5.3 Bond Enthalpies

1. What energy changes occur when chemical bonds are formed and broken?
   a. Energy is absorbed when bonds are formed and when they are broken.
   b. Energy is released when bonds are formed and when they are broken.
   c. Energy is absorbed when bonds are formed and released when they are broken.
   d. Energy is released when bonds are formed and absorbed when they are broken.

   exo ΔH-   endo ΔH+

2. The average bond enthalpies for O—O and O==O are 146 and 496 kJ mol^{-1} respectively. What is the enthalpy change, in kJ, for the reaction below?

   $$H—O—O—H(g) \rightarrow H—O—H(g) + \frac{1}{2}O{=}{=}O(g)$$

   a. − 102
   b. + 102
   c. + 350
   d. + 394

   ~~2(O-H)~~ + 1(O-O) ~~- 2(H-O)~~ + ½(O=O)
   1(+146) + ½(-496)

3. Which reaction has the most negative ΔH^{θ} value? — exo - forming
   look @ electronegativity differences
   a. $LiF(s) \rightarrow Li^{+}(g) + F^{-}(g)$
   b. $Li^{+}(g) + F^{-}(g) \rightarrow LiF(s)$ → 1.0 - 4.0 = 3.0 - larger (wants bond more)
   c. $NaCl(s) \rightarrow Na^{+}(g) + Cl^{-}(g)$
   d. $Na^{+}(g) + Cl^{-}(g) \rightarrow NaCl(s)$ → 0.9 - 3.2 = 2.1

4. For which of the following is the sign of the enthalpy change different from the other three?
   a. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ - breaking
   b. $Na(g) \rightarrow Na^{+}(g) + e^{-}$ - breaking
   c. $CO_2(s) \rightarrow CO_2(g)$ - breaking IMFs
   d. $2Cl(g) \rightarrow Cl_2(g)$ - forming

5. The average bond enthalpy for the C–H bond is 412 kJ mol^{-1}. Which process has an enthalpy change closest to this value?
   a. $CH_4(g) \rightarrow C(s) + 2H_2(g)$
   b. $CH_4(g) \rightarrow C(g) + 2H_2(g)$
   c. $CH_4(g) \rightarrow C(s) + 4H(g)$
   d. $CH_4(g) \rightarrow CH_3(g) + H(g)$

   breaking 1 C-H bond
   if break all 4 (C-H), multiply by 4

6. Identify the bonds which are broken in the following process.

   $$C_2H_6(g) \rightarrow 2C(g) + 6H(g)$$

   1 C-C
   6 C-H

7. Use the bond enthalpies below to calculate ΔH for the reaction:

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

O=O; +498 kJ mol^{-1}
H – H ; +436 kJ mol^{-1}
O – H ; +464 kJ mol^{-1}

2(H-H) + 1(O=O) → 4(O-H)
2(+436) + 1(+498) + 4(-464)
-486 kJmol^{-1}

8. Using the bond enthalpies from Reference section 11, calculate ΔH for the following reaction:

$C_3H_6(g) + H_2(g) \rightarrow C_3H_8(g)$

C=C-C + H-H → -C-C-C-

1(C=C) + 1(C-C) + 6(C-H) + 1(H-H) → 2(C-C) + 8(C-H)
1(+614) + 1(346) + 6(+414) + 1(+436) + 2(-346) + 8(-414)
-106 kJmol^{-1}

9. Using the bond enthalpies from Reference section 11, calculate ΔH for the following reaction:

$C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$

-C-C-C=C + 4 O=O → 4 O=C=O) + 4 (H-O-H)

2(C-C) + 1(C=C) + 8(C-H) + 4 (O=O) + 8(C=O) + 8(O-H)
2(+346) + 1(+614) + 8 (+414) + 4 (+498) + 8(-804) + 8(-463)
-3526 kJmol^{-1}

10. (a) Define the term *average bond enthalpy*, illustrating your answer with an equation for methane, CH4.

Energy needed to break 1mol of a bond in a gaseous molecule averaged over similar compounds

(b) The equation for the reaction between methane and chlorine is

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

Use the values from section 11 of the Data Booklet to calculate the enthalpy change for this reaction.

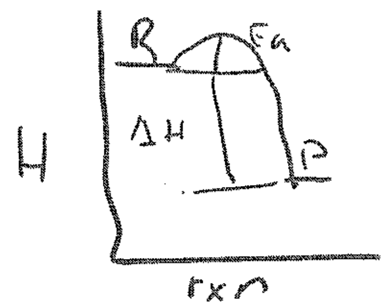
-C- + Cl-Cl → -C-Cl + H-Cl

4(C-H) + 1(Cl-Cl) → 3(C-H) + 1(C-Cl) + 1(H-Cl)
4(+414) + 1(+242) + 3(-414) + 1(-324) + 1(-431) = -99 kJmol^{-1}

(c) Explain why no reaction takes place between methane and chlorine at room temperature unless the reactants are sparked, exposed to UV light or heated.

Molecules have insufficient energy to react/need extra energy to overcome activation energy for reaction

(d) Draw an enthalpy level diagram for this reaction.



exothermic

11. The concentration of ozone in the upper atmosphere is maintained by the following reactions.

i. $O_2 \rightarrow 2O_2\cdot$
ii. $O_2 + O\cdot \rightarrow O_3$ → exo (forming a bond)
iii. $O_3 \rightarrow O_2 + O\cdot$

a. Identify the step which is exothermic. Why.
b. Identify with reference to bonding in O2 and O3, the most endothermic step.

O_2 → due to higher bond enthalpy O=O vs. O−O=O, takes more energy (smaller wavelength) to break O_2 apart