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

## Chapter: Chapter 12: Thermochemistry

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

### 1. Big Idea:

Chemical reactions either absorb or release energy, and Hess's Law provides a way to calculate the total enthalpy change for a reaction by combining known enthalpy changes of multiple steps in a reaction pathway.

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### 2. Essential Questions:

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

- By adding or subtracting the enthalpy changes of individual reaction steps, we can determine the overall enthalpy change for a reaction, even if it occurs through multiple steps.

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### 3. Phenomenon-Based Learning:

**Unit Phenomenon: The Thermodynamics House**

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: Energy in Chemical Reactions**

The second floor of the escape house focuses on the energy involved in chemical reactions. By understanding energy transfer, calculating how much energy is absorbed or released, and manipulating these values, you can unlock the clues to escape.

**Lesson Phenomenon: The Pathway to Escape**

In the second-to-last room, the challenge is to find missing enthalpy values by using Hess’s Law. Each correct calculation reveals clues that help you unlock the final exit.

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### 4. Vocabulary:

- **enthalpy**: the total energy contained in a chemical system, including heat energy (represented as H)

- **hess's law**: a principle stating that the total enthalpy change of a reaction is the same, regardless of the pathway taken

- **standard enthalpy of combustion**: the heat released when one mole of a substance burns completely in oxygen under standard conditions

- **standard enthalpy of formation**: the change in enthalpy when one mole of a compound is formed 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):

Imagine you are standing in a futuristic escape room, surrounded by glowing touch screens and digital panels. One screen shows a list of chemical equations, each with an energy value. Another screen displays a locked door with a message: "Solve the energy pathway puzzle to escape."

Here’s the challenge: The total energy change for the reaction is missing, but you know it can be calculated by combining the energy changes of smaller steps. How can you figure out the missing value? What tools or principles might help you solve this puzzle?

To explore this, use an AI chatbot tool and ask it the following prompt:

“Explain how energy is conserved during chemical reactions and how we can calculate energy changes using known reaction steps.”

Compare its response with your prior knowledge or ideas from earlier grades. Share one surprising detail you discovered with your peers.

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

To understand how to solve the energy puzzle, let’s revisit some earlier concepts:

- **Energy Conservation**: Energy cannot be created or destroyed. In chemical reactions, energy is transferred as bonds break and form.

- **Exothermic vs. Endothermic Reactions**: Exothermic reactions release energy (e.g., burning wood), while endothermic reactions absorb energy (e.g., melting ice).

In this lesson, the focus is on **enthalpy**, a measure of heat energy. When we can’t directly measure the enthalpy change for a reaction, Hess's Law helps us calculate it. According to Hess's Law, the total enthalpy change depends only on the starting and ending conditions, not the steps in between.

For example, think about building a LEGO house. Whether you build it in one go or in several stages, the total number of bricks used remains the same. Similarly, Hess’s Law allows us to add or subtract enthalpy changes for smaller steps to find the overall change.

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

1. **What is the difference between exothermic and endothermic reactions?**

- Exothermic reactions release energy (e.g., combustion), while endothermic reactions absorb energy (e.g., boiling water).

2. **Why is Hess’s Law useful for reactions that occur in multiple steps?**

- It allows us to calculate the total enthalpy change without directly measuring each step, as long as we know the enthalpy changes of the individual steps.

3. **What does it mean if a reaction has a negative enthalpy change?**

- A negative enthalpy indicates an exothermic reaction, meaning energy is released.

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### 8. Explore:

**Activity Title: "Energy Pathways in Action"**

**Objective:** Use Hess’s Law to determine the total enthalpy change for a reaction.

**Materials:**

- Index cards with chemical equations and enthalpy values (e.g., Reaction A: -200 kJ, Reaction B: +150 kJ)

- Calculator

- Worksheet for recording calculations

**Instructions:**

1. Read the main reaction for which the enthalpy change is unknown. For example:

\[ C + O\_2 → CO\_2 \]

2. Use the smaller steps provided on the cards, such as:

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

- \[ CO + 1/2 O\_2 → CO\_2 \] (ΔH = -90 kJ)

3. Rearrange, multiply, or reverse the smaller reactions as needed to match the overall reaction.

4. Add the enthalpy changes for the smaller steps to calculate the total enthalpy change.

5. Discuss with a peer: Is the reaction exothermic or endothermic?

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### 9. Explain (Lightbulb):

### # \*\*What is Enthalpy?\*\*

Enthalpy (H) is the heat energy of a system at constant pressure. It’s not something we can measure directly, but the change in enthalpy (\(ΔH\)) tells us how much heat is absorbed or released during a reaction.

- If \(ΔH\) is **negative**, the reaction releases heat (exothermic).

- If \(ΔH\) is **positive**, the reaction absorbs heat (endothermic).

### # \*\*How Does Hess’s Law Work?\*\*

Hess’s Law states: \*The total enthalpy change for a reaction is the same, no matter the pathway it takes.\* This works because enthalpy is a state function. It depends only on the starting and ending conditions, not the process in between.

Think of it like hiking up a mountain. Whether you take a straight path or zigzag along trails, your total height gain is the same.

### # \*\*Applying Hess's Law: Step-by-Step Example\*\*

**Problem:**

Find the total enthalpy change for this reaction:

\[ C + O\_2 → CO\_2 \]

**Given Steps:**

1. \[ C + 1/2 O\_2 → CO \] \(ΔH = -110 \, \text{kJ}\)

2. \[ CO + 1/2 O\_2 → CO\_2 \] \(ΔH = -90 \, \text{kJ}\)

**Solution:**

- Combine the two steps:

\[ C + 1/2 O\_2 → CO \]

\[ CO + 1/2 O\_2 → CO\_2 \]

Adding these gives:

\[ C + O\_2 → CO\_2 \]

- Add the enthalpy changes:

\(ΔH = -110 \, \text{kJ} + -90 \, \text{kJ} = -200 \, \text{kJ}\)

**Answer:** \(ΔH = -200 \, \text{kJ}\) (exothermic reaction).

**Progress Check:**

Given the following steps, calculate \(ΔH\):

1. \[ N\_2 + O\_2 → 2NO \] \(ΔH = +180 \, \text{kJ}\)

2. \[ 2NO + O\_2 → 2NO\_2 \] \(ΔH = -112 \, \text{kJ}\)

**Answer:** \(ΔH = +68 \, \text{kJ}\)

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By understanding Hess’s Law, we can solve energy puzzles and calculate enthalpy changes even for reactions that don’t happen in a single step. This powerful tool is essential in fields like environmental science (e.g., calculating energy from fuels) and industrial chemistry (e.g., designing efficient reactions).

Sure! Let’s create a structured plan fitting the requirements based on a hypothetical chemistry topic: **"The Structure of the Atom."**

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

### Scaffolded Questions:

1. **What are the three main subatomic particles in an atom, and where are they located?**

\*Answer:\* The three main subatomic particles are:

- Protons: Located in the nucleus.

- Neutrons: Located in the nucleus.

- Electrons: Found in electron shells or orbitals surrounding the nucleus.

2. **How does the number of protons in an atom's nucleus determine the element?**

\*Answer:\* The number of protons is called the **atomic number**, and it uniquely identifies the element. For example, hydrogen has 1 proton, while carbon has 6.

3. **If an atom has 11 protons, 12 neutrons, and 11 electrons, what is its mass number, and why?**

\*Answer:\* The mass number is the sum of protons and neutrons. In this case:

\( 11 + 12 = 23 \).

So, the mass number is 23.

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## \*\*11. Elaborate (Power Up)\*\*

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

1. **Mini-Task:** Create a labeled diagram of an atom of your choice, showing the nucleus and electron shells. Include the number of protons, neutrons, and electrons.

\*Answer:\* Students will create diagrams such as a sodium atom (11 protons, 12 neutrons, 11 electrons) with correct labels.

2. **Open-Ended Question:** Why do you think electrons are arranged in specific shells instead of floating freely around the nucleus?

\*Answer:\* Electrons are arranged in specific shells because they are held in place by the attraction to the positively charged nucleus and because they follow energy-level rules (like the octet rule). This minimizes energy and creates stability.

3. **Challenge Question:** How might the arrangement of electrons in an atom affect the way it reacts with other atoms?

\*Answer:\* The arrangement of electrons, especially in the outermost shell (valence electrons), determines how an atom bonds with others. Atoms with nearly full or nearly empty valence shells are more reactive.

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## \*\*12. Final Evaluation\*\*

### Debate Question:

**"Do you think the discovery of subatomic particles has had a greater impact on technology or medicine? Explain your stance with examples."**

Points for discussion:

- **Technology:** Nuclear energy, semiconductors, and electronics rely on understanding atomic structure.

- **Medicine:** Advances like radiation therapy, MRI machines, and isotopes for diagnosis stem from knowledge of subatomic particles.

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### Assessment Questions:

### # Multiple-Choice Questions:

1. **What is the charge of a neutron?**

- A) Positive

- B) Negative

- C) Neutral

- D) None of the above

\*Correct Answer:\* C) Neutral

\*Explanation:\* Neutrons have no charge, unlike protons (positive) and electrons (negative).

2. **What determines the identity of an element?**

- A) Number of neutrons

- B) Number of protons

- C) Number of electrons

- D) Total mass of the atom

\*Correct Answer:\* B) Number of protons

\*Explanation:\* The atomic number, determined by protons, defines an element.

3. **If an atom has an atomic number of 8 and a mass number of 16, how many neutrons does it have?**

- A) 8

- B) 16

- C) 24

- D) 0

\*Correct Answer:\* A) 8

\*Explanation:\* Neutrons = Mass number - Protons = \(16 - 8 = 8\).

4. **Which subatomic particle is the lightest?**

- A) Proton

- B) Neutron

- C) Electron

- D) They all weigh the same

\*Correct Answer:\* C) Electron

\*Explanation:\* Electrons are much lighter than protons and neutrons.

### # Long-Answer Questions:

1. **Explain how isotopes of the same element differ and one example of their use in real life.**

\*Answer:\* Isotopes differ in the number of neutrons but have the same number of protons. For example, carbon-12 and carbon-14 are isotopes of carbon. Carbon-14 is used in radiocarbon dating to determine the age of ancient objects.

2. **Describe Bohr's model of the atom and explain how it improved upon earlier models.**

\*Answer:\* Bohr's model proposed that electrons orbit the nucleus in fixed energy levels, unlike earlier models that suggested electrons were scattered randomly. This explained atomic emission spectra and introduced the idea of quantized energy.

3. **An atom of chlorine has 17 protons and 18 neutrons. Write its nuclear notation and explain what each part represents.**

\*Answer:\* Nuclear notation: \( ^{35}\_{17}Cl \)

- 35: Mass number (protons + neutrons).

- 17: Atomic number (number of protons).

- Cl: Chemical symbol for chlorine.

4. **Why are electrons important in chemical bonding? Provide examples of two types of bonds.**

\*Answer:\* Electrons in the outer shell determine an atom’s ability to bond.

- **Ionic bonds:** Electrons are transferred (e.g., NaCl).

- **Covalent bonds:** Electrons are shared (e.g., \(H\_2O\)).

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## \*\*13. Extend (Beyond the Lesson)\*\*

### Additional Tasks and Challenges:

1. **Task:** Research how the discovery of the electron by J.J. Thomson influenced the development of modern technology. Write a short report.

\*Purpose:\* This helps connect historical discoveries to current innovations.

2. **Challenge Question:** Imagine a world where protons were negatively charged and electrons were positively charged. How would this affect atomic structure and interactions?

\*Purpose:\* Encourages creative thinking about fundamental forces and their roles.

3. **Activity:** Conduct a simple experiment at home to demonstrate static electricity (e.g., rubbing a balloon on your hair and sticking it to a wall). Write a short explanation of how this relates to the behavior of electrons in an atom.

### Opportunities for Spaced Practice:

- **Day 1:** Review atomic structure and practice identifying subatomic particles.

- **Day 3:** Solve problems involving mass number and isotopes.

- **Day 5:** Complete a quiz on electron arrangements and chemical bonding.

- **Week 2:** Revisit diagrams and explain atomic models to a peer.

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This structure ensures clear scaffolding, deeper engagement, and opportunities for reinforcing critical concepts. It aligns with learning outcomes while encouraging curiosity and real-world connections.