Unit 4: Energy, Rates, and Equilibrium

## Chapter 12: Thermochemistry

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

### 1. Big Idea:

- Chemical reactions involve energy changes that can be measured and calculated. These energy changes help us understand whether a reaction absorbs or releases energy and how reactions can be combined to predict overall energy changes.

### 2. Essential Questions:

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

**Answer:** By using Hess's Law, we can calculate the enthalpy change for a reaction by adding or subtracting the enthalpy changes of individual steps in a reaction pathway. This works because enthalpy is a state function, meaning it depends only on the initial and final states, not the pathway taken.

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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 find yourselves trapped in a 2-story high-tech laboratory escape house. To unlock the final door and escape the house, you must solve a series of puzzles presented to you in each room. The puzzles explore how energy flows through chemical reactions and how these reactions behave under different conditions.

### Chapter Phenomenon:

The second floor of the escape house is devoted to studying the energy involved in chemical reactions. How does energy transfer occur during chemical processes, how much energy is absorbed or released, and how these values can be calculated and manipulated for your escape?

### Lesson Phenomenon:

**"The Pathway to Escape"**

You have now reached the second to last room of the escape house! Your challenge for this room is to find missing enthalpy values based on provided enthalpy values for each reaction step displayed on interactive screens around the room. Each correct calculation helps piece together clues leading you closer to unlocking your final exit.

### 4. Vocabulary:

1. **Enthalpy (H):** The heat content of a system at constant pressure. It represents the energy stored in chemical bonds and is measured in kilojoules (kJ).

2. **Hess's Law:** A principle stating that the total enthalpy change for a reaction is the same, no matter how many steps the reaction is carried out in.

3. **Standard Enthalpy of Combustion (ΔH°c):** The enthalpy change when one mole of a substance burns completely in oxygen under standard conditions (25°C, 1 atm).

4. **Standard Enthalpy of Formation (ΔH°f):** The enthalpy change when one mole of a compound is formed 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:**

Imagine you’re in the second-to-last room of the escape house. On a screen, you see the following scenario:

> “To unlock the next door, you must calculate the total energy change for a reaction. You are given the enthalpy changes for smaller reactions that combine to form the overall reaction. Can you figure it out?”

**Hands-On Experiment:**

Let’s explore energy changes in a simple reaction!

**Materials Needed:**

- Vinegar (acetic acid solution)

- Baking soda (sodium bicarbonate)

- A small plastic cup

- A thermometer

- A measuring spoon

**Procedure:**

1. Measure 50 mL of vinegar and pour it into the plastic cup.

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

3. Add one teaspoon of baking soda to the vinegar and observe the reaction.

4. Record the temperature after the reaction stops.

**Follow-Up Questions:**

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

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

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

**Answer:** The reaction absorbed heat from the surroundings, which caused the temperature to drop.

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

**Background Information:**

Energy changes are a key part of chemical reactions. Some reactions release energy (exothermic), while others absorb energy (endothermic). The amount of energy involved can be measured as the enthalpy change (ΔH).

Hess's Law helps us calculate the total enthalpy change for reactions that occur in multiple steps. It states that the total enthalpy change depends only on the initial and final states of the reaction, not the pathway taken. This is because enthalpy is a state function.

**Interactive Notes:**

- **Exothermic Reactions:** Release heat; ΔH is negative. Example: Combustion of natural gas.

- **Endothermic Reactions:** Absorb heat; ΔH is positive. Example: Melting ice.

- **Hess’s Law:** Allows us to add or subtract enthalpy changes for individual steps to find the total enthalpy change.

**Discussion Questions:**

1. Why do you think Hess’s Law is useful in chemistry?

**Answer:** It allows us to calculate enthalpy changes for reactions that are difficult to measure directly.

2. Can you think of a real-life example where energy changes are important?

**Answer:** Burning fuel in a car engine releases energy to power the vehicle.

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

**Scaffolded Questions:**

1. What is the sign of ΔH for an exothermic reaction?

**Answer:** Negative.

2. How does Hess’s Law simplify the calculation of enthalpy changes?

**Answer:** It allows us to use known enthalpy changes for smaller steps to calculate the total enthalpy change.

3. Why is enthalpy considered a state function?

**Answer:** Because it depends only on the initial and final states, not the pathway taken.

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### 9. Explain (Lightbulb):

**Core Concepts:**

### # 9.1 What is Enthalpy?

Enthalpy (H) is the heat content of a system at constant pressure. It represents the energy stored in chemical bonds. When a reaction occurs, bonds break and new ones form, causing energy to be absorbed or released.

- **Exothermic Reactions:** These release energy to the surroundings. For example, when wood burns, it releases heat and light.

- **Endothermic Reactions:** These absorb energy from the surroundings. For example, photosynthesis absorbs sunlight to produce glucose.

### # 9.2 Writing Thermochemical Equations

A thermochemical equation shows the enthalpy change along with the balanced chemical equation.

Example:

\[ \text{CH}\_4 + 2\text{O}\_2 \rightarrow \text{CO}\_2 + 2\text{H}\_2\text{O} \quad \Delta H = -890 \, \text{kJ} \]

This equation shows that burning methane releases 890 kJ of energy (exothermic).

### # 9.3 Hess’s Law

Hess’s Law states that the total enthalpy change for a reaction is the same, no matter how many steps it takes.

**Example Problem:**

Calculate the enthalpy change for the reaction:

\[ \text{C} + \text{O}\_2 \rightarrow \text{CO}\_2 \]

Given:

1. \[ \text{C} + \frac{1}{2}\text{O}\_2 \rightarrow \text{CO} \quad \Delta H = -110 \, \text{kJ} \]

2. \[ \text{CO} + \frac{1}{2}\text{O}\_2 \rightarrow \text{CO}\_2 \quad \Delta H = -283 \, \text{kJ} \]

**Solution:**

Add the two reactions:

\[ \text{C} + \frac{1}{2}\text{O}\_2 + \text{CO} + \frac{1}{2}\text{O}\_2 \rightarrow \text{CO} + \text{CO}\_2 \]

Cancel out \(\text{CO}\):

\[ \text{C} + \text{O}\_2 \rightarrow \text{CO}\_2 \]

Add the enthalpy changes:

\[ \Delta H = -110 \, \text{kJ} + (-283 \, \text{kJ}) = -393 \, \text{kJ} \]

**Progress Check:**

1. Why can we add enthalpy changes for individual steps?

**Answer:** Because enthalpy is a state function.

2. What is the total enthalpy change for the reaction above?

**Answer:** \(-393 \, \text{kJ}\).

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### Real-World Connection:

Hess’s Law is used in industries to calculate energy requirements for chemical processes, such as producing fertilizers or fuels. By understanding enthalpy changes, chemists can design more efficient and cost-effective processes.

Sure! Let’s break this down step by step into an engaging chemistry lesson for 9th-grade students. The topic we'll focus on is **"The Periodic Table and Trends"**. This lesson will be structured with scaffolded questions, open-ended tasks, assessments, and extension activities.

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

Here are three scaffolded questions to confirm understanding of the key concepts covered in the "Explain" section of the Periodic Table and Trends lesson.

### # Question 1:

**What is the periodic table, and why is it important in chemistry?**

\*(Hint: Think about how it organizes elements and helps predict their properties.)\*

**Answer:**

The periodic table is a chart that organizes all known elements by their atomic number, electron configurations, and recurring chemical properties. It is important because it helps scientists understand patterns in element behavior and predict how different elements will react.

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### # Question 2:

**How do elements in the same group (column) of the periodic table behave similarly?**

\*(Hint: Look at their valence electrons.)\*

**Answer:**

Elements in the same group have the same number of valence electrons. This means they have similar chemical properties, such as how they bond with other elements or their reactivity. For example, all Group 1 elements (alkali metals) are highly reactive with water.

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### # Question 3:

**Why does atomic size decrease as you move across a period from left to right?**

\*(Hint: Think about protons and the pull on electrons.)\*

**Answer:**

As you move across a period, the number of protons in the nucleus increases. This stronger positive charge pulls the electrons closer to the nucleus, making the atomic size smaller.

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### 11. Elaborate (Power Up)

Here are mini-tasks and open-ended questions to encourage deeper thinking:

### # Task 1:

**Compare and contrast the properties of metals, nonmetals, and metalloids. Create a table to organize your findings.**

\*(Hint: Think about conductivity, malleability, and where they are located on the periodic table.)\*

**Answer:**

- **Metals**: Good conductors of heat and electricity, malleable, ductile, shiny, found on the left side of the periodic table.

- **Nonmetals**: Poor conductors, brittle, dull, found on the right side of the periodic table.

- **Metalloids**: Have properties of both metals and nonmetals, found along the "stair-step" line.

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### # Task 2:

**Why do noble gases (Group 18) rarely form compounds? Can you think of a situation where they might?**

\*(Hint: Consider their electron configuration.)\*

**Answer:**

Noble gases rarely form compounds because they have a full outer shell of electrons, making them stable and unreactive. However, under extreme conditions, elements like xenon can form compounds with highly electronegative elements like fluorine.

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### # Task 3:

**If you could design a new element, where would you place it on the periodic table? What properties would it have?**

\*(Hint: Think about trends in groups and periods.)\*

**Answer:**

Answers will vary. Students might place the element in Group 1 and describe it as highly reactive, or in Group 18 as a stable, nonreactive gas. They should justify their choice based on periodic trends.

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### 12. Final Evaluation

### # Debate Question:

**Should we continue to search for and create new elements, or focus on studying the ones we already know?**

- **Arguments For**: Discovering new elements could lead to new technologies and materials. It helps expand our understanding of chemistry and the universe.

- **Arguments Against**: It is expensive and may not have immediate practical benefits. We should focus on using existing elements more efficiently.

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### # Multiple-Choice Questions:

1. **Which of the following elements is a metalloid?**

a) Oxygen

b) Silicon

c) Sodium

d) Neon

**Correct Answer:** b) Silicon

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

2. **What happens to electronegativity as you move down a group in the periodic table?**

a) It increases

b) It decreases

c) It stays the same

d) It fluctuates

**Correct Answer:** b) It decreases

**Explanation:** As you move down a group, the atoms get larger, and the nucleus has less pull on shared electrons.

3. **Which group of elements is the most reactive?**

a) Noble gases

b) Halogens

c) Alkali metals

d) Transition metals

**Correct Answer:** c) Alkali metals

**Explanation:** Alkali metals have one valence electron, making them highly reactive.

4. **What is the atomic number of an element?**

a) The number of neutrons

b) The number of protons

c) The number of electrons in the outer shell

d) The total number of electrons and neutrons

**Correct Answer:** b) The number of protons

**Explanation:** The atomic number represents the number of protons in an atom's nucleus.

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### # Long-Answer Questions:

1. **Explain why elements in the same period have different properties, even though they have the same number of electron shells.**

**Answer:** Elements in the same period have different numbers of protons, which affects their nuclear charge. This changes how strongly they attract electrons, leading to different properties like electronegativity and reactivity.

2. **Describe the trend in ionization energy across a period and down a group. Why does this happen?**

**Answer:** Ionization energy increases across a period because the nuclear charge increases, making it harder to remove an electron. It decreases down a group because the outer electrons are farther from the nucleus and experience less pull.

3. **How do the properties of halogens change as you move down the group? Provide examples.**

**Answer:** Halogens become less reactive as you move down the group. For example, fluorine is highly reactive, while iodine is less so. This is because the atomic size increases, making it harder to attract electrons.

4. **Predict the properties of an unknown element in Group 2, Period 4. Justify your prediction.**

**Answer:** The element would likely be a metal, have two valence electrons, and be reactive (but less so than Group 1 elements). It would also form +2 ions in reactions, similar to calcium.

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### 13. Extend (Beyond the Lesson)

### # Additional Tasks:

1. **Research Task:**

Investigate how the periodic table has changed over time. How did Mendeleev’s table differ from the modern periodic table?

2. **Real-World Application:**

Find an everyday product that uses a transition metal. Explain how the element's properties make it useful in that product.

3. **Challenge Question:**

If a new element were discovered with an atomic number of 119, predict its properties based on its position in the periodic table.

### # Spaced Practice:

- Review the trends in atomic size, ionization energy, and electronegativity weekly.

- Create flashcards for element groups and their key properties.

- Solve periodic table puzzles or games online to reinforce learning.

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This lesson plan ensures students build a strong understanding of the periodic table while encouraging critical thinking and real-world connections.