Worksheet 1.1: Bond Energy Calculations

ChemistrySheets

Specification: GCSE Chemistry (AQA 5.5.1.2 / Edexcel SC13 / OCR Gateway)

Core Concepts: Bond energy is energy to break 1 mole of a bond (endothermic). Energy is released when bonds form (exothermic).

Key Formula:

$\Delta H = \sum \text{bonds broken} - \sum \text{bonds formed}$

Where:

- ΔH: Overall energy change (kJ/mol)
- $\sum$ bonds broken: Total energy absorbed to break bonds in reactants (kJ/mol)
- $\sum$ bonds formed: Total energy released to form bonds in products (kJ/mol)

Rearranged Forms:

$\sum \text{bonds broken} = \Delta H + \sum \text{bonds formed}$

$\sum \text{bonds formed} = \sum \text{bonds broken} - \Delta H$

Section A: Understanding the Formula & Units

1. State the SI unit for each variable in the bond energy calculation formula.
   - ΔH: **kJ/mol**
   - $\sum$ bonds broken: **kJ/mol**
   - $\sum$ bonds formed: **kJ/mol**
2. Rearrange the formula for:
   - $\sum$ bonds broken:

     Model Answer:
     $\sum \text{bonds broken} = \Delta H + \sum \text{bonds formed}$

   - $\sum$ bonds formed:

     Model Answer:
     $\sum \text{bonds formed} = \sum \text{bonds broken} - \Delta H$

3. Perform the following unit conversions:
   a) Convert 3500 J to kJ: **3.5 kJ**
   b) Convert 0.8 kJ to J: **800 J**
   c) Convert 1.5 MJ to kJ: **1500 kJ**
   d) Convert 450000 J to MJ: **0.45 MJ**

Section B: Practice Calculations

Use Table 1 for bond energies. Show working.

Bond	Bond Energy (kJ/mol)
C-H	413
C-C	348
C=C	614
C-O	358
C=O	799
O-H	463
O=O	498
H-H	436
Cl-Cl	242
H-Cl	431
N≡N	945
N-H	391

Table 1: Average bond energies

4. Calculate ΔH for: $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

Model Answer:
Bonds broken: H-H (436) + Cl-Cl (242) = 678 kJ/mol. Bonds formed: 2 × H-Cl (2 × 431) = 862 kJ/mol. $\Delta H = 678 - 862 = -184$ kJ/mol.

5. Calculate ΔH for the complete combustion of methane: CH_4(g) + $2O_2$(g) → CO_2(g) + $2H_2O$(g)

Model Answer:
Bonds broken: 4 × C-H (4×413=1652) + 2 × O=O (2×498=996) = 2648 kJ/mol. Bonds formed: 2 × C=O (2×799=1598) + 4 × O-H (4×463=1852) = 3450 kJ/mol. $\Delta H = 2648 - 3450 = -802$ kJ/mol.

6. The Haber process: N_2(g) + $3H_2$(g) → $2NH_3$(g). If ΔH = -92 kJ/mol, calculate the total energy released when bonds are formed in the products.

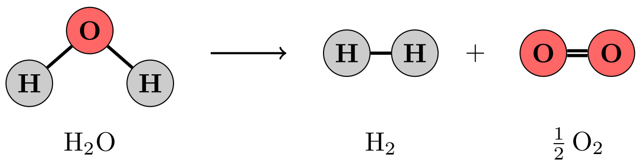
Model Answer:
Bonds broken: N≡N (945) + 3 × H-H (3×436=1308) = 2253 kJ/mol. $\sum$ bonds formed = $\sum$ bonds broken - ΔH = 2253 - (-92) = 2345 kJ/mol.

7. Ethene hydrogenation: C_2H_4(g) + H_2(g) → C_2H_6(g). ΔH = -136 kJ/mol. Using Table 1, calculate the C-C bond energy in ethane.

Model Answer:
Bonds broken: 1 C=C (614) + 4 C-H (4×413=1652) + 1 H-H (436) = 2702 kJ/mol. Bonds formed: 1 C-C (x) + 6 C-H (6×413=2478) = x + 2478 kJ/mol. $\Delta H = (\sum \text{bonds broken}) - (\sum \text{bonds formed})$. $-136 = 2702 - (x + 2478)$. $-136 = 2702 - x - 2478$. $-136 = 224 - x$. $x = 224 + 136 = 360$ kJ/mol. The C-C bond energy is 360 kJ/mol.

Section C: Challenge Context

8. Water decomposition: H_2O(g) → H_2(g) + $\frac{1}{2}O_2$(g).



Using Table 1, calculate ΔH for the decomposition of 1 mole of gaseous water.

Model Answer:
Bonds broken: 2 × O-H (2×463=926) = 926 kJ/mol. Bonds formed: 1 × H-H (436) + 0.5 × O=O (0.5×498=249) = 685 kJ/mol. $\Delta H = 926 - 685 = 241$ kJ/mol.

9. Ethanol combustion: C_2H_5OH(g) + $3O_2$(g) → $2CO_2$(g) + $3H_2O$(g). Calculate the total energy released when 23 g of ethanol undergoes complete combustion (M_r C_2H_5OH = 46 g/mol).

Model Answer:
Bonds broken: 1 C-C (348) + 5 C-H (5×413=2065) + 1 C-O (358) + 1 O-H (463) + 3 O=O (3×498=1494) = 4728 kJ/mol. Bonds formed: 4 C=O (4×799=3196) + 6 O-H (6×463=2778) = 5974 kJ/mol. ΔH per mole = 4728 - 5974 = -1246 kJ/mol. Moles of ethanol = 23 g / 46 g/mol = 0.5 mol. Total energy released = 0.5 mol × (-1246 kJ/mol) = -623 kJ. The energy released is 623 kJ.