Bond Enthalpy

Questions

1. Using bond enthalpies, calculate the enthalpy change for the combustion of hydrogen to produce water shown by the equation below.

\[ 2\text{H}_2 (g) + \text{O}_2 (g) \rightarrow 2\text{H}_2\text{O} (g) \]

2. Use bond enthalpy values from the data book to calculate the enthalpy change for the following reaction.

\[ \text{CH}_4 (g) + \text{Br}_2 (g) \rightarrow \text{CH}_3\text{Br} (g) + \text{HBr} (g) \]

3. The data book gives the enthalpy of combustion of methane as \(-891\text{kJ mol}^{-1}\). Use bond enthalpies to calculate the enthalpy change for this reaction.

\[ \text{CH}_4 (g) + 2\text{O}_2 (g) \rightarrow \text{CO}_2 (g) + 2\text{H}_2\text{O} (g) \]

4. Using bond enthalpy values, calculate the enthalpy change for the following addition reaction.

\[ \text{C}_2\text{H}_4 (g) + \text{HBr} (g) \rightarrow \text{C}_2\text{H}_5\text{Br} (g) \]

5. Use the bond enthalpy values quoted in the data book to calculate the enthalpy change for the hydrogenation of but-1-ene.

\[ \text{C}_4\text{H}_8 (g) + \text{H}_2 (g) \rightarrow \text{C}_4\text{H}_{10} (g) \]

6. Using bond enthalpy values, calculate the enthalpy change for the addition reaction between iodine and propene.

\[ \text{C}_3\text{H}_6 (g) + \text{I}_2 (g) \rightarrow \text{C}_3\text{H}_6\text{I}_2 (g) \]
7. Hydrogen chloride can react with ethyne in a two-stage addition process to give a saturated product. Calculate the enthalpy change for this reaction using bond enthalpy values from the data book.

\[
\text{C}_2\text{H}_2 (g) + 2\text{HCl (g)} \rightarrow \text{C}_2\text{H}_4\text{Cl}_2 (g)
\]

8. The data book gives the enthalpy of combustion of ethanol as \(-1367 \text{ kJ mol}^{-1}\). Use bond enthalpies to calculate the enthalpy change for this reaction.

\[
\text{C}_2\text{H}_5\text{OH (g)} + 3\text{O}_2 (g) \rightarrow 2\text{CO}_2 (g) + 3\text{H}_2\text{O (g)}
\]

9. Calculate the enthalpy of formation for ethene using the enthalpy of sublimation and bond enthalpy values from the data book.

\[
2\text{C (s)} + 2\text{H}_2 (g) \rightarrow \text{C}_2\text{H}_4 (g)
\]

10. The data book quotes the mean bond enthalpy for a carbon-to-carbon double bond (C=C) as 602 kJ mol\(^{-1}\). Use the enthalpy of formation given and bond enthalpies from the data book to calculate the enthalpy of the C=C bond in ethene.

\[
2\text{C (s)} + 2\text{H}_2 (g) \rightarrow \text{C}_2\text{H}_4 (g) \quad \Delta H_{\text{formation}} = 52 \text{ kJ mol}^{-1}
\]
Solutions

1. Using bond enthalpies, calculate the enthalpy change for the combustion of hydrogen to produce water shown by the equation below.

\[2\text{H}_2 (g) + \text{O}_2 (g) \rightarrow 2\text{H}_2\text{O} (g)\]

Bond breaking Bond making

\begin{align*}
2 \text{ mol H–H} &= 2 \times 432 = 864 \\
1 \text{ mol O=O} &= 497 \\
\text{Total energy put in} &= +1361 \text{ kJ} \\
4 \text{ mol H–O} &= 4 \times 458 = 1832 \\
1 \text{ mol O=O} &= 497 \\
\text{Total energy given out} &= –1832 \text{ kJ} \\
\Delta H &= 1361 – 1832 \\
&= -471 \text{ kJ mol}^{-1}
\end{align*}

2. Use bond enthalpy values from the data book to calculate the enthalpy change for the following reaction.

\[\text{CH}_4 (g) + \text{Br}_2 (g) \rightarrow \text{CH}_3\text{Br} (g) + \text{HBr} (g)\]

Bond breaking Bond making

\begin{align*}
4 \text{ mol C–H} &= 4 \times 414 = 1656 \\
1 \text{ mol Br–Br} &= 194 \\
\text{Total energy put in} &= +1850 \text{ kJ} \\
3 \text{ mol C–H} &= 3 \times 414 = 1242 \\
1 \text{ mol C–Br} &= 285 \\
1 \text{ mol H–Br} &= 362 \\
\text{Total energy given out} &= –1889 \text{ kJ} \\
\Delta H &= 1850 – 1889 \\
&= -39 \text{ kJ mol}^{-1}
\end{align*}
3. The data book gives the enthalpy of combustion of methane as \(-891\text{kJ mol}^{-1}\). Use bond enthalpies to calculate the enthalpy change for this reaction.

\[
\text{CH}_4 (\text{g}) + 2\text{O}_2 (\text{g}) \rightarrow \text{CO}_2 (\text{g}) + 2\text{H}_2\text{O} (\text{g})
\]

**Bond breaking**
- 4 mol C–H = 4 \times 414 = 1656
- 2 mol O=O = 2 \times 497 = 994

**Total energy put in** = +2650 kJ

**Bond making**
- 2 mol C=O = 2 \times 798 = 1596
- 4 mol H–O = 4 \times 458 = 1832

**Total energy given out** = –3428 kJ

\[
\Delta H = 2650 - 3428 = -778 \text{kJ mol}^{-1}
\]

4. Using bond enthalpy values, calculate the enthalpy change for the following addition reaction.

\[
\text{C}_2\text{H}_4 (\text{g}) + \text{HBr (g)} \rightarrow \text{C}_2\text{H}_5\text{Br} (\text{g})
\]

**Bond breaking**
- 1 mol C=C = 602
- 4 mol C–H = 4 \times 414 = 1656
- 1 mol H–Br = 362

**Total energy put in** = +2620 kJ

**Bond making**
- 1 mol C–C = 346
- 5 mol C–H = 5 \times 414 = 2070
- 1 mol C–Br = 285

**Total energy given out** = –2701 kJ

\[
\Delta H = 2620 - 2701 = -81 \text{kJ mol}^{-1}
\]
5. Use the bond enthalpy values quoted in the data book to calculate the enthalpy change for the hydrogenation of but-1-ene.

\[ C_4H_8 (g) + H_2 (g) \rightarrow C_4H_{10} (g) \]

Bond breaking
1 mol C=C = 602
2 mol C–C = 2 × 346 = 692
1 mol H–H = 432
8 mol C–H = 8 × 414 = 3312
Total energy put in = +5038 kJ

Bond making
3 mol C–C = 3 × 346 = 1038
10 mol C–H = 10 × 414 = 4140
1 mol H–H = 432
Total energy given out = –5178 kJ

\[ \Delta H = 5038 - 5178 = -140 \text{ kJ mol}^{-1} \]

6. Using bond enthalpy values, calculate the enthalpy change for the addition reaction between iodine and propene.

\[ C_3H_6 (g) + I_2 (g) \rightarrow C_3H_6I_2 (g) \]

Bond breaking
1 mol C=C = 602
1 mol C=C = 346
6 mol C–H = 6 × 414 = 2484
1 mol I–I = 149
Total energy put in = +3581 kJ

Bond making
2 mol C–C = 2 × 346 = 692
6 mol C–H = 6 × 414 = 2484
2 mol C–I = 2 × 213 = 426
Total energy given out = –3602 kJ

\[ \Delta H = 3581 - 3602 = -21 \text{ kJ mol}^{-1} \]
7. Hydrogen chloride can react with ethyne in a two-stage addition process to give a saturated product. Calculate the enthalpy change for this reaction using bond enthalpy values from the data book.

\[
\text{C}_2\text{H}_2 (g) + 2\text{HCl (g)} \rightarrow \text{C}_2\text{H}_4\text{Cl}_2 (g)
\]

**Bond breaking**
- 1 mol C≡C = 835
- 2 mol C–H = 2 × 414 = 828
- 2 mol H–Cl = 2 × 428 = 856

\[
\text{Total energy put in} = +2519 \text{ kJ}
\]

**Bond making**
- 1 mol C–C = 346
- 4 mol C–H = 4 × 414 = 1656
- 2 mol C–Cl = 2 × 326 = 652

\[
\text{Total energy given out} = -2654 \text{ kJ}
\]

\[
\Delta H = 2519 - 2654 = -135 \text{ kJ \text{ mol}^{-1}}
\]
8. The data book gives the enthalpy of combustion of ethanol as –1367 kJ mol\(^{-1}\). Use bond enthalpies to calculate the enthalpy change for this reaction.

\[
\text{C}_2\text{H}_5\text{OH} (\text{g}) + 3\text{O}_2 (\text{g}) \quad \rightarrow \quad 2\text{CO}_2 (\text{g}) + 3\text{H}_2\text{O} (\text{g})
\]

**Bond breaking**
- 1 mol C–C = 346
- 5 mol C–H = 5 \times 414 = 2070
- 1 mol C–O = 358
- 1 mol H–O = 458
- 3 mol O=O = 3 \times 497 = 1491

Total energy put in = +4723 kJ

**Bond making**
- 4 mol C=O = 4 \times 798 = 3192
- 6 mol H–O = 6 \times 458 = 2748

Total energy given out = –5940 kJ

\[
\Delta H = 4723 - 5940 = -1217 \text{ kJ mol}^{-1}
\]
9. Calculate the enthalpy of formation for ethene using the enthalpy of sublimation and bond enthalpy values from the data book.

\[
2 \text{C} (s) + 2 \text{H}_2 (g) \rightarrow \text{C}_2\text{H}_4 (g)
\]

**Bond breaking**
- 2 mol C (s) → C (g) = 2 × 715 = 1430 kJ
- 2 mol H–H = 2 × 432 = 864 kJ
- Total energy put in = +2294 kJ

**Bond making**
- 1 mol C=C = 602 kJ
- 4 mol C–H = 4 × 414 = 1656 kJ
- Total energy given out = –2258 kJ

\[
\Delta H = 2294 - 2258 = +36 \text{ kJ mol}^{-1}
\]

10. The data book quotes the mean bond enthalpy for a carbon-to-carbon double bond (C=C) as 602 kJ mol\(^{-1}\). Use the enthalpy of formation given and bond enthalpies from the data book to calculate the enthalpy of the C=C bond in ethene.

\[
2 \text{C} (s) + 2 \text{H}_2 (g) \rightarrow \text{C}_2\text{H}_4 (g) \quad \Delta H_{\text{formation}} = 52 \text{ kJ mol}^{-1}
\]

**Bond breaking**
- 2 mol C (s) → C (g) = 2 × 715 = 1430 kJ
- 2 mol H–H = 2 × 432 = 864 kJ
- Total energy put in = +2294 kJ

**Bond making**
- 1 mol C=C = \(x\) kJ
- 4 mol C–H = 4 × 414 = 1656 kJ
- Total energy given out = \(-1656 - x\) kJ

\[
\Delta H_{\text{formation}} = 52 = 2294 - (1656 + x)
\]

\[
x = 52 = 2294 - 1656 - 52
\]

\[
= +586 \text{ kJ mol}^{-1}
\]