SL & HL Questions on Bond enthalpies

Use the values of bond enthalpies given in Section 11 of the IB Chemistry data booklet.

1. All hydrocarbons burn according to the following equation (the state of the hydrocarbon, C_xH_y, at standard conditions varies according to its mass and structure):

$$C_xH_y + (x + ¼y)O_2(g) \rightarrow xCO_2(g) + ½yH_2O(l)$$

Explain, in terms of bond enthalpies, why the combustion of all hydrocarbons is exothermic.

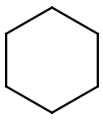
2. Nitrogen and hydrogen react to produce ammonia in the Haber process:

$N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$ Calculate the enthalpy of formation of ammonia.

3. Methane reacts with chlorine in the presence of ultraviolet light to produce chloromethane:

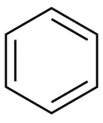
$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$ Calculate the enthalpy change for this reaction.

4. Consider the three compounds cyclohexane, C_6H_{12}, cyclohexene, C_6H_{10} and benzene, C_6H_6.



cyclohexane
C_6H_{12}

cyclohexene
C_6H_{10}



benzene
C_6H_6

(a) Calculate the enthalpy change for the hydrogenation reaction of gaseous cyclohexene to form gaseous cyclohexane. $C_6H_{10}(g) + H_2(g) \rightarrow C_6H_{12}(g)$

(b) Both cyclohexene and cyclohexane are liquids at standard conditions. The enthalpies of vaporization of cyclohexene and cyclohexane are + 33.5 kJ mol^{-1} and + 32.0 kJ mol^{-1} respectively. Use these values to calculate the enthalpy of hydrogenation of cyclohexene, $C_6H_{10}(l) + H_2(g) \rightarrow C_6H_{12}(l)$, and compare your value with the literature value of -121.9 kJ mol^{-1}.

(c) Assuming that benzene consists of alternate C=C and C-C bonds, use average bond enthalpies to calculate the enthalpy of hydrogenation of benzene, $C_6H_6(l) + 3H_2(g) \rightarrow C_6H_{12}(l)$. (Benzene is a liquid at standard conditions and the enthalpy of vaporization of benzene is + 33.9 kJ mol^{-1}).

(d) It might be expected that the enthalpy of hydrogenation of benzene would be three times the value of the enthalpy of hydrogenation of cyclohexene as three double bonds are hydrogenated. In fact the value is – 210 kJ mol^{-1}. The reason for the difference is that the alternate double and single bonds give increased stability to the benzene ring through a process known as delocalization. Estimate the value of the delocalization energy of benzene in kJ mol^{-1}.