Connected Chemistry

Thermodynamics Unit

Lesson 3: Enthalpy and Hess's Law

Student's Lesson at a Glance

Lesson Summary

In the Connecting Activity, students are introduced to Hess's Law and enthalpy through the exploration of the chemical reaction found in hand warmers. Students are introduced to the enthalpy of formation as an extension to the role of bonding in the formation of compounds from individual atoms. Following a teacher's example, students learn how to calculate enthalpy values from Hess's Law. Following a teacher demonstration of a reaction in a CCC simulation, students manipulate the simulation to collect data for temperature, entropy, and enthalpy. Students create submicroscopic representations of two reactions, then answer analysis questions. Students determine how position, composition, motion, and molecular interaction affect the enthalpy of the reactions.

SWBAT (Students Will Be Able To)

- Define what enthalpy is and how it is generated
- Define what the enthalpy of formation is
- Define what Hess's Law is and how to calculate values of enthalpy

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

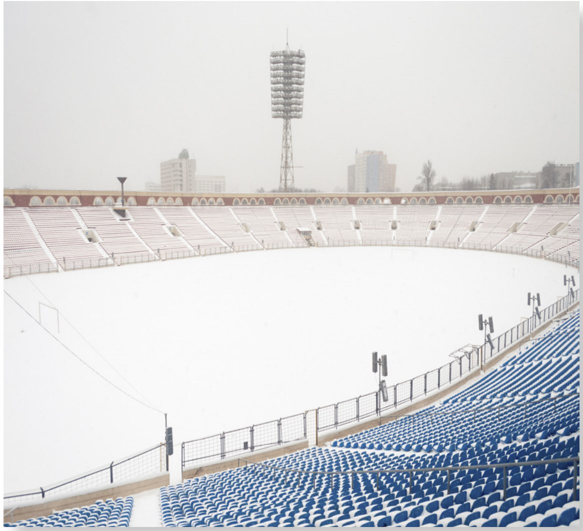
- Students and teachers from many different schools helped designed CCC so that the lessons are more helpful and meaningful for all classroom participants.
- The symbol Σ (sigma) means "the sum of."
- Heat and temperature are not the same thing. By adding or removing thermal energy to a system, you are able to change the temperature of the system. Temperature is a macroscopic measurement.
- Use the vocabulary section and note section to take good notes so that studying for tests and quizzes is easier.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Draw a key when you are sketching. Keys can help you and others decode your sketches at a later time.
- The Δ symbol (delta) is used to mean "change," usually between initial and final values. For example, ΔT = Final temperature - Initial temperature = Change in temperature.

Notes

Homework

Upcoming Quizzes/Tests

Activity 1: Connecting



Hand warmers are frequently used by fans and athletes at sporting events during the late fall and winter. By bending a hand warmer back and forth a few times, the substances inside mix and undergo a physical change that releases thermal energy through heat. In chemistry, thermal energy that is released or absorbed during chemical and physical changes is referred to as enthalpy. **Enthalpy** is represented by the symbol "***H***". The units of measurement for enthalpy are kJ/mol.

Hand warmers contain a supersaturated solution of water and sodium acetate: the water contains many more molecules of sodium acetate than would normally dissolve at room temperature. Bending the hand warmer causes a small disc inside the packet to break, creating a rough surface on which a small solid crystal of sodium acetate forms. Other molecules of sodium acetate collide with this crystal and solidify. This crystallization of the sodium acetate molecules gives off heat.

1. Does every physical change release heat? *Support your claim with evidence from your own experiences.*

2. Using a combustion reaction (e.g., fuel and oxygen) as an example, what determines how much energy is released?

Activity 2: Hess's Law

The "sticks and lines bond model" better helps us understand the relationships between atoms in a compound. It is important to remember that the lines and sticks we use to represent bonds are models just like the computer simulations you have viewed. In reality, a bond is not something physical, but an unseen force between atoms. When any compound forms from the bonding of atoms, a specific amount of heat is released. This heat is called the **heat of formation** (H_f).

When a chemical reaction occurs, heat can be either released or absorbed. This depends on the energy required to break reactant bonds (positive enthalpy) and the energy released by forming bonds between products (negative enthalpy).

Hess's Law states that the total enthalpy of a reaction (ΔH_{rxn}) can be calculated by subtracting the sum of the ΔH of reactant formation from the sum of the ΔH of product formation. Depending on the values of the enthalpies of formation of products and reactants, the total enthalpy of a reaction can be either positive or negative

$$\Delta H_{rxn} = \Sigma \Delta H_{f\ products} - \Sigma \Delta H_{f\ reactants}$$

The symbol Σ (sigma), stands for "the sum of."

With laboratory experiments, chemists have created tables of values for the standard enthalpy of formation (ΔH_f°) for many common compounds. These values are for standard conditions. You can find this table on page 93.

The standard enthalpy of formation is represented as ΔH_f° where the degree symbol denotes the standard conditions (i.e. Pressure = 1 bar, and Temperature = 250°C). The subscript "*f*" stands for formation.

Refer to the table on page 93 in Appendix B as needed to complete the following Activities 3 and 4. While every compound has a unique standard enthalpy of formation on the table, pure elements like H_2 or O_2, are always 0 kJ.

The equation and data below is for standard conditions for the formation of carbon dioxide and was collected from standard enthalpy of formations. For an example of how to calculate Hess's Law using the values from the table, see page 91.

$$C\ (graphite) + O_2\ (g) \rightarrow CO_2\ (g)$$

Substance	ΔH_f° kJ/mol
C (graphite)	0
O_2 (g)	0
CO_2 (g)	-393.51

3. Calculate ΔH_{rxn} for the reaction.

Activity 3: Demonstrating Hess's Law

Demonstration: *Use Simulation 7, Set 1*

- *You teacher will demonstrate how Hess's Law works with a simulation. Before the teacher starts the simulation, sketch the initial reactants, record the data from the monitors, and write down your submicroscopic observations.*
- *Your teacher will run the reaction for 30 seconds before pausing it. Create a sketch of the products that have formed after thirty seconds, record data from the monitors, and write down your submicroscopic observations. Do not worry if the simulation runs over a few seconds.*
- *Use your sketches, data, and observations to answer the questions and complete the calculations.*

	Create a Submicroscopic Sketch of the Simulation	Record Data from Monitors			
Initial		Temperature of System		Entropy of System	
		Enthalpy of Reactant		Enthalpy of Products	
		Moles of Hydrogen Peroxide			
		Record Your Observations			
	Create a Submicroscopic Sketch of the Simulation	Record Data from Monitors			
Time: 30s		Temperature of System		Entropy of System	
		Enthalpy of Reactant		Enthalpy of Products	
		Moles of Oxygen Gas		Moles of Water Vapor	
		Record Your Observations			
Key					

4. Create a balanced chemical equation for the reaction in the simulation.

5. Show how the enthalpy of the reactants was calculated.

6. Show how the enthalpy of the products was calculated.

7. Calculate the *ΔH* for the reaction using Hess's Law.

8. Do you think the system became more or less ordered after the reaction? *Explain your answer at the submicroscopic level.*

Activity 4: Simulating Hess's Law

Reaction 1: *Use Simulation 7, Set 2*

- *Before starting the simulation, sketch the initial reactants, record the data from the monitors, and write down your observations.*
- *Next, run the reaction for thirty seconds before pausing. Create a sketch of the products, record data from monitors, and write down observations. Do not worry if the simulation runs over a few seconds.*
- *Use your sketches, data, and observations to answer the questions and complete calculations.*

	Create a Submicroscopic Sketch of the Simulation	Record Data from Monitors			
Initial		Temperature of System		Entropy of System	
		Enthalpy of Reactants		Enthalpy of Products	
		Moles of Propane		Moles of Oxygen Gas	
		Record Your Observations			
Time: 30s	Create a Submicroscopic Sketch of the Simulation	Record Data from Monitors			
		Temperature of System		Entropy of System	
		Enthalpy of Reactants		Enthalpy of Products	
		Moles of Water Vapor		Moles of Carbon Dioxide Gas	
		Record Your Observations			
Key					

9. Create a balanced chemical equation for the reaction in the simulation.

10. Show how the enthalpy of the reactants was calculated.

11. Show how the enthalpy of the products was calculated.

12. Calculate the ΔH for the reaction using Hess's Law.

13. Do you think the system became more or less ordered after the reaction? Explain your answer at the submicroscopic level.

Reaction 2: *Use Simulation 7, Set 3*

	Create a Submicroscopic Sketch of the Simulation	Record Data from Monitors			
Initial		Temperature of System		Entropy of System	
		Enthalpy of Reactants		Enthalpy of Products	
		Moles of OxygenGas		Moles of Ammonia Gas	
		Record Your Observations			
Time: 30s	**Create a Submicroscopic Sketch of the Simulation**	**Record Data from Monitors**			
		Temperature of System		Entropy of System	
		Enthalpy of Reactants		Enthalpy of Products	
		Moles of Nitric Oxide		Moles of Water Vapor	
		Record Your Observations			
Key					

14. Create a balanced chemical equation for the reaction in the simulation.

15. Show how the enthalpy of the reactants was calculated.

16. Show how the enthalpy of the products was calculated.

17. Calculate the ΔH for the reaction using Hess's Law.

18. Do you think the system became more or less ordered after the reaction? *Explain your answer at the submicroscopic level.*

Lesson Reflection Questions

Consider the previous two reactions. Explain how each submicroscopic observation you noted relates to the enthalpy of the reaction.

19. How does the location of the molecules relate to the enthalpy of the reaction?

20. How does the composition of the molecules relate to the enthalpy of the reaction?

21. How does the motion of the molecules relate to the enthalpy of the reaction?

22. How does the interaction of the molecules relate to the enthalpy of the reaction?