NATIONAL QUALIFICATIONS CURRICULUM SUPPORT

Chemistry

Bond Enthalpy

Support Materials

[HIGHER]

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Contents

Bond Enthalpy

Questions

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

$$2H_2\,(g) + O_2\,(g) \longrightarrow 2H_2O\,(g)$$

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

$$CH_4\,(g) + Br_2\,(g) \longrightarrow CH_3Br\,(g) + HBr\,(g)$$

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

$$CH_4\,(g) + 2O_2\,(g) \longrightarrow CO_2\,(g) + 2H_2O\,(g)$$

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

$$C_2H_4\,(g) + HBr\,(g) \longrightarrow C_2H_5Br\,(g)$$

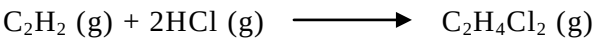
5. Use the bond enthalpy values quoted in the data book to calculate the enthalpy change for the hydrogenation of but-1-ene.

$$C_4H_8\,(g) + H_2\,(g) \longrightarrow C_4H_{10}\,(g)$$

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

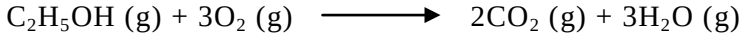
$$C_3H_6\,(g) + I_2\,(g) \longrightarrow C_3H_6I_2\,(g)$$

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.



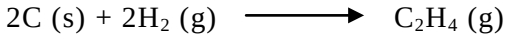
$$C_2H_2\ (g) + 2HCl\ (g) \longrightarrow C_2H_4Cl_2\ (g)$$

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.



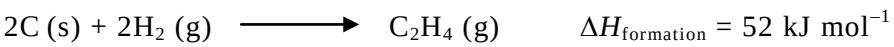
$$C_2H_5OH\ (g) + 3O_2\ (g) \longrightarrow 2CO_2\ (g) + 3H_2O\ (g)$$

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



$$2C\ (s) + 2H_2\ (g) \longrightarrow C_2H_4\ (g)$$

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.

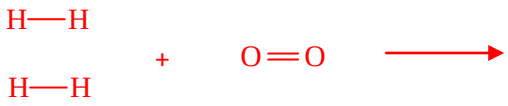


$$2C\ (s) + 2H_2\ (g) \longrightarrow C_2H_4\ (g) \qquad \Delta H_{formation} = 52\ kJ\ mol^{-1}$$

Solutions

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

$$2H_2\,(g) + O_2\,(g) \longrightarrow 2H_2O\,(g)$$



Bond breaking
2 mol H–H = 2 × 432 = 864
1 mol O=O = 497

Total energy put in = +1361 kJ

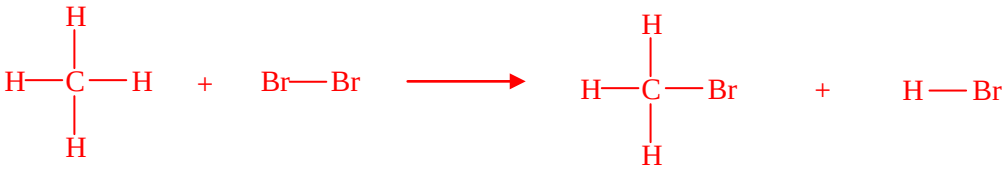
Bond making
4 mol H–O = 4 × 458 = 1832

Total energy given out = –1832 kJ

$$\Delta H = 1361 - 1832$$
$$= -471 \text{ kJ mol}^{-1}$$

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

$$CH_4\,(g) + Br_2\,(g) \longrightarrow CH_3Br\,(g) + HBr\,(g)$$



Bond breaking
4 mol C–H = 4 × 414 = 1656
1 mol Br–Br = 194

Total energy put in = +1850 kJ

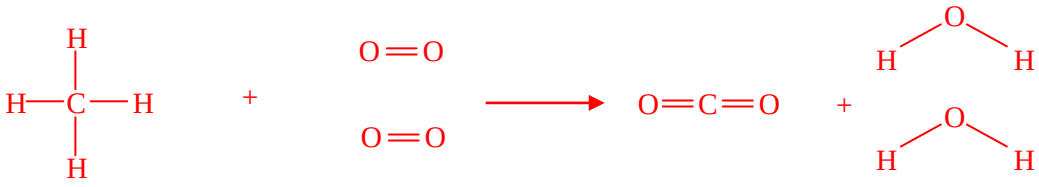
Bond making
3 mol C–H = 3 × 414 = 1242
1 mol C–Br = 285
1mol H–Br = 362

Total energy given out = –1889 kJ

$$\Delta H = 1850 - 1889$$
$$= -39 \text{ kJ mol}^{-1}$$

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

$$CH_4\,(g) + 2O_2\,(g) \longrightarrow CO_2\,(g) + 2H_2O\,(g)$$



Bond breaking
4 mol C–H = 4 × 414 = 1656
2 mol O=O = 2 × 497 = 994

Total energy put in = +2650 kJ

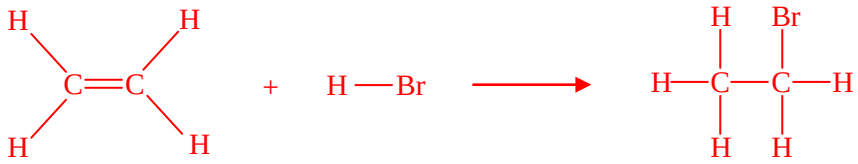
Bond making
2 mol C=O = 2 × 798 = 1596
4 mol H–O = 4 × 458 = 1832

Total energy given out = –3428 kJ

ΔH = 2650 – 3428
= –778 kJ mol^{-1}

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

$$C_2H_4\,(g) + HBr\,(g) \longrightarrow C_2H_5Br\,(g)$$



Bond breaking
1 mol C=C = 602
4 mol C–H = 4 × 414 = 1656
1 mol H–Br = 362

Total energy put in = +2620 kJ

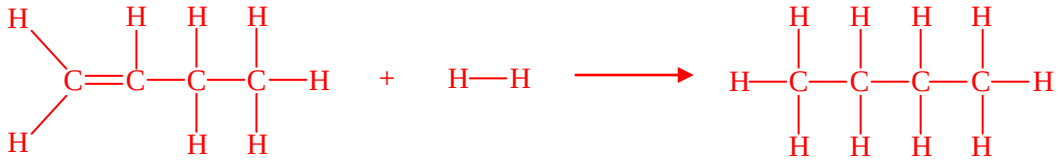
Bond making
1 mol C–C = 346
5 mol C–H = 5 × 414 = 2070
1 mol C–Br = 285

Total energy given out = –2701 kJ

ΔH = 2620 – 2701
= –81 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.

$$C_4H_8\ (g) + H_2\ (g) \longrightarrow C_4H_{10}\ (g)$$



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

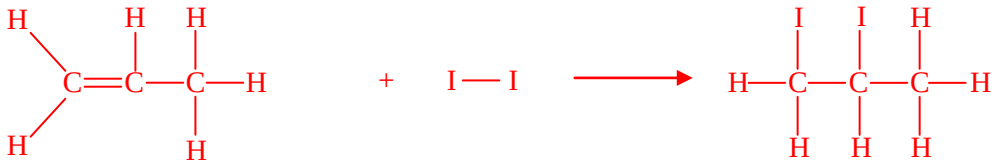
Bond making
3 mol C–C = 3 × 346 = 1038
10 mol C–H = 10 × 414 = 4140

Total energy given out = –5178 kJ

$\Delta H = 5038 - 5178$
$= -140\ kJ\ mol^{-1}$

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

$$C_3H_6\ (g) + I_2\ (g) \longrightarrow C_3H_6I_2\ (g)$$



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

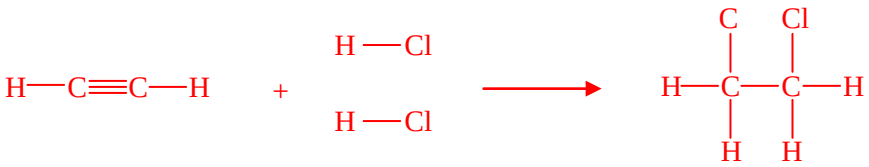
Bond making
2 mol C–C = 2 × 346 = 692
6 mol C–H = 6 × 414 = 2484
2 mol C–I = 2 × 213 = 426

Total energy given out = –3602 kJ

$\Delta H = 3581 - 3602$
$= -21\ kJ\ mol^{-1}$

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.

$$C_2H_2\,(g) + 2HCl\,(g) \longrightarrow C_2H_4Cl_2\,(g)$$



Bond breaking

1 mol C≡C = 835
2 mol C–H = 2 × 414 = 828
2 mol H–Cl = 2 × 428 = 856

Total energy put in = +2519 kJ

Bond making

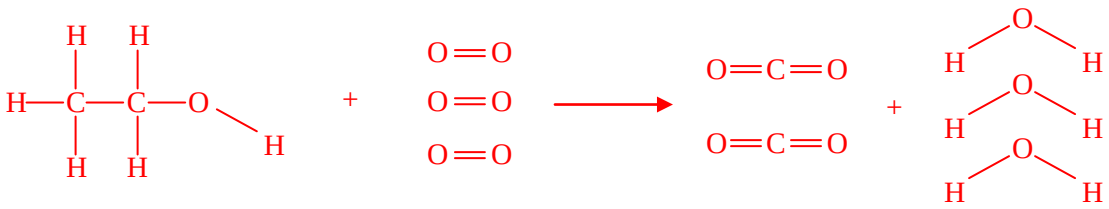
1 mol C–C = 346
4 mol C–H = 4 × 414 = 1656
2 mol C–Cl = 2 × 326 = 652

Total energy given out = –2654 kJ

ΔH = 2519 – 2654
= –135 kJ 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.

$$C_2H_5OH\ (g) + 3O_2\ (g) \longrightarrow 2CO_2\ (g) + 3H_2O\ (g)$$



Bond breaking

1 mol C–C = 346
5 mol C–H = 5 × 414 = 2070
1 mol C–O = 358
1 mol H–O = 458
3 mol O=O = 3 × 497 = 1491

Total energy put in = +4723 kJ

Bond making

4 mol C=O = 4 × 798 = 3192
6 mol H–O = 6 × 458 = 2748

Total energy given out = –5940 kJ

$$\Delta H = 4723 - 5940$$
$$= -1217\ kJ\ mol^{-1}$$

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

$$2C\ (s) + 2H_2\ (g) \longrightarrow C_2H_4\ (g)$$

Bond breaking

2 mol C (s) ⟶ C (g) = 2 × 715 = 1430

2 mol H–H = 2 × 432 = 864

Total energy put in = +2294 kJ

Bond making

1 mol C=C = 602

4 mol C–H = 4 × 414 = 1656

Total energy given out = –2258 kJ

ΔH = 2294 – 2258

= + 36 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.

$$2C\ (s) + 2H_2\ (g) \longrightarrow C_2H_4\ (g) \qquad \Delta H_{formation} = 52\ kJ\ mol^{-1}$$

Bond breaking

2 mol C (s) ⟶ C (g) = 2 × 715 = 1430

2 mol H–H = 2 × 432 = 864

Total energy put in = +2294 kJ

Bond making

1 mol C=C = x

4 mol C–H = 4 × 414 = 1656

Total energy given out = –(1656 + x) kJ

$\Delta H_{formation}$ = 52 = 2294 – (1656 + x)

52 = 2294 – 1656 – x

x = 2294 – 1656 – 52

= + 586 kJ mol^{-1}