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CHEMISTRY WORKSHEET

MIXED THERMOCHEMISTRY PROBLEMS

Course: Grade 12 Chemistry

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50 Practice Problems with Answers and Detailed Solutions

Full version of this worksheet contains 4 selected problems on:

✓q = m·c·ΔT calorimetry, ✓Phase changes and heating curves, ✓Coffee-cup and bomb calorimetry sign convention, ✓Heat exchange and final temperature, ✓Hess's Law and formation enthalpy, ✓Bond energy estimates, ✓Thermochemical stoichiometry with limiting reagents.

All problems are designed to reflect style and difficulty commonly seen on quizzes, tests, and final exams. Detailed solutions are included to help students understand the reasoning behind every step.

PART A - FUNDAMENTAL PROBLEMS Selected Problem 8	**PART B - INTERMEDIATE PROBLEMS** Selected Problem 16
PART C - ADVANCED PROBLEMS Selected Problem 32	**PART D - CHALLENGE PROBLEMS** Selected Problem 45

SUITABLE FOR:
quizzes, unit tests and final exam preparation

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Section 1 - Essential Information – included in full version

This page includes only the formulas and habits needed to solve calorimetry problems efficiently.

Formula	Use
$q = m \times c \times \Delta T$	Heat gained or lost by a substance
$\Delta T = T_f - T_i$	Temperature change with sign
$q_{cal} = C_{cal} \Delta T$	Heat absorbed by a calorimeter
$q_{reaction} = -q_{surroundings}$	Sign convention for coffee-cup and bomb calorimetry
$q_{hot} + q_{cold} = 0$	Heat exchange between substances
$\Delta H = q_{reaction}/n$	Molar enthalpy at constant pressure

Important definitions: coffee-cup calorimetry is usually constant pressure, so q_p can be used for ΔH. Bomb calorimetry is constant volume, so the result is commonly treated as ΔU for SCH4U-style calculations.

Fast method: identify what gains heat, identify what loses heat, convert volumes to masses when density is given, calculate ΔT carefully, include C_{cal} when provided, then apply the sign convention at the end.

Important notes: for dilute aqueous solutions, use density = 1.00 g/mL and $c = 4.184$ J/(g·°C) only when stated or clearly assumed. For reactions, the solution and calorimeter are surroundings, while the chemical reaction is the system.

Common mistakes: using only one solution volume after mixing, forgetting that $q_{reaction}$ has the opposite sign of $q_{solution}$, ignoring the limiting reagent, mixing J and kJ, and using the sample mass instead of moles when a molar answer is requested.

Section 2 - Practice Problems

Part A - Fundamental Problems (Problem 8)

Problem 8

Decide whether the equation below can be used directly as the standard enthalpy of formation equation for $CO_{2(g)}$

$$C(\text{graphite}) + O_{2(g)} \rightarrow CO_{2(g)}$$

Part B - Intermediate Problems (Problem 16)

Problem 16

50.0 mL of 1.00 mol/L $HCl_{(aq)}$ is mixed with 50.0 mL of 1.00 mol/L $NaOH_{(aq)}$. The temperature rises from 21.5 °C to 28.2 °C. Assume density = 1.00 g/mL and c = 4.184 J/(g·°C). Calculate $\Delta H_{neutralization}$ per mole of $H_2O_{(l)}$ formed

Part C - Advanced Problems (Problem 32)

Problem 32

A 20.0 g sample of ice at 0 °C is added to 250.0 g of water at 30.0 °C. Assuming no heat loss, determine the final temperature

Part D - Challenge Problems (Problem 45)

Problem 45

Estimate ΔH_{rxn} for the reaction below

$$CH_3OH_{(g)} + 3/2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$$

Using bond energies: C-H = 413 kJ/mol, C-O = 358 kJ/mol, O-H = 463 kJ/mol, O=O = 498 kJ/mol, and C=O in CO_2 = 799 kJ/mol

If 4.00 g of $CH_3OH_{(g)}$ burns and 70.0% of the released heat warms 500.0 g of water, calculate the water temperature increase

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Section 3 - Solutions

Problem 8 Solution

Given: The equation is C(graphite) + $O_{2(g)}$ → $CO_{2(g)}$. It forms $CO_{2(g)}$ from elements in their standard states

Find: Whether the equation directly represents $\Delta H^\circ_f[CO_{2(g)}]$

Method: A standard enthalpy of formation equation must form exactly 1 mol of compound from elements in their standard states

Formula: Formation equation: elements in standard states → 1 mol compound

Calculations: The equation forms exactly 1 mol $CO_{2(g)}$. Carbon is written as graphite, the standard state of carbon, and oxygen is $O_{2(g)}$, the standard state of oxygen

This is a definition question, so significant figures do not apply

Final answer: Yes, it is a valid formation equation for $CO_{2(g)}$

Problem 16 Solution

Given: The acid and base volumes are each 50.0 mL, each concentration is 1.00 mol/L, total solution mass is 100.0 g, and $\Delta T = 28.2\ ^\circ C - 21.5\ ^\circ C = 6.7\ ^\circ C$

Find: The neutralization enthalpy per mole of $H_2O_{(l)}$ formed

Method: The solution absorbs heat, so the reaction releases the same amount of heat. The moles of water formed equal the moles of limiting HCl or NaOH because this is a 1:1 neutralization

Formula: $q_{solution} = m \cdot c \cdot \Delta T$, $q_{reaction} = -q_{solution}$, and $\Delta H = q_{reaction}/n_{H2O}$

Calculations: $q_{solution} = (100.0\ g)(4.184\ J/(g \cdot ^\circ C))(6.7\ ^\circ C) = 2803.28\ J = 2.80328\ kJ$. $n_{H2O} = (0.0500\ L)(1.00\ mol/L) = 0.0500\ mol$. $\Delta H = -2.80328\ kJ / 0.0500\ mol = -56.0656\ kJ/mol$

The value is close to the expected strong acid-strong base value near -57 kJ/mol. The final answer is rounded to three significant figures

Final answer: -56.1 kJ/mol H_2O

Problem 32 Solution

Given: The ice mass is 20.0 g at 0 °C, and the water mass is 250.0 g at 30.0 °C. Use ΔH_{fus} = 334 J/g and c_{water} = 4.184 J/(g·°C)

Find: The final temperature after the ice melts and the mixture reaches equilibrium

Method: First check whether the warm water can melt all the ice. Then use remaining heat to warm the melted ice and original water together

Formula: qwater to 0 = $m_{water} \cdot c \cdot \Delta T$, qmelt = $m_{ice} \cdot \Delta H_{fus}$, and $q_{remaining} = (m_{total}) \cdot c \cdot T_f$

Calculations: qwater to 0 = (250.0)(4.184)(30.0) = 31380 J. qmelt = (20.0)(334) = 6680 J. Remaining heat = 24700 J. T_f = 24700 J / [(270.0 g)(4.184 J/(g·°C))] = 21.8646 °C

All the ice melts because the warm water can release more heat cooling to 0 °C than is needed to melt the ice. The answer is rounded to three significant figures

Final answer: 21.9 °C

Problem 45 Solution

Given: The reaction is $CH_3OH_{(g)} + 3/2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$. The methanol mass is 4.00 g, and 70.0% of the released heat warms 500.0 g of water

Find: The estimated reaction enthalpy and the resulting water temperature increase

Method: Use bond energies to estimate ΔH. Then convert methanol mass to moles, calculate released heat, apply the efficiency, and use $q = m \cdot c \cdot \Delta T$ for water

Formula: $\Delta H_{rxn} \approx \Sigma$ bonds broken - Σ bonds formed, $q_{useful} = \text{efficiency} \cdot n \cdot |\Delta H|$, and $\Delta T = q_{useful}/(m \cdot c)$

Calculations: Broken bonds = 3(C-H) + C-O + O-H + 1.5(O=O) = 3(413) + 358 + 463 + 1.5(498) = 2807 kJ. Formed bonds = 2(C=O) + 4(O-H) = 2(799) + 4(463) = 3450 kJ. ΔH ≈ -643 kJ/mol. n = 4.00/32.04 = 0.1248 mol. Useful heat = 0.700(0.1248)(643 kJ) = 56.19 kJ. ΔT = 56190 J / [(500.0 g)(4.184 J/(g·°C))] = 26.86 °C

The water receives only part of the combustion energy, so the efficiency must be applied before calculating ΔT. The final temperature increase is rounded to three significant figures

Final answer: $\Delta H_{rxn} \approx -643$ kJ/mol; ΔT = 26.9 °C

Section 4 - Answer Key

Problem	Answer
8	Yes, it is a valid formation equation for $CO_{2(g)}$
16	-56.1 kJ/mol H_2O
32	21.9 °C
45	$\Delta H_{rxn} \approx$ -643 kJ/mol; ΔT = 26.9 °C

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