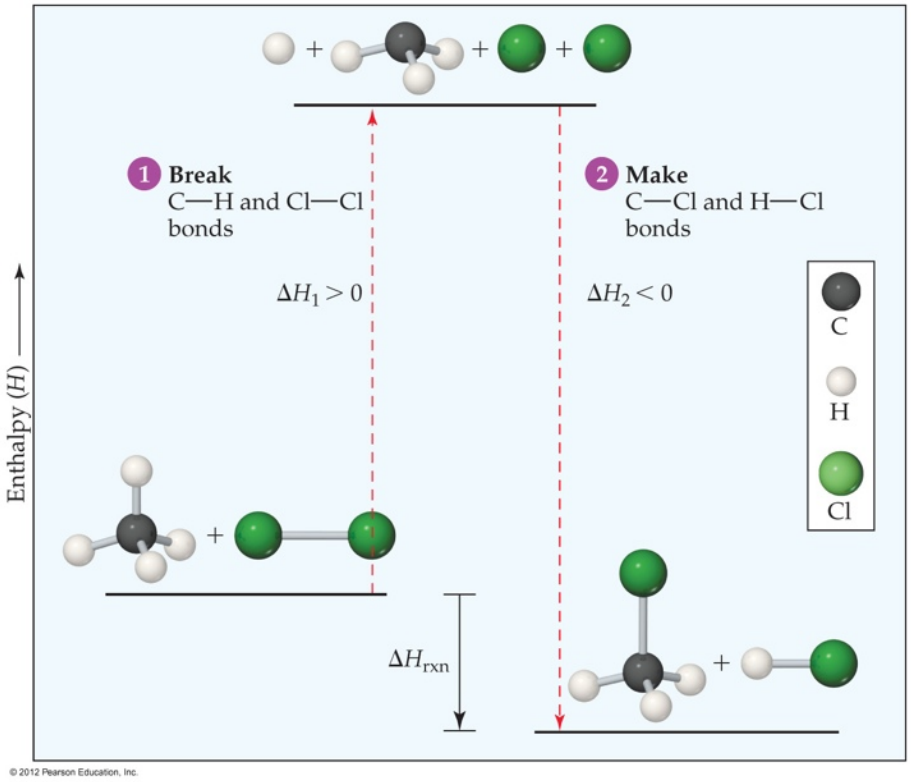
Enthalpies of Reaction

- Yet another way to estimate ΔH for a reaction is to compare the bond enthalpies of bonds broken to the bond enthalpies of the new bonds formed.



- In other words,

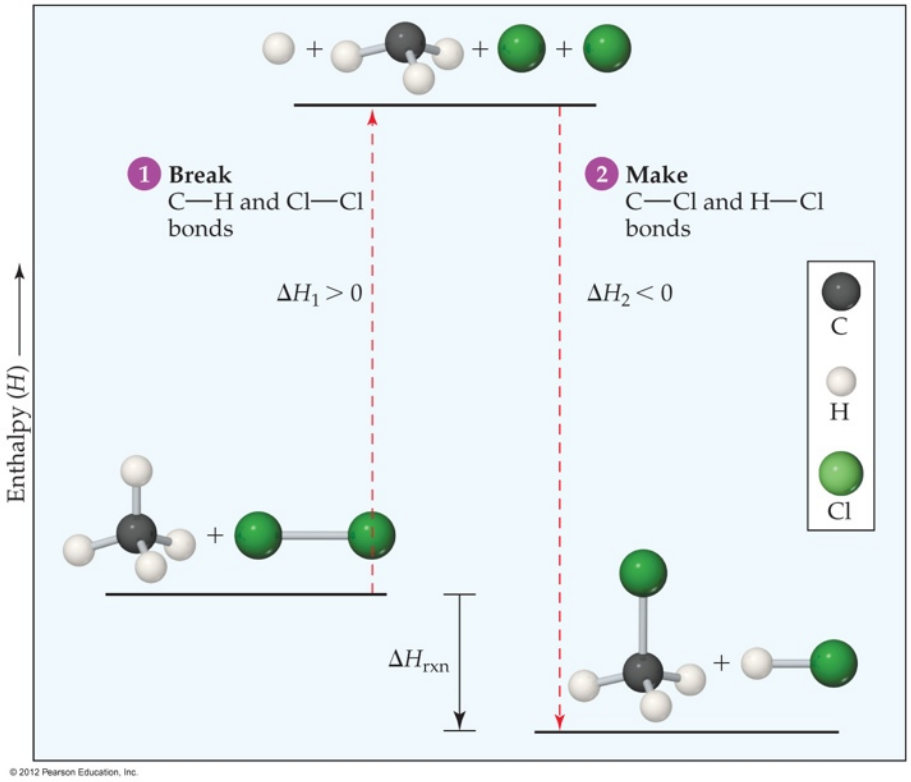
$$\Delta H_{rxn} = \Sigma(\text{bond enthalpies of bonds broken}) - \Sigma(\text{bond enthalpies of bonds formed})$$

Basic Concepts of Chemical Bonding

Enthalpies of Reaction

$$CH_4(g) + Cl_2(g) \longrightarrow CH_3Cl(g) + HCl(g)$$

In this example, one C—H bond and one Cl—Cl bond are broken; one C—Cl and one H—Cl bond are formed.



Basic Concepts of Chemical Bonding

Enthalpies of Reaction

So,

$$\Delta H = [D(\text{C—H}) + D(\text{Cl—Cl})] - [D(\text{C—Cl}) + D(\text{H—Cl})]$$

$$= [(413\ \text{kJ}) + (242\ \text{kJ})] - [(328\ \text{kJ}) + (431\ \text{kJ})]$$

$$= (655\ \text{kJ}) - (759\ \text{kJ})$$

$$= -104\ \text{kJ}$$

Bond Enthalpy and Bond Length

TABLE 8.5 • Average Bond Lengths for Some Single, Double, and Triple Bonds

Bond	Bond Length (Å)	Bond	Bond Length (Å)
C—C	1.54	N—N	1.47
C=C	1.34	N=N	1.24
C≡C	1.20	N≡N	1.10
C—N	1.43	N—O	1.36
C=N	1.38	N=O	1.22
C≡N	1.16		
		O—O	1.48
C—O	1.43	O=O	1.21
C=O	1.23		
C≡O	1.13		

- We can also measure an average bond length for different bond types.
- As the number of bonds between two atoms increases, the bond length decreases.

Example: Using BDEs

break bonds | make bonds

349	495

846

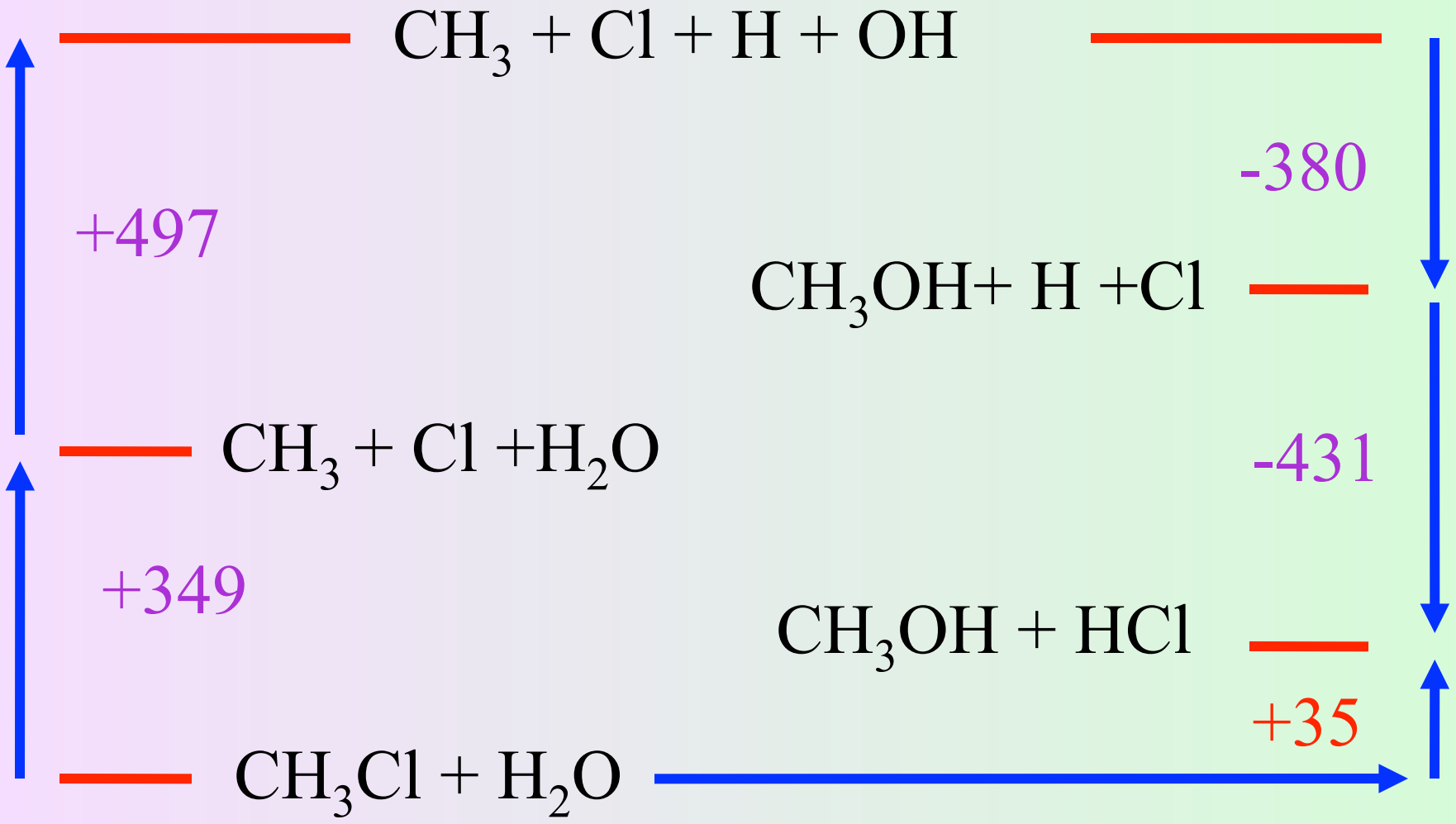
380	431

811

$\Delta H^\circ = \Sigma(\text{BDEs broken}) - \Sigma(\text{BDEs formed})$

$\Delta H^\circ = 846 - 811 =$ +35kJ

Hess's Law, BDEs, and ΔH°



Bond Dissociation Energy

The energy required to break a bond

Endothermic for stable compounds :

ΔH° is always positive (+)

Use of Bond Energies in Thermochemistry (The heat energy released or absorbed)

Bond-dissociation energies can be used to calculate $\Delta H^{\circ}_{reaction}$