Unit 4: Energy, Rates, and Equilibrium

## Chapter 12: Thermochemistry

### Lesson 3: Enthalpy Changes and Hess's Law

### 1. Big Idea:

Energy changes in chemical reactions can be calculated and manipulated using thermochemical equations and Hess's Law, helping us understand how energy flows during chemical processes.

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### 2. Essential Questions:

### # How do we calculate the enthalpy change for a reaction using Hess’s Law?

**Answer:** Hess's Law states that the total enthalpy change for a chemical reaction is the same, no matter which pathway the reaction takes. By adding or subtracting the enthalpy changes of individual steps in a reaction pathway, we can calculate the overall enthalpy change for the reaction.

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### 3.1 Phenomenon-Based Learning:

### # Unit Phenomenon:

**The Thermodynamics House: Can You Solve the Puzzles and Escape?**

You and your classmates are trapped in a 2-story high-tech laboratory escape house. To unlock the final door and escape, you must solve puzzles that explore the flow of energy in chemical reactions and how these reactions behave under different conditions.

### # Chapter Phenomenon:

The second floor of the escape house focuses on energy changes in chemical reactions. How does energy transfer occur during reactions? How much energy is absorbed or released? How can these values be calculated and manipulated to help you escape?

### # Lesson Phenomenon:

**"The Pathway to Escape"**

You’ve reached the second-to-last room of the escape house! Your challenge is to calculate missing enthalpy values based on provided enthalpy values for reaction steps displayed on interactive screens. Each correct calculation reveals clues to unlock the final door.

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### 4. Vocabulary:

- **Enthalpy (H):** The total heat content of a system, often measured as the energy absorbed or released during a chemical reaction.

- **Hess's Law:** A principle stating that the total enthalpy change of a reaction is the same, regardless of the pathway taken, as long as the initial and final states are the same.

- **Standard Enthalpy of Combustion (ΔH°c):** The enthalpy change when one mole of a substance burns completely in oxygen under standard conditions.

- **Standard Enthalpy of Formation (ΔH°f):** The enthalpy change when one mole of a compound forms from its elements in their standard states under standard conditions.

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### 5. SMART Objectives:

- Write thermochemical equations.

- Calculate the enthalpy change for a reaction to classify it as endothermic or exothermic.

- Apply Hess's Law to predict the enthalpy change for a multi-step reaction.

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### 6. Engage (Ignite):

### # Phenomenon-Related Task:

**Scenario:** Imagine you’re in the escape house. The room has an interactive screen displaying the following:

1. A reaction where methane burns in oxygen.

2. Another reaction where carbon dioxide and water form from their elements.

3. A third reaction where methane forms from carbon and hydrogen.

Your task is to calculate the enthalpy change for the combustion of methane using the given enthalpy values for the other reactions.

### # Hands-On Experiment:

**Experiment Title:** **"Heat Transfer in a Chemical Reaction"**

**Objective:** Observe and measure the heat released or absorbed in a simple chemical reaction.

**Materials Needed:**

- Baking soda (sodium bicarbonate)

- Vinegar (acetic acid)

- A small plastic cup

- A thermometer

- A stopwatch

**Procedure:**

1. Place 1 tablespoon of baking soda in the plastic cup.

2. Measure the initial temperature of the vinegar using the thermometer.

3. Slowly pour 2 tablespoons of vinegar into the cup with baking soda.

4. Observe the reaction (bubbling and fizzing) and record the temperature every 10 seconds for 1 minute.

**Follow-Up Questions:**

1. Did the temperature increase or decrease during the reaction?

**Answer:** The temperature decreased, indicating that the reaction absorbed heat (endothermic).

2. What does this tell you about the energy flow in the reaction?

**Answer:** The reaction absorbed energy from its surroundings, causing the temperature to drop.

3. How does this relate to enthalpy changes?

**Answer:** Enthalpy changes reflect whether a reaction absorbs (endothermic) or releases (exothermic) energy.

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### 7. Pre-Explore (Direct Instruction):

### # Background Information:

Energy changes are a key part of chemical reactions. These changes can be measured and expressed as enthalpy (H), which is the heat content of a system. When a reaction occurs:

- If energy is **released**, the reaction is **exothermic** (ΔH is negative).

- If energy is **absorbed**, the reaction is **endothermic** (ΔH is positive).

Hess's Law helps us calculate the enthalpy change for reactions that occur in multiple steps. By combining the enthalpy changes of individual steps, we can determine the total enthalpy change for the overall reaction.

### # Interactive Notes:

- **Thermochemical Equations:** These equations include the enthalpy change (ΔH) along with the chemical equation. For example:

\[ CH\_4 + 2O\_2 → CO\_2 + 2H\_2O \ \ \ \ ΔH = -890 \, kJ \]

This means 890 kJ of energy is released when methane burns.

- **Standard Conditions:** Enthalpy changes are measured under standard conditions (25°C, 1 atm pressure, 1 M concentration).

### # Scaffolded Questions:

1. What does a negative ΔH value mean?

**Answer:** It means the reaction is exothermic and releases energy.

2. Why is it important to include ΔH in a thermochemical equation?

**Answer:** It shows how much energy is absorbed or released during the reaction.

3. How can Hess's Law simplify calculations for complex reactions?

**Answer:** It allows us to calculate the overall enthalpy change by adding or subtracting enthalpy changes of individual steps.

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### 8. Evaluate (Progress Check) - Pre-Explore:

### # Questions:

1. Write the thermochemical equation for the combustion of propane (\( C\_3H\_8 \)).

**Answer:** \( C\_3H\_8 + 5O\_2 → 3CO\_2 + 4H\_2O \ \ \ ΔH = -2219 \, kJ \)

2. Is the combustion of propane endothermic or exothermic?

**Answer:** Exothermic, because ΔH is negative.

3. How does Hess's Law apply to this reaction?

**Answer:** If the combustion of propane occurs in multiple steps, Hess's Law allows us to calculate the total enthalpy change by summing the enthalpy changes of each step.

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### 9. Explain (Lightbulb):

### # Core Concept: Enthalpy Changes

Enthalpy (H) is the heat content of a system. During chemical reactions, energy is either absorbed or released. The enthalpy change (ΔH) tells us how much energy is involved.

- **Exothermic Reactions:** Release energy to the surroundings (ΔH < 0). Example: Combustion of fuels.

- **Endothermic Reactions:** Absorb energy from the surroundings (ΔH > 0). Example: Photosynthesis.

### # Core Concept: Hess's Law

Hess's Law states that the total enthalpy change of a reaction is the same, no matter how many steps it takes. This is because enthalpy is a state function—it depends only on the starting and ending states, not the pathway.

**Example Problem:**

Calculate the enthalpy change for the reaction:

\[ C + O\_2 → CO\_2 \]

Given:

1. \( C + 1/2O\_2 → CO \ \ \ ΔH = -110 \, kJ \)

2. \( CO + 1/2O\_2 → CO\_2 \ \ \ ΔH = -283 \, kJ \)

**Solution:**

1. Add the two reactions:

\[ (C + 1/2O\_2 → CO) + (CO + 1/2O\_2 → CO\_2) \]

\[ C + O\_2 → CO\_2 \]

2. Add the enthalpy changes:

\[ ΔH = -110 \, kJ + (-283 \, kJ) = -393 \, kJ \]

**Progress Check:**

1. Use Hess's Law to calculate the enthalpy change for the reaction:

\[ N\_2 + 3H\_2 → 2NH\_3 \]

Given:

- \( N\_2 + O\_2 → 2NO \ \ \ ΔH = +180 \, kJ \)

- \( 2NO + O\_2 → 2NO\_2 \ \ \ ΔH = -114 \, kJ \)

- \( 2NO\_2 + 4H\_2 → 2NH\_3 + 2H\_2O \ \ \ ΔH = -117 \, kJ \)

**Answer:**

Combine the equations and sum the enthalpy changes:

\[ ΔH = +180 \, kJ - 114 \, kJ - 117 \, kJ = -51 \, kJ \]

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By the end of this lesson, you'll have the tools to calculate enthalpy changes for reactions, classify them as endothermic or exothermic, and apply Hess's Law to multi-step reactions.

Sure! Below is a structured response based on the provided requirements. Let’s assume the topic is **"The Periodic Table and Chemical Properties."** This example will align with the Flesch Reading Ease Score and Grade Level requirements.

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### 10. Evaluate (Progress Check) - Explain

**Scaffolded Questions to Confirm Understanding:**

1. **Question:** What is the purpose of the periodic table?

**Answer:** The periodic table organizes elements based on their atomic number, electron configurations, and recurring chemical properties. It helps scientists predict how elements will react.

2. **Question:** Why do elements in the same group of the periodic table have similar chemical properties?

**Answer:** Elements in the same group have the same number of valence electrons. This determines how they bond with other elements, giving them similar chemical properties.

3. **Question:** How does the position of an element on the periodic table help you predict whether it is a metal, non-metal, or metalloid?

**Answer:** Metals are usually on the left and center of the table, non-metals are on the right, and metalloids are found along the zigzag line between metals and non-metals.

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### 11. Elaborate (Power Up)

**Mini-Tasks and Open-Ended Questions:**

1. **Task:** Create a color-coded version of the periodic table. Use different colors to represent metals, non-metals, and metalloids. Write a short explanation of why you chose each color.

**Answer:** Students should color metals (e.g., blue), non-metals (e.g., yellow), and metalloids (e.g., green) and explain that these categories are based on shared properties like conductivity and reactivity.

2. **Question:** If a new element were discovered and placed in Group 1, what properties would you expect it to have?

**Answer:** It would likely be highly reactive, soft, and have one valence electron, similar to other alkali metals.

3. **Question:** How might the periodic table change in the future as new elements are discovered?

**Answer:** New elements could expand the table, especially in the higher atomic number ranges. Scientists may also revise how elements are grouped if new properties are discovered.

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### 12. Final Evaluation

**Debate Question:**

- **Should scientists rearrange the periodic table to make it easier for beginners to understand, even if it changes the traditional layout?**

- **Arguments For:** It could help students and beginners learn faster by grouping elements in a more visually intuitive way.

- **Arguments Against:** The current layout is based on scientific principles like atomic number and electron configuration, which are essential for advanced understanding.

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**Assessment Questions:**

**Multiple-Choice Questions:**

1. **What does the atomic number of an element represent?**

- A) The number of protons in an atom

- B) The number of neutrons in an atom

- C) The total number of protons and neutrons

- D) The number of electrons in an atom

**Correct Answer:** A) The number of protons in an atom

**Explanation:** The atomic number is equal to the number of protons, which defines the element.

2. **Which group on the periodic table contains the noble gases?**

- A) Group 1

- B) Group 2

- C) Group 17

- D) Group 18

**Correct Answer:** D) Group 18

**Explanation:** Noble gases are in Group 18 and are known for being inert due to their full valence electron shells.

3. **What is a characteristic property of metals?**

- A) Poor conductivity

- B) Brittle when solid

- C) Malleable and ductile

- D) Low melting point

**Correct Answer:** C) Malleable and ductile

**Explanation:** Metals can be shaped and stretched without breaking, which makes them malleable and ductile.

4. **Which of the following is a metalloid?**

- A) Oxygen

- B) Silicon

- C) Sodium

- D) Chlorine

**Correct Answer:** B) Silicon

**Explanation:** Silicon has properties of both metals and non-metals, making it a metalloid.

**Long-Answer Questions:**

1. **Explain how Dmitri Mendeleev organized the first periodic table and how it differs from the modern periodic table.**

**Answer:** Mendeleev arranged elements by increasing atomic mass and grouped them by similar properties. The modern table is arranged by atomic number, which better reflects the periodic law.

2. **Describe the trends in atomic size as you move across a period and down a group in the periodic table.**

**Answer:** Atomic size decreases across a period because the increasing number of protons pulls electrons closer to the nucleus. Atomic size increases down a group because new energy levels are added, making the atom larger.

3. **Why are alkali metals more reactive than alkaline earth metals?**

**Answer:** Alkali metals have one valence electron, which is easier to lose compared to the two valence electrons in alkaline earth metals. This makes alkali metals more reactive.

4. **Predict the chemical properties of an element with an atomic number of 117 based on its position in the periodic table.**

**Answer:** Element 117 would be a halogen, so it would likely be highly reactive, especially with alkali and alkaline earth metals. It might also form salts and exist as a diatomic molecule.

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### 13. Extend (Beyond the Lesson)

**Additional Tasks and Challenges:**

1. **Task:** Research how the periodic table is used in industries like medicine or technology. Write a short report on one application.

**Example Answer:** In medicine, the periodic table helps identify elements like iodine (used in thyroid treatments) and platinum (used in cancer drugs).

2. **Challenge Question:** How can the periodic table help predict the environmental impact of certain elements, like heavy metals?

**Example Answer:** The periodic table shows which elements are heavy metals (e.g., lead, mercury). These elements are toxic and can accumulate in ecosystems, causing harm to plants and animals.

3. **Spaced Practice Activity:** Create flashcards for 10 elements, including their symbol, atomic number, and one key property. Review these flashcards weekly to reinforce your knowledge.

4. **Real-World Application:** Imagine you are designing a new smartphone. Use the periodic table to choose three elements that would be important for its construction and explain why.

**Example Answer:** Silicon (for semiconductors), lithium (for batteries), and aluminum (for the lightweight case).

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This structure ensures clarity, engagement, and alignment with the learning outcomes while maintaining readability and accessibility for Grade 9 students.