SL & HL Answers to Bond enthalpies questions

1. The sum of the strong O—H and C=O bonds being formed is always greater than the sum of the weaker C—H, O=O (and C=C or C≡C where relevant) bonds being broken.

2. Energy in to break N≡N and 3H—H = 945 + (3 x 436) = 2253 kJ
Energy out to form 6N-H = 6 x 391 = 2346 kJ
ΔH for reaction (which involves formation of two mol of NH_3) = 2253 − 2346 = − 93 kJ
Enthalpy of formation of ammonia = ½ x - 93 = − 46.5 kJ mol^{-1}

3. Energy in to break C—H and Cl—Cl = 414 + 242 = 656 kJ
Energy out to form C—Cl and H—Cl = 324 + 431 = 755 kJ
ΔH = 656 − 755 = − 99 kJ mol^{-1}

4. (a) Energy in to break C=C and H—H = 614 + 436 = 1050 kJ
Energy out to form C—C and 2C—H = 346 + (2 x 414) = 1174 kJ
ΔH = 1050 − 1174 = − 124 kJ mol^{-1}

(b) Extra energy in to vaporize cyclohexene to gaseous state = 33.5 kJ mol^{-1}
Extra energy out to condense cyclohexane gas to liquid state = 32.0 kJ mol^{-1}
Enthalpy of hydrogenation of cyclohexene = −124 + (33.5 − 32.0) = − 122.5 kJ mol^{-1}
Difference with literature value = [(122.5 − 121.9) / 121.9] x 100 = 0.49%.
This difference is because average bond enthalpies were used for the C-C, C-H and C=C bonds which are not the exact values for the bonds in cyclohexene and cyclohexane.

(c) Energy in to vaporise C_6H_6 and to break 3C=C and 3H—H = 33.9 + (3 x 614) + (3 x 436) = 3184 kJ
Energy out to form 3C—C and 6C—H and condense C_6H_{12} = (3 x 346) + (6 x 414) + 32.0 = 3554 kJ
Enthalpy of hydrogenation of benzene = 3184 − 3554) = − 370 kJ mol^{-1}

(d) Benzene is expected to give out either 370 kJ mol^{-1} (calculated from average bond enthalpies) or 366 kJ mol^{-1} (calculated from 3 x literature value) when hydrogenated. In fact it only gives out 210 kJ mol^{-1} as the difference in energy has been used to overcome the delocalization energy. Hence the delocalization energy of benzene is approximately 160 kJ mol^{-1}.