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CHEMISTRY WORKSHEET

HESS'S LAW

Course: Grade 12 Chemistry

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50 Practice Problems with Answers and Detailed Solutions

Full version of this worksheet contains 4 selected representative problems on:

✓ Finding enthalpy of overall reaction from enthalpies of its steps ✓Reversing and scaling thermochemical equations, ✓Adding steps and cancelling intermediates, ✓Standard enthalpy of formation calculations, ✓Combustion data used with Hess's Law, ✓Bond enthalpy estimates

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 Problems 1-15. Simple calculations and basic applications	**PART B - INTERMEDIATE PROBLEMS** Problems 16-30. Typical unit test questions involving multiple steps
PART C - ADVANCED PROBLEMS Problems 31-40. More challenging calculations requiring deeper understanding	**PART D - CHALLENGE PROBLEMS** Problems 41-50. Difficult exam-style questions combining multiple concepts

SUITABLE FOR:
quizzes, unit tests and final exam preparation

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Section 1 - Essential Information - included in full version

Section 2 - Practice Problems

Part A - Fundamental Problems (Problems 1-15)

Problem 8

Calculate ΔH_{rxn} for the combustion of methane using the ΔH_f° values below

$CH_{4(g)} + 2O_2(g) \rightarrow CO_{2(g)} + 2H_2O(l)$

ΔH_f° values: $CH_{4(g)}$ = -74.8 kJ/mol, $CO_{2(g)}$ = -393.5 kJ/mol, $H_2O_{(l)}$ = -285.8 kJ/mol, $O_{2(g)}$ = 0 kJ/mol

Part B - Intermediate Problems (Problems 16-30)

Problem 16

Use the two steps below to calculate ΔH_{rxn} for the formation of nitrogen dioxide from nitrogen and oxygen

$N_{2(g)} + O_{2(g)} \rightarrow 2NO(g)$

ΔH_{rxn} = +180.5 kJ

$2NO(g) + O_{2(g)} \rightarrow 2NO_2(g)$

ΔH_{rxn} = -114.1 kJ

Target reaction:

$N_{2(g)} + 2O_2(g) \rightarrow 2NO_2(g)$

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Part C - Advanced Problems (Problems 31-40)

Problem 32

Calculate ΔH_{rxn} for combustion of benzene using standard enthalpies of formation

$$C_6H_{6(l)} + 15/2\ O_{2(g)} \rightarrow 6CO2(g) + 3H2O(l)$$

ΔH_f° values: $C_6H_{6(l)}$ = +49.0 kJ/mol, $CO_{2(g)}$ = -393.5 kJ/mol, $H_2O_{(l)}$ = -285.8 kJ/mol, $O_{2(g)}$ = 0 kJ/mol

Part D - Challenge Problems (Problems 41-50)

Problem 45

Use the two equations below to calculate ΔH_{rxn} for formation of methanol from carbon, hydrogen, and oxygen

$$C_{(s)} + 1/2\ O_{2(g)} \rightarrow CO_{(g)}$$

ΔH_{rxn} = -110.5 kJ

$$CO_{(g)} + 2H2(g) \rightarrow CH_3OH_{(l)}$$

ΔH_{rxn} = -128.1 kJ

Target reaction:

$$C_{(s)} + 2H2(g) + 1/2\ O_{2(g)} \rightarrow CH_3OH_{(l)}$$

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Section 3 - Solutions

Problem 8 Solution

Given: ΔH_f° values are provided for $CH_{4(g)}$, $CO_{2(g)}$, $H_2O_{(l)}$, and $O_{2(g)}$

Find: ΔH_{rxn} for methane combustion, in kJ/mol of $CH_{4(g)}$

Method: Add the formation enthalpies of all products, subtract the formation enthalpies of all reactants, and remember that $O_{2(g)}$ has $\Delta H_f^\circ = 0$

Formula: $\Delta H_{rxn} = \Sigma n \cdot \Delta H_f^\circ(\text{products}) - \Sigma n \cdot \Delta H_f^\circ(\text{reactants})$

Calculations: Using the values, $\Delta H_{rxn} = [(-393.5) + 2(-285.8)] - [(-74.8) + 2(0)] = -965.1 + 74.8 = -890.3$ kJ/mol

Final answer: -890.3 kJ/mol CH_4

Significant figures: The final answer is reported with appropriate significant figures because the tabulated enthalpy values are given to about four significant figures

Problem 16 Solution

Given: The first equation forms $NO_{(g)}$, and the second equation converts $NO_{(g)}$ to $NO_{2(g)}$

Find: ΔH_{rxn} for $N_{2(g)}$ + 2O2(g) → 2NO2(g), in kJ

Method: Add the two equations exactly as written. The 2NO(g) produced in the first equation cancels with the 2NO(g) used in the second equation

Formula: $\Delta H_{target} = \Delta H_1 + \Delta H_2$

Calculations: Using the values, $\Delta H_{target} = +180.5 \text{ kJ} + (-114.1 \text{ kJ}) = +66.4$ kJ

Final answer: +66.4 kJ

Significant figures: The final answer is reported with appropriate significant figures because both enthalpy values are given to one decimal place

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Problem 32 Solution

Given: The balanced combustion equation and ΔH_f° values for benzene, carbon dioxide, liquid water, and oxygen are provided

Find: ΔH_{rxn} for burning 1 mol of $C_6H_{6(l)}$, in kJ/mol

Method: Multiply each formation enthalpy by its coefficient. Oxygen is not included in the numerical sum because ΔH_f° for $O_{2(g)}$ is zero

Formula: $\Delta H_{rxn} = \Sigma n \cdot \Delta H_f^\circ(\text{products}) - \Sigma n \cdot \Delta H_f^\circ(\text{reactants})$

Calculations: Using the values, $\Delta H_{rxn} = [6(-393.5) + 3(-285.8)] - [(+49.0) + 15/2(0)] = -3218.4 - 49.0 = -3267.4$ kJ/mol

Final answer: -3267.4 kJ/mol C_6H_6

Significant figures: The final answer is reported with appropriate significant figures because the enthalpy values are given to one decimal place

Problem 45 Solution

Given: Carbon can first form $CO_{(g)}$, and $CO_{(g)}$ can then react with $H_{2(g)}$ to form $CH_3OH_{(l)}$

Find: ΔH_{rxn} for forming $CH_3OH_{(l)}$ from $C_{(s)}$, $H_{2(g)}$, and $O_{2(g)}$, in kJ/mol

Method: Add the two equations as written. $CO_{(g)}$ is an intermediate because it is produced in the first equation and consumed in the second equation

Formula: $\Delta H_{target} = \Delta H_1 + \Delta H_2$

Calculations: Using the values, $\Delta H_{target} = -110.5\text{ kJ} + (-128.1\text{ kJ}) = -238.6$ kJ/mol

Final answer: -238.6 kJ/mol CH_3OH

Significant figures: The final answer is reported with appropriate significant figures because both enthalpy values are given to one decimal place

Section 4 - Answer Key

Problem	Answer
8	-890.3 kJ/mol CH_4
16	+66.4 kJ
32	-3267.4 kJ/mol C_6H_6
45	-238.6 kJ/mol CH_3OH

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