# Unit: Unit 4: Energy, Rates, and Equilibrium

## Chapter: Chapter 12: Thermochemistry

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

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### Essential Questions:

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

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### 1. Big Idea:

Chemical reactions involve energy changes that can be measured, calculated, and manipulated. By understanding enthalpy and Hess's Law, we can predict energy changes in multi-step reactions.

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### 2. Essential Questions:

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

**Answer:** To calculate the enthalpy change using Hess’s Law, we break the reaction into smaller steps for which enthalpy changes are known. By adding or subtracting these enthalpy changes, we find the total enthalpy change for the overall reaction.

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### 3.1 Phenomenon-Based Learning:

**Unit Phenomenon:**

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

**Chapter Phenomenon:**

The second floor of the escape house focuses on energy changes in chemical reactions. You must calculate energy transfer, determine whether energy is absorbed or released, and use these values to solve puzzles and escape.

**Lesson Phenomenon:**

**"The Pathway to Escape"**

You are in the second-to-last room of the escape house. Interactive screens display enthalpy values for reaction steps. Your task is to calculate missing enthalpy values using Hess’s Law to unlock the final door. Each correct calculation reveals a clue to your escape.

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### 3.2 Lesson Phenomenon:

**"The Pathway to Escape"**

The room’s puzzle challenges you to use Hess's Law and thermochemical equations to calculate enthalpy changes. By solving these puzzles, you will uncover the energy pathways that lead to your escape.

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### 4. Vocabulary:

1. **Enthalpy:** The heat energy absorbed or released during a chemical reaction at constant pressure.

2. **Hess's Law:** A principle stating that the total enthalpy change for a reaction is the same, no matter how many steps it takes to complete the reaction.

3. **Standard Enthalpy of Combustion:** The enthalpy change when one mole of a substance burns completely in oxygen under standard conditions.

4. **Standard Enthalpy of Formation:** The enthalpy change when one mole of a compound forms from its elements in their standard states.

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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):

### # Activity: \*\*"Burning a Candle: Where Does the Energy Go?"\*\*

**Materials Needed:**

- A small candle

- Matches or a lighter

- A metal spoon

- Ice cube

**Procedure:**

1. Light the candle and observe the flame.

2. Hold a metal spoon above the flame for a few seconds.

3. Place an ice cube on the heated spoon and observe what happens.

**Follow-Up Questions:**

1. What happens to the ice cube when placed on the heated spoon?

**Answer:** The ice cube melts because heat energy from the candle flame is transferred to the spoon and then to the ice.

2. Is energy being absorbed or released when the candle burns?

**Answer:** Energy is released as heat and light during the combustion of the candle wax.

3. How can we measure the energy released in a chemical reaction like this?

**Answer:** By calculating the enthalpy change of the reaction.

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

### # Background Information:

Every chemical reaction involves energy changes. Some reactions absorb energy (endothermic), while others release energy (exothermic). Enthalpy (\( \Delta H \)) is a measure of this energy change at constant pressure.

Hess’s Law helps us calculate the enthalpy change for complex reactions by breaking them into smaller, simpler steps. This is useful because it’s often easier to measure the enthalpy changes for individual steps than for the overall reaction.

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

1. Define enthalpy in your own words.

**Answer:** Enthalpy is the heat energy absorbed or released during a chemical reaction at constant pressure.

2. What does it mean if a reaction is exothermic?

**Answer:** An exothermic reaction releases heat energy to the surroundings.

3. Why is Hess's Law useful in thermochemistry?

**Answer:** Hess's Law allows us to calculate the enthalpy change of reactions that are difficult to measure directly by using known enthalpy changes of related reactions.

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### 9. Explain (Lightbulb):

### # Core Concepts:

**1. Writing Thermochemical Equations:**

A thermochemical equation shows the enthalpy change (\( \Delta H \)) along with the balanced chemical equation. For example:

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

This equation tells us that burning one mole of methane (\( \text{CH}\_4 \)) releases 890 kJ of energy.

**Sample Problem:**

Write the thermochemical equation for the combustion of hydrogen (\( \text{H}\_2 \)):

\[ 2\text{H}\_2 + \text{O}\_2 \rightarrow 2\text{H}\_2\text{O} \, \, \Delta H = -572 \, \text{kJ} \]

**Progress Check:**

What does the negative sign in \( \Delta H \) mean?

**Answer:** The negative sign indicates that the reaction is exothermic (releases energy).

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**2. Classifying Reactions as Endothermic or Exothermic:**

- **Endothermic Reaction:** Absorbs energy (\( \Delta H \) is positive). Example: Melting ice.

- **Exothermic Reaction:** Releases energy (\( \Delta H \) is negative). Example: Combustion of fuels.

**Real-World Example:**

When you burn wood in a fireplace, heat and light are released (exothermic). When you cook food, energy is absorbed to break chemical bonds in the food (endothermic).

**Progress Check:**

Is boiling water an endothermic or exothermic process?

**Answer:** Endothermic, because it absorbs heat to change water into steam.

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**3. Applying Hess's Law:**

Hess’s Law states:

\[ \Delta H\_{\text{overall}} = \Delta H\_1 + \Delta H\_2 + \Delta H\_3 + \dots \]

This means that the total enthalpy change for a reaction is the sum of the enthalpy changes for each step, regardless of the pathway.

**Sample Problem:**

Given the following reactions:

1. \( \text{C} + \text{O}\_2 \rightarrow \text{CO}\_2 \, \, \Delta H = -393 \, \text{kJ} \)

2. \( \text{CO}\_2 \rightarrow \text{CO} + \frac{1}{2}\text{O}\_2 \, \, \Delta H = +283 \, \text{kJ} \)

Calculate \( \Delta H \) for the reaction:

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

**Solution:**

Add the two reactions:

\[ \text{C} + \text{O}\_2 \rightarrow \text{CO}\_2 \, \, \Delta H = -393 \, \text{kJ} \]

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

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

**Progress Check:**

What is the enthalpy change for the reaction \( \text{C} + \frac{1}{2}\text{O}\_2 \rightarrow \text{CO} \)?

**Answer:** \( \Delta H = -110 \, \text{kJ} \).

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### Real-World Connection:

Hess's Law is used in industries to calculate energy requirements for large-scale chemical processes, such as the production of fertilizers or fuels. It helps engineers design energy-efficient methods.

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### Lesson Wrap-Up:

By understanding enthalpy and Hess’s Law, we can measure and predict energy changes in chemical reactions. This knowledge is essential for solving real-world problems, from designing efficient engines to understanding biological processes.

Sure! Below is a structured response based on your request. I'll create an example for a chemistry topic: **"The Periodic Table and Element Properties."**

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

Here are three scaffolded questions to check understanding of key concepts about the periodic table:

1. **Question 1**: What is the periodic table, and how are elements arranged in it?

**Answer**: The periodic table is a chart that organizes all known elements based on their atomic number (number of protons). Elements are arranged in rows (periods) and columns (groups) according to their properties.

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

**Answer**: Elements in the same group have the same number of valence electrons, which determines their chemical behavior. For example, Group 1 elements (alkali metals) all have one valence electron, making them highly reactive.

3. **Question 3**: Predict the reactivity of elements in Group 1 as you move down the group. Explain why this happens.

**Answer**: The reactivity of Group 1 elements increases as you move down the group. This is because the valence electron is farther from the nucleus, making it easier to lose due to weaker attraction.

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### 11. Elaborate (Power Up)

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

1. **Mini-Task**: Research and compare the properties of sodium (Na) and potassium (K). How are they similar, and how do they differ?

**Answer**: Sodium and potassium are both alkali metals in Group 1. They are soft, shiny, and highly reactive with water. Potassium is more reactive than sodium because its valence electron is farther from the nucleus. Potassium also has a lower melting point.

2. **Open-Ended Question**: If you were designing a new periodic table for an alien planet, what properties would you use to organize the elements? Why?

**Answer**: Students might suggest organizing elements by atomic mass, density, or reactivity. They could also consider physical states (solid, liquid, gas) or bonding types (metallic, covalent, ionic).

3. **Extension Question**: How do the trends in the periodic table (like electronegativity or atomic radius) help scientists predict the behavior of unknown elements?

**Answer**: Trends like electronegativity and atomic radius allow scientists to estimate how reactive an unknown element might be, what kind of bonds it could form, and its physical properties.

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### 12. Final Evaluation

### # Debate Question:

**Debate**: Should scientists continue adding new synthetic elements to the periodic table, even if they are unstable and exist only for fractions of a second?

**Arguments For**:

- Expands our understanding of atomic structure and nuclear physics.

- Helps us discover new materials with potential applications.

**Arguments Against**:

- High cost and limited practical use.

- Ethical concerns about using resources for unstable elements.

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### # Assessment Questions:

**Multiple-Choice Questions**

1. Which of the following determines an element's position in the periodic table?

a) Atomic mass

b) Atomic number

c) Number of neutrons

d) Density

**Answer**: b) Atomic number

**Explanation**: The periodic table is arranged by increasing atomic number, which is the number of protons in an atom.

2. What is a characteristic property of noble gases?

a) High reactivity

b) Low boiling points

c) Metallic bonding

d) Easily lose electrons

**Answer**: b) Low boiling points

**Explanation**: Noble gases are non-reactive and exist as gases at room temperature, with low boiling points.

3. Which group contains the most reactive metals?

a) Group 1

b) Group 2

c) Group 17

d) Group 18

**Answer**: a) Group 1

**Explanation**: Group 1 elements (alkali metals) are highly reactive because they have one valence electron that is easily lost.

4. What happens to atomic size as you move across a period from left to right?

a) It increases

b) It decreases

c) It stays the same

d) It fluctuates randomly

**Answer**: b) It decreases

**Explanation**: As you move across a period, the number of protons increases, pulling electrons closer to the nucleus and reducing atomic size.

**Long-Answer Questions**

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

**Answer**: Mendeleev organized the periodic table by increasing atomic mass and grouped elements with similar properties. He left gaps for undiscovered elements. The modern periodic table is organized by atomic number, not mass, which corrected some inconsistencies.

2. Describe the trends in electronegativity across a period and down a group. Provide examples.

**Answer**: Electronegativity increases across a period (e.g., from sodium to chlorine) because atoms have more protons and a stronger pull on electrons. It decreases down a group (e.g., fluorine to iodine) because the outer electrons are farther from the nucleus.

3. Compare and contrast the properties of metals, nonmetals, and metalloids.

**Answer**: Metals are shiny, good conductors, and malleable. Nonmetals are dull, poor conductors, and brittle. Metalloids have properties of both, like silicon, which is shiny but brittle and a semi-conductor.

4. Predict the chemical and physical properties of an element in Group 2, Period 4 of the periodic table.

**Answer**: The element is calcium (Ca). It is a metal, shiny, and reacts with water to form a hydroxide and hydrogen gas. It has two valence electrons and forms ionic compounds.

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### 13. Extend (Beyond the Lesson)

1. **Additional Tasks**:

- Research how the periodic table is used in real-world applications, such as material science or medicine.

- Create a poster showing periodic trends like atomic radius, ionization energy, and electronegativity.

2. **Readings**:

- "The Disappearing Spoon" by Sam Kean (stories about the periodic table).

- Articles on how synthetic elements like Californium are used in industry.

3. **Challenge Question**:

- Imagine you discovered a new element. What group would it belong to, and what properties would it have?

4. **Spaced Practice**:

- Week 1: Review periodic trends and practice identifying elements based on their position.

- Week 2: Solve problems predicting chemical reactions of elements in different groups.

- Week 3: Create a summary chart of element properties and trends for quick revision.

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This structure ensures students not only recall facts but also apply and extend their knowledge in meaningful ways!