AP CHEMISTRY

TOPIC 9: THERMODYNAMICS, MORE PRACTICE – BOND ENERGIES

Day 115:

Average Bond Energies (kJ/mol)

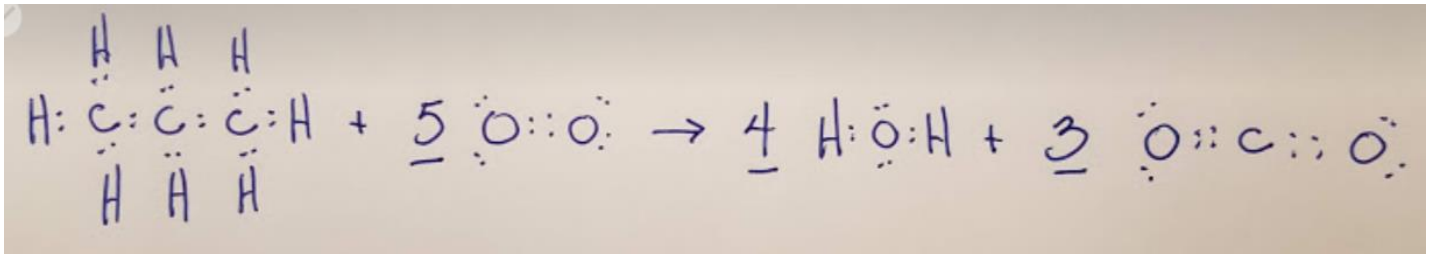
Single Bonds						Multiple Bonds	
H—H	432	N—H	391	I—I	149	C=C	614
H—F	565	N—N	160	I—Cl	208	C≡C	839
H—Cl	427	N—F	272	I—Br	175	O=O	495
H—Br	363	N—Cl	200			C=O*	745
H—I	295	N—Br	243	S—H	347	C≡O	1072
		N—O	201	S—F	327	N=O	607
C—H	413	O—H	467	S—Cl	253	N=N	418
C—C	347	O—O	146	S—Br	218	N≡N	941
C—N	305	O—F	190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

*C=O(CO_2) = 799

1. Using the bond energies (from the table provided) to calculate the ΔH for the reaction below: (the equation is not balanced… yet)

$$\_\_\_\ C_3H_{8\,(g)} + \_\_\_\ O_{2\,(g)} \rightarrow \_\_\_\ H_2O_{(g)} + \_\_\_\ CO_{2\,(g)}$$

$$\_\_\_\ C_3H_{8\,(g)} + \_5\_\ O_{2\,(g)} \rightarrow \_4\_\ H_2O_{(g)} + \_3\_\ CO_{2\,(g)}$$



[8 C – H + 2 C – C + 5 O = O] - [8 H – O + 6 C = O]

$\Delta H^0_{B.E.}$ = Σ Bond energies of bonds broken (Reactants) - Σ Bond energies of bonds formed (Products)

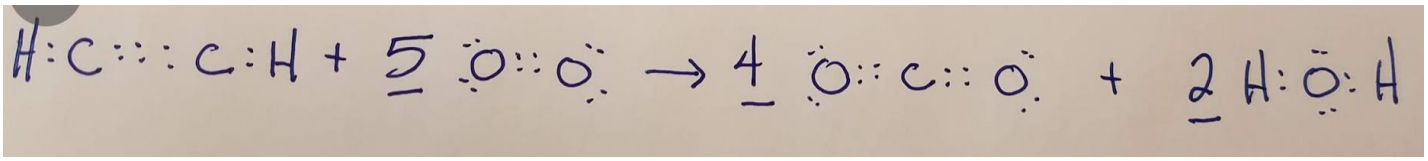
$$\Delta H_{B.E.} = \sum_{\text{Reactants}} - \sum_{\text{Products}}$$

$$\Delta H_{B.E.} = \left[8\left(\frac{413\ kJ}{mol}\right) + 2\left(\frac{347\ kJ}{mol}\right) + 5\left(\frac{495\ kJ}{mol}\right)\right] - \left[8\left(\frac{467\ kJ}{mol}\right) + 6\left(\frac{745\ kJ}{mol}\right)\right] = -1733\ kJ\ mol^{-1}$$

2. Using the bond energies (from the table provided) to calculate the ΔH for the reaction below: (the equation is not balanced… yet)

$$\_\_\_\ C_2H_{2\,(g)} + \_\_\_\ O_{2\,(g)} \rightarrow \_\_\_\ H_2O_{(g)} + \_\_\_\ CO_{2\,(g)}$$

$$\_\ 2\ \_\ C_2H_{2\,(g)} + \_\ 5\ \_\ O_{2\,(g)} \rightarrow \_\ 4\ \_\ CO_{2\,(g)} + \_\ 2\ \_\ H_2O_{(g)}$$



$$\boldsymbol{4\ C-H\ +\ 2\ C\equiv C\ +\ 5\ O=O\ \rightarrow\ 4\ H-O\ +\ 8\ C=O}$$

$\Delta H^0_{B.E.}$ = Σ Bond energies of bonds broken (Reactants) - Σ Bond energies of bonds formed (Products)

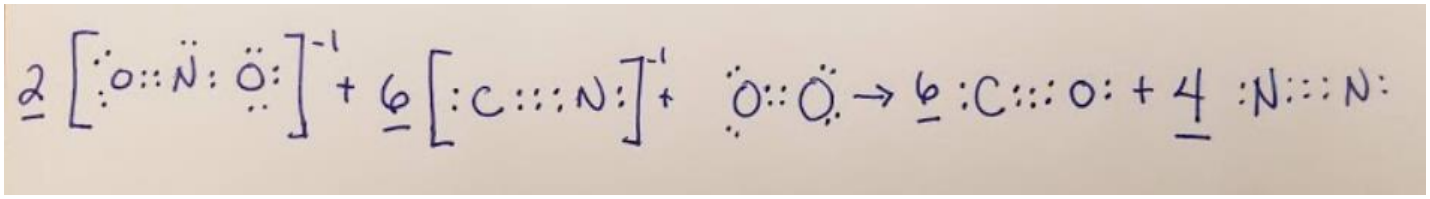
$$\Delta H_{B.E.} = \sum_{\text{Reactants}} - \sum_{\text{Products}}$$

$$\Delta H_{B.E.} = \left[4\left(\frac{413\ kJ}{mol}\right)+2\left(\frac{839\ kJ}{mol}\right)+5\left(\frac{495\ kJ}{mol}\right)\right] - \left[4\left(\frac{467\ kJ}{mol}\right)+8\left(\frac{745\ kJ}{mol}\right)\right] = -2023\ kJ\ mol^{-1}$$

3. Using the bond energies (from the table provided) to calculate the ΔH for the reaction below: (the equation is not balanced… yet)

$$\_\_\_\ NO_2^{-1} + \_\_\_\ CN^{-1} + \_\_\_\ O_2 \rightarrow \_\_\_\ CO + \_\_\_\ N_2$$

$$\_\ 2\ \_\ NO_2^{-1} + \_\ 6\ \_\ CN^{-1} + \_\_\_\ O_2 \rightarrow \_\ 6\ \_\ CO + \_\ 4\ \_\ N_2$$



$$\boldsymbol{2\ N=O\ +\ 2\ N-O\ +\ 4\ C\equiv N\ +\ O=O\ \rightarrow\ 4\ C\equiv O\ +\ 3\ N\equiv N}$$

$\Delta H^0_{B.E.}$ = Σ Bond energies of bonds broken (Reactants) - Σ Bond energies of bonds formed (Products)

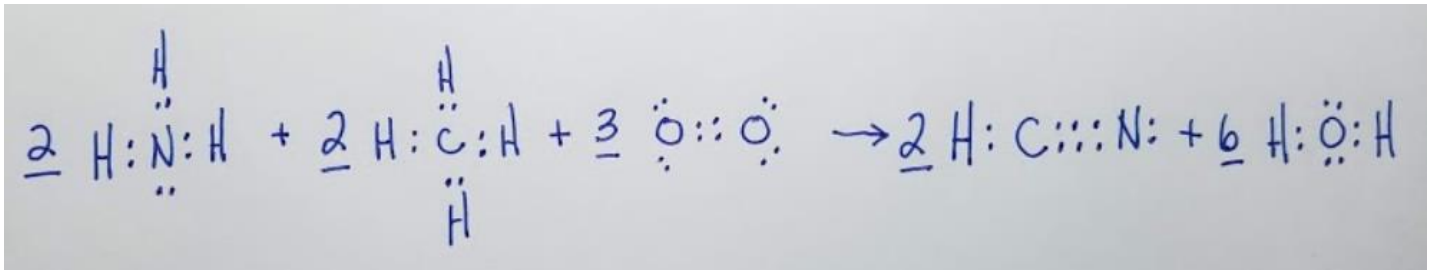
$$\Delta H_{B.E.} = \sum_{\text{Reactants}} - \sum_{\text{Products}}$$

$$\Delta H_{B.E.} = \left[2\left(\frac{607\ kJ}{mol}\right)+2\left(\frac{201\ kJ}{mol}\right)+6\left(\frac{891\ kJ}{mol}\right)+\left(\frac{495\ kJ}{mol}\right)\right] - \left[6\left(\frac{1072\ kJ}{mol}\right)+4\left(\frac{941\ kJ}{mol}\right)\right] = -2739\ kJ\ mol^{-1}$$

4. Using the bond energies (from the table provided) to calculate the ΔH for the reaction below: (the equation is not balanced… yet)

$$\_\_\_\ NH_3 + \_\_\_\ CH_4 + \_\_\_\ O_2 \rightarrow \_\_\_\ HCN + \_\_\_\ H_2O$$

$$\_2\_\ NH_3 + \_2\_\ CH_4 + \_3\_\ O_2 \rightarrow \_2\_\ HCN + \_6\_\ H_2O$$



6 N – H + 8 C – H + 3 O = O → 2 C – H + 2 C ≡ N + 12 H – O

$\Delta H^0_{B.E.}$ = Σ Bond energies of bonds broken (Reactants) - Σ Bond energies of bonds formed (Products)

$$\Delta H_{B.E.} = \sum_{\text{Reactants}} - \sum_{\text{Products}}$$

$$\Delta H_{B.E.} = \left[6\left(\frac{391\ kJ}{mol}\right) + 8\left(\frac{413\ kJ}{mol}\right) + 3\left(\frac{495\ kJ}{mol}\right)\right] - \left[2\left(\frac{413\ kJ}{mol}\right) + 2\left(\frac{891\ kJ}{mol}\right) + 12\left(\frac{467\ kJ}{mol}\right)\right] = -1077\ kJ\ mol^{-1}$$