

Heat, enthalpy and Hess's law

AP Chemistry · Worksheet

Name: _____ Date: _____ Class: _____

These twenty problems train the main skills of AP Chemistry Unit 6: classifying heat flow, using $q = mc\Delta T$, combining equations with Hess's law, and calculating ΔH from formation data and bond enthalpies. Early problems check definitions and signs; later ones involve calorimeter constants, graphs and multi-step reasoning. Show every step and keep the sign of ΔH .

Level: AP Chemistry · **Curriculum:** AP Chem Unit 6

Problem 1 Exothermic or endothermic (easy)

Classify each as exothermic or endothermic.

1. A reaction has $\Delta H = -92 \text{ kJ}$.
2. An instant ice pack gets cold when the seal is broken.
3. The products have more enthalpy than the reactants.
4. The test tube becomes hot to the touch.

Problem 2 Heat absorbed by water (easy)

Chiamaka in Lagos heats 250 g of water from 20.0 °C to 35.0 °C ($c = 4.18 \text{ J/(g °C)}$).

1. Calculate q in joules.
2. Convert it to kJ.

Problem 3 Specific heat of copper (easy)

A 100.0 g piece of copper absorbs 962 J and warms from 20.0 °C to 45.0 °C.

1. Calculate the temperature change.
2. Calculate the specific heat capacity.

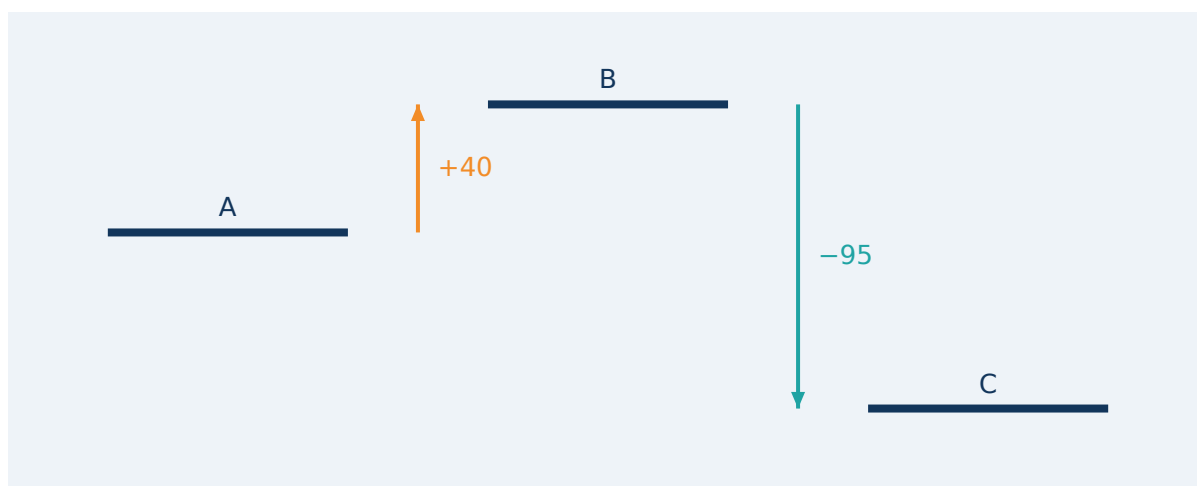
Problem 4 Heat from burning methane (easy)

Burning 1 mol of CH_4 releases 890 kJ ($M = 16.04 \text{ g/mol}$).

1. Write the sign of ΔH .
2. Calculate the heat released when 4.00 g of CH_4 burns.

Problem 5 Adding two steps (easy)

The enthalpy levels are shown.



Two steps from A to C.

1. State ΔH for $A \rightarrow B$ and $B \rightarrow C$.
2. Calculate ΔH for $A \rightarrow C$.
3. State ΔH for $C \rightarrow A$.

Problem 6 Reversing and scaling (easy)

$N_2(g) + O_2(g) \rightarrow 2 NO(g)$ has $\Delta H = +180 \text{ kJ}$.

1. State ΔH for $2 NO(g) \rightarrow N_2(g) + O_2(g)$.
2. State ΔH for $\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightarrow NO(g)$.
3. State ΔH for $3 N_2(g) + 3 O_2(g) \rightarrow 6 NO(g)$.

Problem 7 Writing formation equations (easy)

1. Write the equation whose enthalpy is ΔH°_f of $CO_2(g)$.
2. Write the equation for ΔH°_f of ethanol, $C_2H_5OH(l)$.
3. Explain why ΔH°_f of $Cl_2(g)$ is 0.

Problem 8 Neutralisation in a cup (medium)

Diego in Texas mixes 50.0 mL of 1.00 M HCl and 50.0 mL of 1.00 M NaOH, both at 21.0 °C. The temperature rises to 27.5 °C. Take 1.00 g/mL and 4.18 J/(g °C).

1. Calculate q gained by the solution.
2. Calculate the moles of water formed.
3. Calculate ΔH in kJ/mol.

Problem 9 A cold dissolving (medium)

A student dissolves 8.00 g of NH_4NO_3 ($M = 80.04 \text{ g/mol}$) in 100.0 g of water. The temperature falls from 22.0 °C to 16.4 °C. Use 4.18 J/(g °C) and the total mass 108.0 g.

1. Calculate q for the solution.
2. Calculate ΔH of solution in kJ/mol and state its sign.
3. Explain the temperature drop.

Problem 10 Hess's law with combustion data (medium)

Combustion enthalpies: $\text{C}_2\text{H}_4(\text{g}) -1411 \text{ kJ/mol}$; $\text{C}_2\text{H}_6(\text{g}) -1560 \text{ kJ/mol}$; $\text{H}_2(\text{g}) -286 \text{ kJ/mol}$ (all to $\text{CO}_2(\text{g})$ and $\text{H}_2\text{O}(\text{l})$).

1. Write the equation for $\text{C}_2\text{H}_4 + \text{H}_2 \rightarrow \text{C}_2\text{H}_6$.
2. Calculate ΔH using the combustion data.

Problem 11 Formation enthalpies (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 (kJ/mol): $\text{Fe}_2\text{O}_3 -824.2$, $\text{CO} -110.5$, $\text{CO}_2 -393.5$.

1. State ΔH°_f of $\text{Fe}(\text{s})$.
2. Calculate ΔH° .
3. State whether the reaction is exothermic.

Problem 12 Bond enthalpies for HCl (medium)

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

1. Calculate the energy to break the bonds.
2. Calculate the energy released on forming bonds.
3. Calculate ΔH .

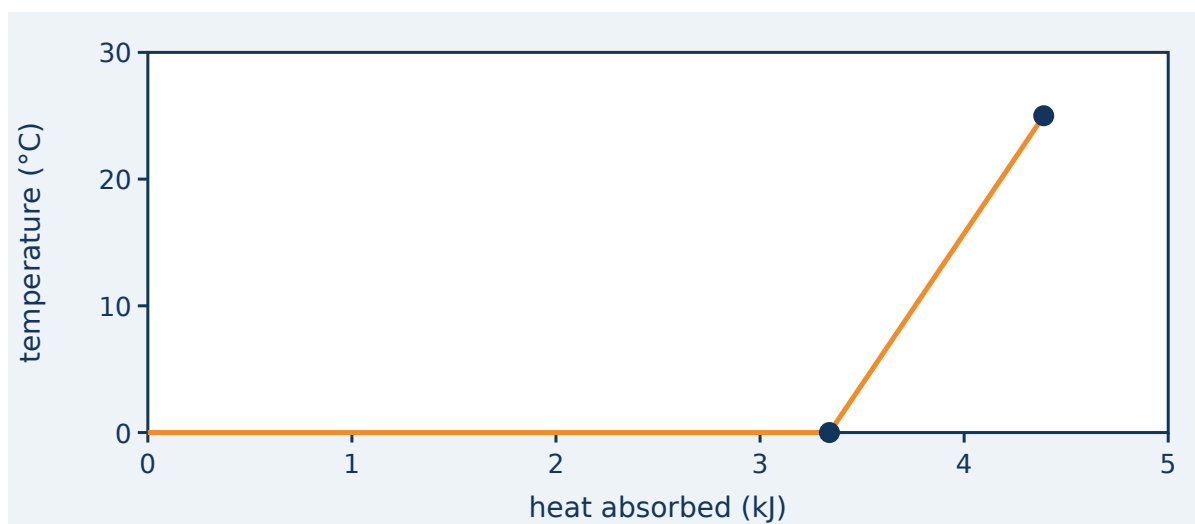
Problem 13 Spirit burner (medium)

A burner heats 200.0 g of water from 20.0 °C to 45.0 °C and loses 1.20 g of ethanol ($M = 46.07 \text{ g/mol}$).

1. Calculate the heat gained by the water.
2. Calculate the experimental molar enthalpy of combustion.
3. The data book value is -1367 kJ/mol ; calculate the percentage of the heat that reached the water.

Problem 14 Melting and warming ice (medium)

Mei in Singapore melts 10.0 g of ice at 0 °C and warms the water to 25.0 °C. $\Delta H_{\text{fus}} = 334 \text{ J/g}$; $c = 4.18 \text{ J/(g } ^\circ\text{C)}$.



Ice at 0 °C is heated until the liquid reaches 25 °C.

1. Calculate the heat to melt the ice.
2. Calculate the heat to warm the water.
3. Calculate the total.

Problem 15 Hydrogenation by bond enthalpy (medium)

$\text{C}_2\text{H}_4 + \text{H}_2 \rightarrow \text{C}_2\text{H}_6$. Bond enthalpies (kJ/mol): C=C 614, H-H 436, C-C 347, C-H 413.

1. Calculate ΔH from bond enthalpies.
2. Compare with the value -137 kJ from Hess's law and suggest why they differ.

Problem 16 Calorimeter with a heat capacity (hard)

Excess zinc is added to 100.0 mL of 0.100 M CuSO_4 in a calorimeter of heat capacity 25.0 J/°C. The temperature rises from 21.0 °C to 25.9 °C. Take 1.00 g/mL and 4.18 J/(g °C).

1. Calculate the heat absorbed by the solution and by the calorimeter.
2. Calculate ΔH per mole of Cu^{2+} reacted.
3. Explain why zinc is used in excess.

Problem 17 Formation enthalpy from combustion (hard)

The enthalpy of combustion of methanol, $\text{CH}_3\text{OH}(\text{l})$, is -726 kJ/mol to $\text{CO}_2(\text{g})$ and $\text{H}_2\text{O}(\text{l})$. ΔH°_f : CO_2 -393.5 , $\text{H}_2\text{O}(\text{l})$ -285.8 kJ/mol.

1. Write the balanced combustion equation.
2. Calculate ΔH°_f of methanol.

Problem 18 Ethyne from its elements (hard)

Given: (1) $\text{C}_2\text{H}_2(\text{g}) + 5/2 \text{O}_2(\text{g}) \rightarrow 2 \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$, $\Delta H = -1300$ kJ; (2) $\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$, $\Delta H = -393.5$ kJ; (3) $\text{H}_2(\text{g}) + 1/2 \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$, $\Delta H = -285.8$ kJ.

1. Combine the equations to give $2 \text{C}(\text{s}) + \text{H}_2(\text{g}) \rightarrow \text{C}_2\text{H}_2(\text{g})$.
2. Calculate ΔH .

3. State whether ethyne is more or less stable than its elements.

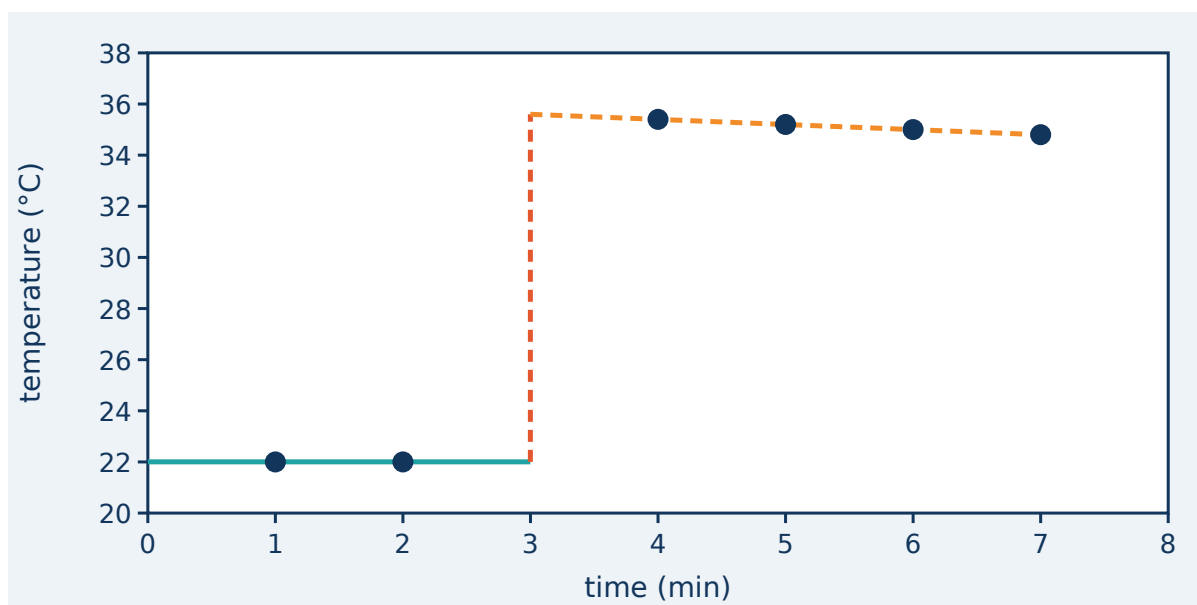
Problem 19 Ammonia synthesis (hard)

$\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightarrow 2 \text{NH}_3(\text{g})$. Bond enthalpies (kJ/mol): $\text{N}\equiv\text{N}$ 945, $\text{H}-\text{H}$ 436, $\text{N}-\text{H}$ 391.

1. Calculate ΔH .
2. Calculate the heat released per kilogram of NH_3 formed ($M = 17.03 \text{ g/mol}$).
3. Explain why the industrial reactor must remove heat.

Problem 20 Reading a temperature-time graph (hard)

A student mixes 50.0 cm^3 of 2.00 M HCl and 50.0 cm^3 of 2.00 M NaOH (3 min mark) in a cup.



Mixing happens at 3 min; the dashed line is extrapolated back.

1. Explain why the dashed line is extrapolated back to 3 min.
2. Read the extrapolated maximum temperature and ΔT .
3. Calculate ΔH (100.0 g, $4.18 \text{ J/(g } ^\circ\text{C)}$).
4. Compare with the result if the highest reading ($35.4 \text{ } ^\circ\text{C}$) were used, and explain the difference.