

Heat changes, energy cycles and bond enthalpies

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These 20 problems cover enthalpy definitions, calorimetry with $q = m c \Delta T$, Hess cycles from combustion and formation data, and ΔH estimated from bond enthalpies. They begin with definitions and single-step calculations and end with multi-step cycles and critical evaluation of methods.

The level suits IB Chemistry, A Level, CBSE Class 11-12 and WAEC/NECO senior students. Always write the unit and the sign of ΔH .

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB R1.1-R1.2

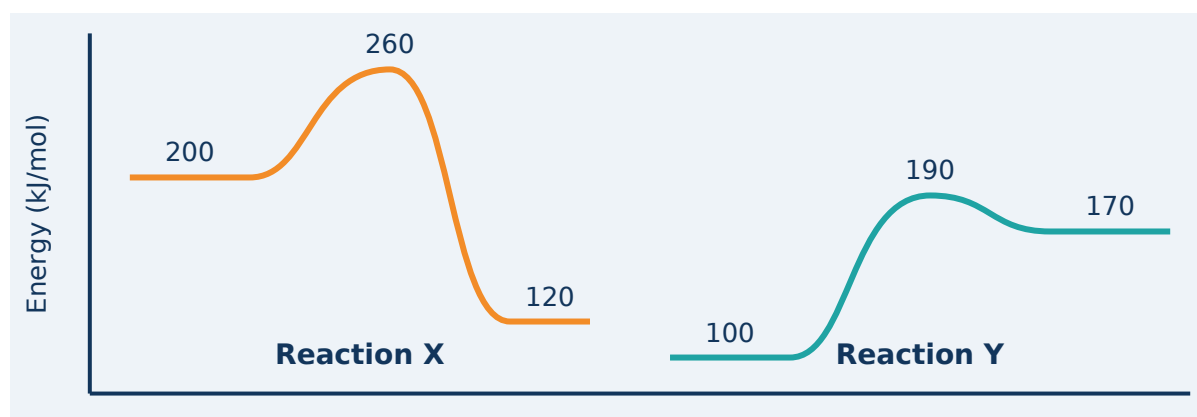
Problem 1 Name the enthalpy change (easy)

Mei in Singapore revises definitions.

1. Write the equation, with state symbols, for the standard enthalpy of formation of ethanol, $C_2H_5OH(l)$.
2. Write the equation for the standard enthalpy of combustion of hydrogen.
3. State the standard pressure and the usual standard temperature.

Problem 2 Exothermic or endothermic? (easy)

Aarav in Pune studies two reactions.



Energy profiles for reactions X and Y (energies in kJ/mol).

1. Classify X and Y as exothermic or endothermic.
2. Calculate ΔH for each reaction.

3. Calculate the forward activation energy of X and the activation energy of the reverse reaction of X.

Problem 3 Heat in a water bath (easy)

Chiamaka in Lagos heats 150 g of water from 18.0 °C to 27.5 °C ($c = 4.18 \text{ J/(g K)}$).

1. Calculate ΔT .
2. Calculate the heat absorbed, in J and in kJ.
3. Calculate the temperature rise if the same energy heated 300 g of water.

Problem 4 Dissolving sodium hydroxide (easy)

Kofi in Accra dissolves 2.00 g of NaOH ($M = 40.0 \text{ g/mol}$) in 100 g of water. The temperature rises by 5.3 °C.

1. Calculate the moles of NaOH.
2. Calculate the heat absorbed by the water.
3. Calculate ΔH of solution in kJ/mol.

Problem 5 Neutralisation (easy)

25.0 cm³ of 1.00 mol/dm³ hydrochloric acid is mixed with 25.0 cm³ of 1.00 mol/dm³ sodium hydroxide. The temperature rises by 6.8 K. Assume density 1.00 g/cm³ and $c = 4.18 \text{ J/(g K)}$.

1. Calculate the heat absorbed by the solution.
2. Calculate the moles of water formed.
3. Calculate ΔH of neutralisation in kJ/mol.

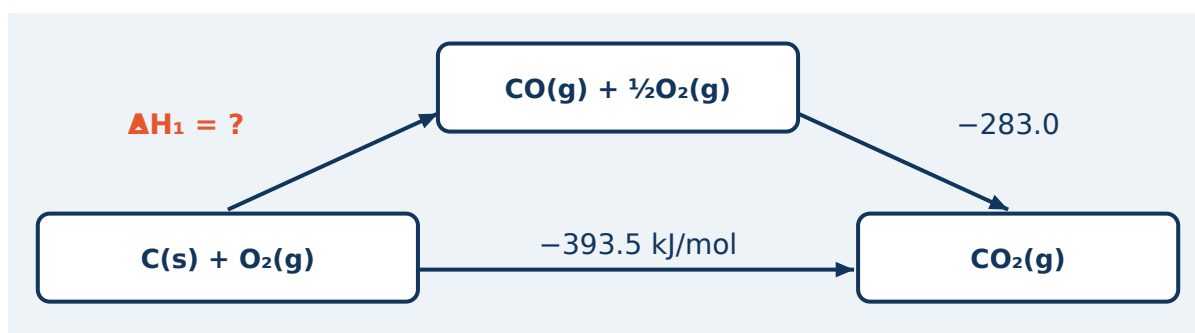
Problem 6 Energy per gram and in kilocalories (easy)

Bilal in Lahore reads that the enthalpy of combustion of glucose, C₆H₁₂O₆ ($M = 180.0 \text{ g/mol}$), is -2803 kJ/mol .

1. Calculate the energy released per gram.
2. Calculate the energy released by 25.0 g.
3. Convert your answer to part 2 to kilocalories ($1 \text{ kcal} = 4.184 \text{ kJ}$).

Problem 7 Carbon, carbon monoxide and Hess (medium)

Emma in Leeds wants ΔH for $\text{C(s)} + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{CO(g)}$, which cannot be measured directly.



Hess cycle for carbon (all values in kJ/mol).

1. State Hess's law.
2. Calculate ΔH_1 using the cycle.
3. Write the equation for the second step and state its type of enthalpy change.

Problem 8 Combining equations (medium)

$\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g})$ has $\Delta H = +180.5$ kJ. $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$ has $\Delta H = -114.1$ kJ.

1. Write the overall equation for the two steps.
2. Calculate ΔH for the overall equation.
3. Calculate ΔH per mole of NO_2 formed.

Problem 9 Formation of butane (medium)

Diego in Texas has ΔH_c values: $\text{C}(\text{s}) -393.5$, $\text{H}_2(\text{g}) -285.8$, $\text{C}_4\text{H}_{10}(\text{g}) -2877$ kJ/mol.

1. Write the equation for the formation of butane.
2. Calculate ΔH_f of butane using combustion data.

Problem 10 Reducing iron ore (medium)

$\text{Fe}_2\text{O}_3(\text{s}) + 3\text{CO}(\text{g}) \rightarrow 2\text{Fe}(\text{s}) + 3\text{CO}_2(\text{g})$. ΔH_f values (kJ/mol): $\text{Fe}_2\text{O}_3 -824.2$, $\text{CO} -110.5$, $\text{CO}_2 -393.5$.

1. Calculate the total ΔH_f of the products.
2. Calculate the total ΔH_f of the reactants.
3. Calculate ΔH for the reaction.

Problem 11 Hydrogen chloride (medium)

Use bond enthalpies: H-H 436, Cl-Cl 243, H-Cl 432 kJ/mol for $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{HCl}(\text{g})$.

1. Calculate the energy needed to break the bonds.
2. Calculate the energy released when the bonds form.
3. Calculate ΔH and ΔH per mole of HCl.

Problem 12 Hydrogenation of ethene (medium)

$\text{C}_2\text{H}_4 + \text{H}_2 \rightarrow \text{C}_2\text{H}_6$. Bond enthalpies (kJ/mol): $\text{C}=\text{C}$ 612, H-H 436, C-C 347, C-H 413.

1. List the bonds broken and formed.
2. Calculate ΔH .
3. State whether the reaction is exothermic.

Problem 13 Spirit burner (medium)

Wanjiru in Nairobi burns propan-1-ol ($\text{C}_3\text{H}_8\text{O}$, $M = 60.0$ g/mol) under 200 g of water. The burner loses 0.80 g and the water warms by 24.0 K. The data-book value is -2021 kJ/mol.

1. Calculate the heat absorbed by the water.
2. Calculate the experimental ΔH_c in kJ/mol.
3. Calculate the percentage of the data-book energy not measured and suggest two reasons.

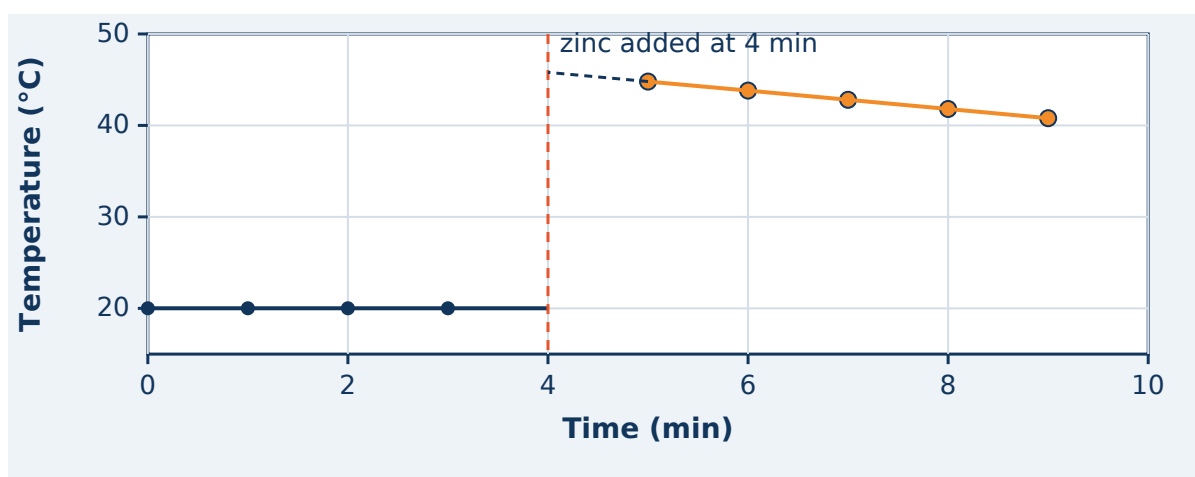
Problem 14 Bond enthalpy versus data (medium)

Methanol vapour burns: $\text{CH}_3\text{OH}(\text{g}) + 1\frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$. Bond enthalpies (kJ/mol): C-H 413, C-O 358, O-H 464, O=O 498, C=O 805.

1. Calculate ΔH using bond enthalpies.
2. ΔH_f values are $\text{CH}_3\text{OH}(\text{g}) -201.0$, $\text{CO}_2 -393.5$, $\text{H}_2\text{O}(\text{g}) -241.8$ kJ/mol. Calculate ΔH from these.
3. Calculate the difference and explain it.

Problem 15 Zinc and copper sulfate (medium)

Excess zinc is added to 50.0 cm^3 of 0.500 mol/dm^3 copper(II) sulfate at 4 min. The graph shows readings.



Temperature readings during the displacement reaction.

1. Extrapolate to 4 min and state ΔT .
2. Calculate q .
3. Calculate ΔH per mole of copper sulfate.

Problem 16 Hydration of copper sulfate (hard)

Anhydrous $\text{CuSO}_4(\text{s})$ dissolves in water with $\Delta H = -66.1 \text{ kJ/mol}$. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s})$ dissolves with $\Delta H = +11.7 \text{ kJ/mol}$.

1. Draw the Hess cycle in words, linking the solid hydrate, the anhydrous solid and the solution.
2. Calculate ΔH for $\text{CuSO}_4(\text{s}) + 5\text{H}_2\text{O}(\text{l}) \rightarrow \text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s})$.
3. State why this value cannot be measured directly.

Problem 17 Formation of ethyne (hard)

ΔH_c (kJ/mol): C(s) -393.5 , H₂(g) -285.8 , C₂H₂(g) -1300 .

1. Write the formation equation of ethyne.
2. Calculate ΔH_f of ethyne.
3. Explain what the sign of your answer tells you about the stability of ethyne relative to its elements.

Problem 18 Mean C-H bond enthalpy (hard)

ΔH_f of CH₄(g) = -74.8 kJ/mol. ΔH_{at} (atomisation) of C(s) = $+716.7$ kJ/mol and of H₂(g) per mole of H atoms = $+218.0$ kJ/mol.

1. Write the equation for CH₄(g) $\rightarrow$ C(g) + 4H(g) and state which data combine to give its ΔH .
2. Calculate ΔH for the equation.
3. Calculate the mean C-H bond enthalpy.

Problem 19 Hydration of ethene (hard)

C₂H₄(g) + H₂O(g) $\rightarrow$ C₂H₅OH(g). Bond enthalpies (kJ/mol): C=C 612, C-C 347, C-H 413, C-O 358, O-H 464. ΔH_f (kJ/mol): C₂H₄ $+52.3$, H₂O(g) -241.8 , C₂H₅OH(g) -235.3 .

1. Calculate ΔH from bond enthalpies.
2. Calculate ΔH from formation data.
3. Calculate the percentage difference relative to the formation-data value and suggest one reason.

Problem 20 Spot the errors (hard)

Find and correct the error in each calculation or statement.

1. A student uses $q = 2.00 \times 4.18 \times 5.3$, where 2.00 g is the mass of solid NaOH.
2. A student states that the temperature rose, so ΔH is $+44.3$ kJ/mol.
3. A student writes $q = 2215$ J and gives $\Delta H = -2215 / 0.0500 = -44.3$ J/mol.
4. A student calculates $\Delta H = \Sigma(\text{bonds formed}) - \Sigma(\text{bonds broken})$.