MODULE 4 (Physical Science) INTRODUCTION

Module Name: Chemical Reactions.

Content of this Introduction:
1. Overview of the Module.
2. Prerequisite knowledge
3. Standards covered by the module.
4. Materials needed for the module.
5. Pacing guides for 5 lessons, including learning objectives and assessment questions.

1. Overview of the Module
This Physical Science module explores chemical reactions: the conditions under which they occur, the evidence of a chemical reaction, limiting reactants versus reactants in excess, and when chemical reactions stop.

The chemical reaction simulated in the base model is that of Silver Nitrate and Copper.
$$2\ AgNO_{3\ (aq)} + Cu_{\ (s)} \longrightarrow Cu(NO_3)_{2\ (aq)} + 2\ Ag_{\ (s)}$$
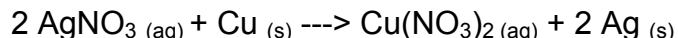
The goal is to run experiments with different amounts of reactants and predict the amount of product formed. Students use, modify and customize an agent-based model of a chemical reaction and experiment with factors that impact the rate of a chemical reaction.

2. Prerequisite knowledge and assumptions encompassed by the Module
This Physical Science module offers some disciplinary core concepts through direct instruction and activities but assumes the students are familiar with concepts such as what are atoms and ions, and what is evidence of a chemical reaction. Students are also to be familiar with solids dissolving in water; the concepts of single replacement (displacement) and double replacement reactions; and balancing equations.

It is necessary to have completed Module 1 is a prerequisite for this model.

3. Standards covered by the module.

Please see the Standards Document for a detailed description of Standards covered by this Module, Lesson by Lesson.

4. Materials needed for this Module
You will need the following materials to teach this module:
- Computer and projector
- Link to the video presentation of the Silver nitrate and copper chemical reaction OR access to materials for the live demonstration.
- Silver nitrate and copper base StarLogo Nova model (detailed in Lesson

plans).

- Guided Introduction to StarLogo Nova document [for reference]
- CS Concepts guide document [for reference & student handout]
- StarLogo Nova Blocks Reference Guide [for reference & student handout]
- USING a Computer Model to do Science document [student handout]
- Experimental Design form document [student handout]
- Model observation form [student handout]
- Project design form [student handout]
- Model design form [student handout]
- Lesson plans for 5 lessons
- Associated student activity sheets
- Slide presentation with instructions

5. **Pacing Guides for 5 Lessons, including Learning Objectives and Assessment Questions.** (See following pages.)

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DAY 1 - Introduction to Chemical Reactions

Pacing Guide

Getting started	Properties of matter, chemical formulas and evidence of a chemical reaction.	15 mins
Activity 1	Demonstration (live or via downloaded video) of silver nitrate and copper chemical reaction	15 mins
Activity 2	Previewing the Chemical Reaction base model	15 mins
Wrap-Up	Signs of a chemical reaction.	5 mins

Learning Objectives: Students will…

Disciplinary Core Concepts	Differentiate between atoms and ions. Identify evidence of a chemical reaction. Learn the importance of water as a medium for some chemical reactions to occur.
Cross cutting concepts	The initial preview of the base model will suggest that cause and effect relationships may be used to predict both microscopic and macroscopic behavior. The conservation of matter is suggested but not explicitly stated in this first lesson.
Modeling and Simulation	Learn how computer models can be used to run simulations when dangerous or expensive materials are involved. Identify aspects of the chemical reaction that are not included in the base model.

Assessments of understanding:

Complex Adaptive Systems	What features of a complex adaptive system are exhibited in the model of silver nitrate and copper chemical reaction?
Disciplinary Core Ideas	What is the difference between atoms and ions? What evidence of a chemical reaction was seen in real life an in the computer model? Could the chemical reaction take place without water?
Modeling and Simulation	Why might we want to simulate chemical reactions on a computer rather than in real life?

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DAY 2: Modeling Chemical Reactions

Pacing Guide

Getting started	Chemical Reaction overview	10 mins
Activity 1	Analyzing the base model	20 mins
Activity 2	Modifying the base model to add/remove water molecules and move the copper rod.	15 mins
Wrap-Up	How does his model help us learn about the chemical reaction?	5 mins

Learning Objectives: Students will…

Disciplinary Core Concepts	Differentiate between chemical and physical properties of substances. Identify atomic symbols and chemical formulas of the reactions in this module. Identify which reactant is limiting and which is in excess. Identify signs of a chemical reaction and when a chemical reaction stops.
Modeling and Simulation	The role of parameters and initial conditions are presented and students gain experience with the representation of entities within the model. The setup procedures and other code block are examined. Automation is observed in this USE phase (student's using a largely pre-built model).
Computer Science	Begin to understand the execution order of code and gain exposure to the CS concepts of "looping", parameters and logic, expressions, variables and functions. Use various debugging and testing methods to ensure program correctness.

Assessments of understanding:

Disciplinary Core Ideas	What is the difference between the chemical and physical properties of copper? Describe how many silver nitrate molecules are needed to react with each copper atom? Which reactant is limiting the reaction? Which reactant is in excess in the reaction? How do we know that a chemical reaction has taken place? How do we know when a chemical reaction has stopped?
Modeling and Simulation	Assessment of whether student was able to implement modifications to the base model.
Computer Science	Use of CS concepts and constructs such as looping, logic, expressions, conditionals, functions and variables.

DAY 3: Products of Chemical Reactions

Pacing Guide

Getting started	When does a chemical reaction stop?	5 mins
Activity 1	Modifying the model to add the production of copper nitrate.	25 mins
Activity 2	Running experiments with different initial quantities of copper or silver nitrate.	15 mins
Wrap-Up	What are models good for?	5 mins

Learning Objectives: Students will…

Disciplinary Core Concepts	Identify the products of a chemical reaction. Identify the factors that stop a chemical reaction. Learn about concepts of limiting reactants and reactants in excess. Learn the importance of balancing chemical equations.
Crosscutting concepts	Patterns: Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. Scale, Proportion, and Quantity: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. Energy and Matter: Matter is conserved because atoms are conserved in physical and chemical processes.
Modeling and Simulation	Learn how to make new breeds and create agents in agent-based modelling. Collect and analyze data to look for patterns.

Assessments of understanding:

Disciplinary Core Ideas	What were the reactants in the chemical reaction we studied? What were the products in the chemical reaction we studied? What determines which are the limiting reactants? What determines which are the reactants in excess? In your own words, describe the law of conservation of mass.
Modeling and Simulation	What aspects of the chemical reaction were included in the base model? What do the agents represent? Are there agents that are not part of the "essential" behavior of the model?
Computer Science	What is an instruction? What is a loop? What is an iteration?

DAY 4: Complex Ions in Solution

Pacing Guide

Getting started	10 mins
Activity 1	20 mins
Activity 2	15 mins
Wrap-Up	5 mins

Learning Objectives: Students will...

Ionic compounds, ionic equations, and complexes.	
Modifying the model further: creating hydrated copper ions and turning the solution blue.	
Characterizing the rate of reaction	
Using computer models in scientific investigations	

Disciplinary Core Ideas	Differentiate between chemical equations, ionic equation and net ionic equation. Learn about at least one type of complex ions. Become familiar with rate of a reaction and availability of reactants.
Cross cutting concepts	Patterns: Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. Scale, Proportion, and Quantity: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. Energy and Matter: Matter is conserved because atoms are conserved in physical and chemical processes.
Modeling and Simulation	Learn to implement interactions using collisions.

Assessments of understanding:

Disciplinary Core Ideas	What is an example of an ionic compound? Describe what happens to ionic compounds in solution. In the experiment we did today, what determines the rate of silver production? In your own words, describe the shape of the silver production curve and what caused it to have that shape.
Modeling and Simulation	Student modification of the model as an experimental testbed. Adding instrumentation. How can a computer model help in figuring out the impact of availability of reactants?
Computer Science	Describe the logic involved in implementing the three stages of hydrating copper ions.

DAY 5: Factors that Impact the Rate of a Chemical Reaction

Pacing Guide

Getting Started	Availability of reactants as a limiting factor	10 mins
Activity 1	Factors impacting the rate of reaction: Mixing and Step size.	15 mins
Activity 2	Running experiments	15 mins
Wrap Up	Sharing results and conclusions	10 mins

Learning Objectives: Students will….

Disciplinary Core Ideas	Review findings on how availability of reactants impacts the rate of reaction. Become familiar with rate of a reaction and kinetic energy effect.
Cross cutting concepts	Patterns: Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. Scale, Proportion, and Quantity: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. Energy and Matter: Matter is conserved because atoms are conserved in physical and chemical processes.
Modeling and Simulation	Learn how agent movement can impact outcome in simulations. Learn to simulate kinetic energy in an agent-based model. Run virtual experiments to determine how kinetic energy impacts the rate of chemical reaction.

Assessments of understanding:

Disciplinary Core Ideas	What are some factors that impact the rate of reaction? How would you design an experiment to determine the impact of one of the factors? How was an increase in kinetic energy simulated in this lesson? Describe a feedback loop in the chemical reaction studied.
Modeling and Simulation	What real-world aspects did you model? What real-world aspects did you leave out? Why? What experiments did you run in the model? Student model, shared with instructor digitally, will be the principal assessment of this activity.
Computer Science	Student model, shared with instructor digitally, will be the principal assessment of computer science learning.

4

Lesson 1

Introduction to Chemical Reactions

50 minutes (1 day)

Lesson Overview

In this lesson students will learn to recognize the changes that are characteristic of a chemical reaction. They will learn about the properties of ions in solution. They will observe a real-world example of a reaction that will become the basis in subsequent lessons of a "virtual lab" computer model. Finally, students will be introduced to the base model that is provided in this module.

Teaching Summary

Getting started – 15 minutes
1. Properties of matter, chemical formulas and evidence of a chemical reaction.

Activity #1: Wet lab or virtual lab – 15 minutes
2. Demonstration of chemical reaction- live or video via projection.

Activity #2: Previewing the Chemical Reaction base model – 15 minutes
3. Computer model: "silver nitrate and copper reaction," teacher-led demo.
4. Run the model and discuss abstraction and application to real-world phenomena.

Wrap-Up – 5 minutes
5. Signs of a chemical reaction.

Lesson Objectives

The student will:
✓ Differentiate between atoms and ions [LO1]
✓ Identify evidence of a chemical reaction [LO2]
✓ Learn the importance of water as a medium for some chemical reactions to occur [LO3]
✓ Learn that models are important when dangerous or expensive materials are involved [LO4]
✓ Identify what aspects of a Chemical Reaction not included in the base model [LO5]

Teaching Guide

Materials, Resources and Preparation

For the Students
• Their attention and curiosity

For the Teacher
● Computer and projector
● If performing live demonstration: necessary reactants, beaker and safety glasses
● Slide presentation
● StarLogo Nova base model: "silver nitrate and copper reaction"

Getting started - 15 min

1. Properties of matter, chemical formulas and evidence of a chemical reaction.
• Tell students that creating and using a model of chemical reactions first requires an understanding of the atomic and ionic structures, chemical formulas and evidence of a chemical reaction. In addition, prime the students by telling students that they will learn about ionic compounds and the role of water in separating the ions. Students will identify the essential aspects of chemical structure and properties of matter as it relates to reactivity.
• Use the slide presentation to focus on one chemical reaction. There is examination of its atomic and ionic nature and states of matter. Chemical concepts to be covered in the slide presentation:
    • Physical and chemical properties of matter
    • Chemical symbols
    • Atoms, ions and ionic compounds
    • Ionic compounds in water and aqueous state
    • Properties of aqueous solutions
    • Signs of a chemical reaction
In addition, review the properties that are characteristic of the chemical reaction and the conditions under which a chemical reaction will occur.

Activity #1: Wet lab or virtual lab - 15 min

2. Live demonstration or watch and discuss video
• The activity is a teacher-led demonstration of a copper and silver nitrate reaction. The demonstration can either be live (if the teacher is able to obtain reactants and the necessary equipment) or it can be virtual, via one of the many videos available for download online.
Some examples: https://www.youtube.com/watch?v=rgYhkVy5cBU
                          https://www.youtube.com/watch?v=dccDiAwztUQ
• The demonstration should be accompanied by a slide presentation using direct instruction and discussion to review key concepts, such as atoms and their ionic counterparts, ionization in water, and the notions of a chemical compound and complexes.
• To do a live demonstration requires a solution of silver nitrate and copper rod or copper

ribbon. It is recommended to use a concentration of 0.5 M of silver nitrate solution and to give the reaction at least 30 minutes for the full effect of a chemical reaction to occur. It is recommended to start the reaction at the beginning of class. To make 0.5 M solution of silver nitrate, dissolve 3.4 g of solid silver nitrate in 40 mL of water.

## Activity #2: Previewing the Chemical Reaction base model - 15 min

3. Introduce the StarLogo Nova base model: "silver nitrate and copper reaction"
- Focus on the reactants and the setup procedures.
- Show the connections between the model interface, Spaceland, and the Workspace (coding window) below.
- Emphasize that agents in this model are used to represent real-world entities, in this case, ionic compounds and molecules.
- The reaction modeled is: Aqueous silver nitrate added to solid copper will react to form solid silver and aqueous copper nitrate.

    In a balanced chemical equation format:
    $2 \ AgNO_3 \ (aq) + Cu \ (s) ---> Cu(NO_3)_2 \ (aq) + 2 \ Ag \ (s)$
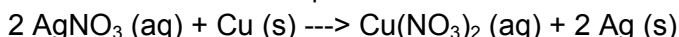
- Discussion: What part of the code determines the total number of Copper agents created?
- Go over what this block means in the Copper Setup:
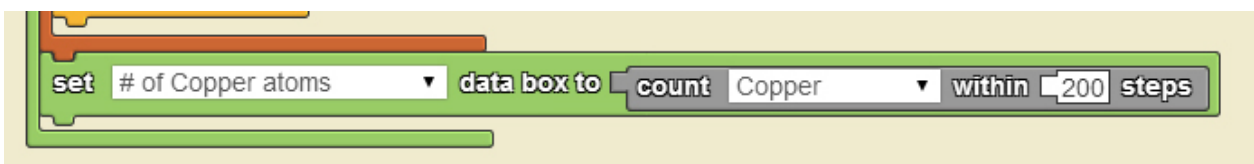
    Discuss: why 200 steps? [Spaceland has boundaries between -50 and 50 in x, y and z dimensions. Spaceland is centered at (0,0,0) and considering the number of steps diagonally, 200 steps is a safe bet.]
- Go over the Copper Setup procedure, emphasizing how agents can be created at specific (x,y) coordinates with a specific heading, and agents can create new agents within repeat loops.

4. Run the model and discuss abstraction and application to real-world phenomena.
- Each atom of silver or copper is represented by one computer modeling agent.
- Each compound of silver nitrate is represented by one computer modeling agent.
- Each water agent in the model corresponds to 1 water molecule (H_2O)
- Copper atoms are stationary and present in a single location.
- Fluid motion is represented by the "Wiggle Walk" for each agent – see silver nitrate tab in workspace.

Wrap-up - 5 min

5. What are signs of a chemical reaction?
- What are signs of a chemical reaction? [Precipitate, color change, bubbles, temperature

change]
- Role of water in chemical reaction. [ions dissociating]
- Do chemical reactions depend on randomness?

Extension: Does the silver depositing on the copper rod remind you of a real-world application? [silver plating]

Assessment Questions

- What is the difference between atoms and ions?
- What evidence of a chemical reaction was seen in real life and in the computer model?
- Would the chemical reaction take place without water?
- Why might we want to simulate chemical reactions on a computer rather than in real life?
- What aspects of a chemical reaction were not included in the computer model?

Background information

- http://www.chemistry-blog.com/2009/04/03/chemistry-lab-demonstrations-silver-nitratecopper-wire/
- http://chemmovies.unl.edu/chemistry/dochem/DoChem019.html

Standards Addressed

NRC Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

PS1.B: Chemical Reactions
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.

NRC Scientific and Engineering Practice Standards

Practice 1: Asking questions and defining problems
1A: Ask questions that arise from careful observation of phenomena, models, or unexpected results.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument.
1E: Ask questions that require sufficient and appropriate empirical evidence to answer.
1F: Ask questions that can be investigated within the scope of the classroom, outdoor environment, and based on observations and scientific principles.

Practice 2: Developing and using models:
2A: Evaluate limitations of a model for a proposed object or tool.

Practice 8: Obtaining, evaluating, and communicating information:
8E: Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in

writing and/or through oral presentations.

NRC Crosscutting Concepts

1. Patterns:
1A: Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

3. Scale, Proportion, and Quantity:
3A: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
3E: Phenomena that can be observed at one scale may not be observable at another scale.

4. Systems and Systems models:
4B: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
4C: Models are limited in that they only represent certain aspects of the system under study.

5. Energy and Matter:
5A: Matter is conserved because atoms are conserved in physical and chemical processes.
6. Structure and Function
6A: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

CSTA K-12 Computer Science Standards

CT	Abstraction	3A-9	Discuss the value of abstraction to manage problem complexity.
CT	Connections to other fields	2-15	Provide examples of interdisciplinary applications of computational thinking.
CT	Modeling & simulation	1:6-4	Describe how a simulation can be used to solve a problem.
CT	Modeling & simulation	2-10	Evaluate the kinds of problems that can be solved using modeling and simulation.
CT	Modeling & simulation	2-11	Analyze the degree to which a computer model accurately represents the real world.
CT	Modeling & simulation	2-9	Interact with content-specific models and simulations to support learning and research.

4

Lesson 2
Modeling Chemical Reactions

50 minutes (1 day)

Lesson Overview

In this lesson students will explore the role of reactants in a chemical reaction. Discussion will be closely tied to the example reaction modeled. Emphasis is placed on concept of limiting reactant and reactants in excess. Students will make some modifications to the model and run experiments to determine the consequences of varying the quantities of reactants.

Teaching Summary

Getting started: – 10 minutes
1. Chemical reaction overview

Activity #1: Analyzing the model – 20 minutes
2. Examine the base model

Activity #2: Modifying the model – 15 minutes
3. Add or remove water molecules
4. Move the copper rod to a different location

Wrap-Up – 5 minutes
5. How does this model help us learn about the chemical reaction?

Lesson Objectives

The student will:
✓ Differentiate between chemical and physical properties of substances [LO6]
✓ Identify atomic symbols [LO7]
✓ Identify chemical formulas of the reactions in this module [LO8]
✓ Identify which reactant is limiting and which is in excess [LO9]
✓ Identify signs of a chemical reaction and when a chemical reaction stops [LO10]

Teaching Guide

Materials, Resources and Preparation

For the Students
- StarLogo Nova base model: "silver nitrate and copper reaction"
- Model Observation Form
- Student Activity Sheet

For the Teacher
- Computer and projector
- Slide presentation
- StarLogo Nova base model: "silver nitrate and copper reaction"

Getting started – 10 min

1. **Chemical reaction overview**
   - Use the slide presentation to review chemical reactions and computer science concepts.
   - Creating and using a model of chemical reactions first requires an understanding of the different aspects of a chemical reaction. In addition, the following concepts are needed before proceeding and need to be reviewed in class:

     Writing chemical equations

     Balancing chemical equations

     Limiting reagents

     Chemical and physical properties of silver, copper, silver nitrate and copper nitrate

     Atomic symbols and chemical formulas of reaction in this module
   - Introduce the silver nitrate and copper chemical reaction:

     $2\ AgNO_3\ (aq) + Cu\ (s) ---> Cu(NO_3)_2\ (aq) + 2\ Ag\ (s)$

   - Introduce the computer science concepts to be used today:

     (x, y) coordinates and heading

     Repeat loop

     Agent count

Activity #1: Analyzing the model – 20 min

2. **Examine the base model**
   - Hand out the Model Observation form.
   - In pairs, have students examine the base model to determine the agents, their behaviors and interactions between agents.
   - Have students record their observations on the Model Observation form.
   - If time permits, ask each pair to report out to the class on a single aspect discovered about the model.

Activity #2: Modifying the model – 15 min

3. **Add or remove water molecules**
   - Guide students in modifying the code to add or remove some or all of the water molecules in the model.
   - Ask "does it affect the execution of the model and real-world representation?"

   Extension: Discuss abstraction in computer modeling.

4. **Move the copper rod to a different location**
   - Offer a challenge to students who finish the previous task quickly.
   - The challenge is to modify the code to move the copper rod somewhere else in the solution, keeping the number of copper agents the same. This number can be tested when executing the program and checking the number of atoms of copper in a databox (interface).
   - To complete this challenge, students will need to figure out how to set up agents in specific (x,y) coordinates with specific headings. They will also get a deeper understanding about using repeat loop and agents creating agents.
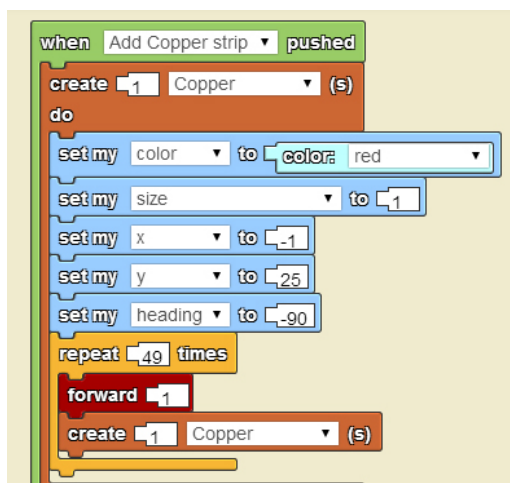
Wrap-up – 5 min

5. Discussion: Ask students:
   Does it matter where the copper is placed when you modify the code?
   Does the model allow you to add more copper? [Try clicking on "Add copper" button twice.]
   Would the shape of copper, such as coil or rod, matter from the model perspective?

Assessment Questions

- What is the difference between the chemical and physical properties of copper?
- Describe how many silver nitrate molecules are needed to react with each copper atom?
- Which reactant is limiting the reaction?
- Which reactant is in excess in the reaction?
- How do we know that a chemical reaction has taken place?
- How do we know when a chemical reaction has stopped?

Standards Addressed

NRC Scientific and Engineering Practice Standards

Practice 1: Asking questions and defining problems
1A: Ask questions that arise from careful observation of phenomena, models, or unexpected results.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument.
1C: Ask questions to determine relationships between independent and dependent variables and relationships in models.
1E: Ask questions that require sufficient and appropriate empirical evidence to answer.
1F: Ask questions that can be investigated within the scope of the classroom, outdoor environment, and based on observations and scientific principles.

Practice 2: Developing and using models
2A: Evaluate limitations of a model for a proposed object or tool.
2B: Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.
2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.
2D: Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
2E: Develop and/or use a model to predict and/or describe phenomena.
2G: Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Practice 4: Analyzing and interpreting data
4D: Analyze and interpret data to provide evidence for phenomena.
4F: Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).
4H: Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.

Practice 6: Constructing explanations and designing solutions
6A: Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
6B: Construct an explanation using models or representations.
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
6H: Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

Practice 8: Obtaining, evaluating, and communicating information
8E: Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

NRC Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
• Substances are made from different types of atoms, which combine with one another in various ways. Atoms form

molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

PS1.B: Chemical Reactions
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.

NRC Crosscutting Concepts

1. Patterns:
1A: Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

3. Scale, Proportion, and Quantity
3A: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
3E: Phenomena that can be observed at one scale may not be observable at another scale.

4. Systems and Systems models
4B: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
4C: Models are limited in that they only represent certain aspects of the system under study.

5. Energy and Matter:
5A: Matter is conserved because atoms are conserved in physical and chemical processes.

6. Structure and Function
6A: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

CSTA K-12 Computer Science Standards

CT	Abstraction	3A-9	Discuss the value of abstraction to manage problem complexity.
CT	Connections to other fields	2-15	Provide examples of interdisciplinary applications of computational thinking.
CT	Data representation	2-8	Use visual representation of problem state, structure and data.
CT	Modeling & simulation	2-10	Evaluate the kinds of problems that can be solved using modeling and simulation.
CT	Modeling & simulation	2-9	Interact with content-specific models and simulations to support learning and research.

Student Activity #2 Guide:

Remix the base model: "silver nitrate and copper reaction and change its name to include your name and your partner's name.

Challenge #1:
Modify the code to add or remove some or all of the water molecules in the model.

Reminder: Execute your model every time you add a piece of code. Debug as needed. Save often.

Hint: Look at the setup instructions for the water agents.
After you change the code, go up to the SpaceLand interface, save the model and click on "Run Code' before running the model by clicking on the interface buttons. Debug the model as needed.

Q: Does removing the water molecules affect the execution of the model and real-world representation? If time allows after you are done, think about what is included in this model and what is missing.

Challenge #2:
Modify the code to move the copper rod somewhere else in the solution keeping the number of agents of copper the same. Please note: The base model gives 150 copper agents to represent 150 copper atoms.

Hint: Look at the setup instructions for the copper agents (section shown below)
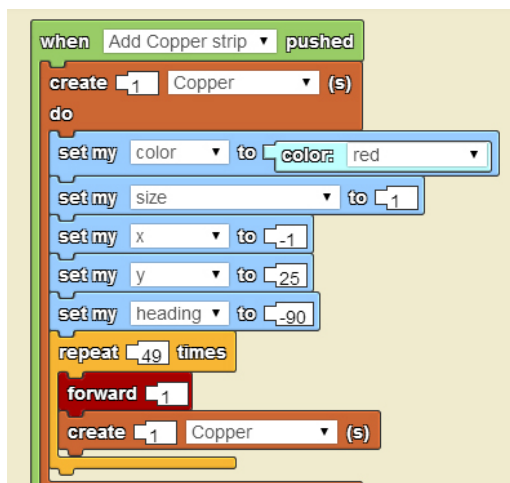
After you change the code, go up to the interface and hit "Save" and "Run Code" before executing the model. Debug the code as needed.

What does the command "set my x to" do? What does the command "set my heading to" do?
What happens if you change the number of times the loop repeats?

Model observation form

Name(s): _____Date: _____

Model name: _____

Abstractions
Who are the <u>Agents</u>?   What is the <u>Environment</u>?   What are the <u>Interactions</u>? *What do ticks represent?*   *What are the variables of interest?*
Automation
What happens each time through the forever (or main) loop?
Assumption(s)
What are the assumptions made in this model?
Analysis
What patterns did you observe? Do these patterns occur in real-life?

4

Lesson 3
Products of Chemical Reactions

50 minutes (1 day)

Lesson Overview

In this lesson students will engage in discussion on the reactants and products of a chemical reaction. Emphasis is on balancing chemical equations, the amounts of reactants used up and products formed. Focus will be on the products and the observation of the atomic rationale for conservation of mass.

Teaching Summary

Getting started – 5 minutes
1. When does a chemical reaction stop?

Activity #1: Modifying the model – 25 minutes
2. The production of copper nitrate

Activity #2: Running experiments – 15 minutes
3. Different initial quantities of copper or silver nitrate

Wrap-up – 5 minutes
4. What are models good for?

Lesson Objectives

The student will:
- ✓ Identify the products of a chemical reaction [LO11]
- ✓ Identify the factors that stop a chemical reaction [LO12]
- ✓ Learn about concepts of limiting reactants and reactants in excess [LO13]
- ✓ Learn the importance of balancing chemical equations [LO14]
- ✓ Learn how to make new breeds and create agents in agent-based modeling [LO15]

Teaching Guide

Materials, Resources and Preparation

For the Students
- StarLogo Nova base model: "silver nitrate and copper reaction"
- Student Activity Sheet
- Experimental Design Form

For the Teacher
- Computer and projector
- Slide presentation
- StarLogo Nova base model: "silver nitrate and copper reaction"

Getting started - 5 min

1. **When does a chemical reaction stop?**
   - In this slide presentation you will review the chemical reaction being modeled.
   - Discuss the conservation of mass and how the balancing of chemical equations preserves this law.
   - Illustrate how 2 $AgNO_3$ is broken apart in water, then how 2 NO_3 bind with one Cu to produce the "product" $Cu(NO_3)_2$
   - Introduce the concepts of the limiting reagent and reactants in excess.
   - The key question to pose to students is, "When does the reaction stop?"
   - Tell students that this will be the basis for our investigations today.

     Computer science concepts: Agents represented by breeds. Default breed in StarLogo Nova is "Turtle." Breeds can be added and renamed.

Activity #1: Modifying the code – 25 min
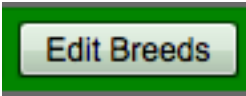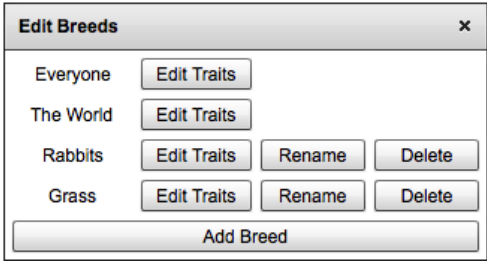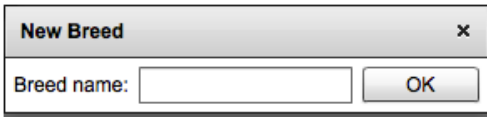
2. **The production of copper nitrate**
   - Review the chemical reaction being represented in the base model so far and what is missing. Aqueous silver nitrate added to solid copper will react to form solid silver and aqueous copper nitrate.

     Chemical reaction: 2 $AgNO_3$ (aq) + Cu (s) $\rightarrow$ $Cu(NO_3)_2$ (aq) + 2 Ag (s)

   - Note that in our model we have breeds for $AgNO_3$, Cu, and Ag, but no $Cu(NO_3)_2$. We are missing one of the products!
   - Review the concept of conservation of mass and that to be accurate, all mass must be accounted for.
   - So let's add the production of copper nitrate to the model: first we will need to make a breed called "copper nitrate," then create the agents with breed copper nitrate inside a collision block, and give the copper nitrate agents some behavior. Copper nitrate is a soluble ionic compound - it stays suspended in water.
   - Have students open and remix the StarLogo Nova base model "silver nitrate and copper

reaction."

- Pose the challenge: modifying the code to add copper nitrate agents.
- Introduce new computer science concept: adding new breeds.
- Review the breeds that students know already. "Turtles" are the default breed of agents in StarLogo Nova. New breeds can be added using the "Edit Breeds" panel and the new breed can be given traits.
- Show the edit breeds panel and demonstrate how to add a breed.

Edit Breeds	Use the Edit Breeds button in the Spaceland area to create a new breed.
Edit Breeds ... Everyone [Edit Traits] The World [Edit Traits] Rabbits [Edit Traits] [Rename] [Delete] Grass [Edit Traits] [Rename] [Delete] [Add Breed]	Click on "Add Breed" to add a new breed.
New Breed ... Breed name: [ ] [OK]	In the "New Breed" dialog box, give the breed a name and press OK.

- Point out to the students that once you add a new breed, a new page for that breed appears in the Workspace. This is where the procedures for agents of that breed are written and stored.
- Next, we'll need to create a copper nitrate agent when there is a collision between a "gray" copper, and a silver nitrate.
- The newly created copper nitrate should have the following traits: its shape should be a sphere, its color should be white and its size should be 1.
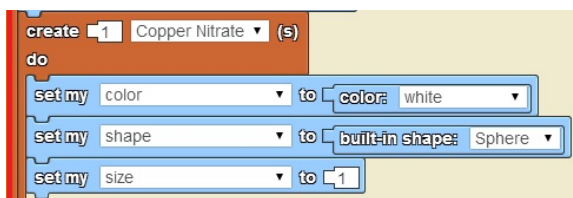

- Where is the correct location of this procedure? [in the copper tab]
- Review what we learned about the base model in the previous lesson. The first time a silver nitrate reacts with copper, the copper turns gray. The second time a silver nitrate reacts with a copper, silver and now copper nitrate are produced. So we know that the copper nitrate should be created when the silver is created. (See the code blocks on the next page.)
- Next we need to give the copper nitrate some movement. This code should be added to the copper nitrate page. [You can copy and paste the Wiggle Walk procedure from the water page or the silver nitrate page to the copper nitrate page.]

Extension: Create a data box to display the amount of copper nitrate produced.

Extension: Introduce the concept of inheritance of all agents from the "everyone" breed in StarLogo Nova. Then show how the Wiggle Walk procedure can be moved into the "everyone" page and removed from the other breed specific pages. Why might this be a good idea? [Avoids duplication, prevents one of the breeds from having a different behavior, and is easy to change, since it is in one place.]

Extension: Move this whole collision procedure from the copper page to the silver nitrate page. Change the heading of the collision block to reflect "On collision with copper" instead of "On collision with silver nitrate" and execute the model. What do you notice? [The silver ends up deposited at the location of the center of the silver nitrate rather than the copper. As a result, the copper strip does not get "plated" evenly.]
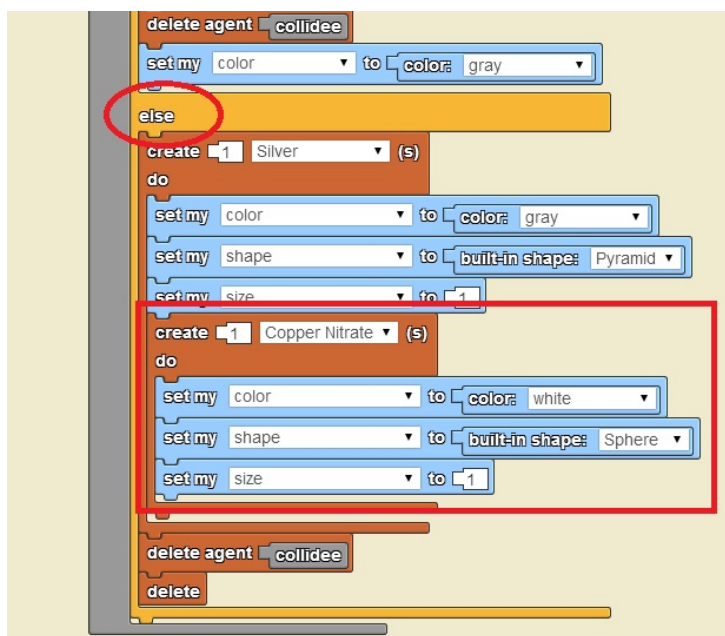
Activity #2: Running experiments – 15 min

3. **Different initial quantities of copper or silver nitrate**
   - Run experiments with the modified model. Experiment with different initial quantities of copper or silver nitrate and record the amount of silver produced. (If a student's modification of the model was unsuccessful, the base model can be used for this experimentation.)
   - Instruct the students on using the Experimental Design Form to guide their experimentation. Remind students to include multiple trials at every different setting of the initial amounts used.
   - Students are to note when the copper is in excess and when the silver nitrate is in excess. Also, how much silver was produced in each case?

Wrap-up – 5 min

4. What are models good for?
Lead a discussion with the students:
- What is your conclusion about the limiting reagent? When does the reaction stop?
- What experiments did you run that validate this conclusion?
- If your goal was not to waste reactants, how is the model helping in figuring out the amounts needed from reactants and when the reaction stops?

Assessment Questions

- What were the reactants in the chemical reaction we studied?
- What were the products in the chemical reaction we studied?
- What determines which are the limiting reactants?
- What determines which are the reactants in excess?
- In your own words, describe the law of conservation of mass.

Standards Addressed

NRC Scientific and Engineering Practice Standards

Practice 1: Asking questions and defining problems
1A: Ask questions that arise from careful observation of phenomena, models, or unexpected results.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument.
1C: Ask questions to determine relationships between independent and dependent variables and relationships in models.
1D: Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.
1E: Ask questions that require sufficient and appropriate empirical evidence to answer.
1F: Ask questions that can be investigated within the scope of the classroom, outdoor environment, and based on observations and scientific principles.
1G: Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.

Practice 2: Developing and using models
2A: Evaluate limitations of a model for a proposed object or tool.
2B: Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.
2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.
2D: Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
2E: Develop and/or use a model to predict and/or describe phenomena.
2G: Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Practice 4: Analyzing and interpreting data
4D: Analyze and interpret data to provide evidence for phenomena.
4G: Analyze and interpret data to determine similarities and differences in findings.

Practice 5: Using mathematics and computational thinking
5C: Create algorithms (a series of ordered steps) to solve a problem.

Practice 6: Constructing explanations and designing solutions
6A: Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
6B: Construct an explanation using models or representations.
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
6E: Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.

6H: Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

Practice 8: Obtaining, evaluating, and communicating information
8E: Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

NRC Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

PS1.B: Chemical Reactions
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.

NRC Crosscutting Concepts

1. Patterns:
1A: Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

3. Scale, Proportion, and Quantity
3A: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
3C: Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
3E: Phenomena that can be observed at one scale may not be observable at another scale.

4. Systems and Systems models
4B: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
4C: Models are limited in that they only represent certain aspects of the system under study.

5. Energy and Matter:
5A: Matter is conserved because atoms are conserved in physical and chemical processes.

6. Structure and Function
6A: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

CSTA K-12 Computer Science Standards

CT	Abstraction	3A-9	Discuss the value of abstraction to manage problem complexity.
CT	Data representation	2-8	Use visual representation of problem state, structure and data.
CT	Modeling & simulation	2-10	Evaluate the kinds of problems that can be solved using modeling and simulation.
CT	Modeling & simulation	2-9	Interact with content-specific models and simulations to support learning and research.
CPP	Data collection & analysis	2-9	Collect and analyze data that are output from multiple runs of a computer program.
CPP	Programming	2-5	Implement a problem solution in a programming environment using looping behavior, conditional statements, logic, expressions, variables and functions.

Student Activity #1 Guide:

Your Challenge: Change the code to add copper nitrate agents to represent the missing chemical product from the model.

The reaction modeled is:
Aqueous silver nitrate added to solid copper will react to form solid silver and aqueous copper nitrate.
Chemical reaction: 2 AgNO$_3$ (aq) + Cu (s) ---> Cu(NO$_3$)$_2$ (aq) + 2 Ag (s)

Start with base model - StarLogo Nova base model: "silver nitrate and copper reaction"
Remix the base model and change its name to include your name and your partner's name.

Reminder: Save and test your model every time you add a piece of code. Debug if needed. Save often.

[Hints: (A) Add breed for new agent, (B) create agents inside a collision block, (C) give the agent some movement in water since it is a soluble ionic compound.]

One solution to the Challenge:

A- Add the copper nitrate agent as a new breed.
    Click on edit Breed. Click on add Breed. Name the breed 'copper nitrate". Exit edit breed.

    Is there a new page/tab in Workspace now that they created copper nitrate breed?

B- When "gray" copper collides with silver nitrate, copper nitrate is created.
        Give the copper nitrate agent the following traits:
        Shape is sphere, color is white and size is 1.
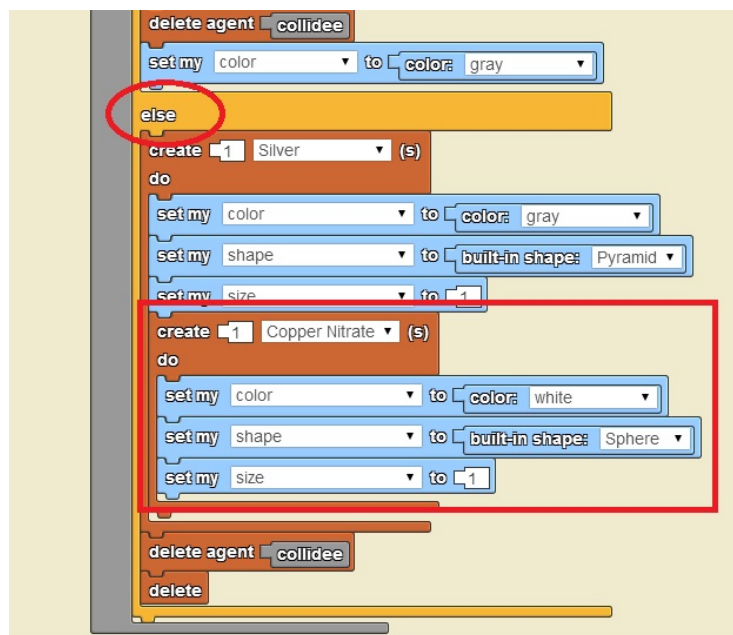
Where is the correct location of this procedure? Why?

C- Add movement to copper nitrate: copy and paste Wiggle Walk procedure from water page or silver
    nitrate page to the copper nitrate page.
    To copy, with the mouse clicked, drag a box over the piece of code you want to copy, and click on the
    copy button under the drawers.

Student Activity #2 Guide:

Start with the above modified model.

Your Challenge: Run experiments with different initial quantities of copper or silver nitrate and get the amount of silver produced. How much silver is produced in each case? Note when the copper is in excess and when the silver nitrate is in excess.

Use the Experimental Design Form to guide you.
Multiple trials are needed at every different setting of initial amounts used.

Can you predict what amount of silver nitrate is needed to use up all the copper with no excess left of either?

Experimental Design form

Name(s): _____Date: _____

Model name: _____

Question
What is your question?

Variables
What are the dependent and independent variables in your experiment?

Range
What is the range of values you will use for each variable?

Trials
How many trials will you run at each setting? Why?

Data Collection
What data will you collect?

Data Analysis
How will you analyze your data?

Interpretation
What is the answer to your question?
Interpretation
How does the analysis of your data help you answer your question?

4

Lesson 4

Complex Ions in Solution

50 minutes (1 day)

Lesson Overview

In this lesson students will engage in discussion on the ionic equations and formation of complex ions. Students will discover the underlying chemical cause of the emergent blue hue that develops in the physically demonstrated silver nitrate/copper reaction. Emphasis is on the complex ion Cu(II).3H$_2$O or simply hydrated copper ion complex. Students will add instrumentation to the model and run experiments to determine the impact of the availability of reactants on the rate of chemical reaction.

Teaching Summary

Getting started – 10 minutes
1. Ionic compounds, ionic equations and complexes

Activity #1: Modifying the model further – 20 minutes
2. Create hydrated copper ions
3. Turn the solution blue

Activity #2: Running experiments – 15 minutes
4. Characterizing the rate of reaction

Wrap-up – 5 minutes
5. Using computer models in scientific investigations.

Lesson Objectives

The student will:
✓ Differentiate between chemical equations, ionic equation and net ionic equation [LO16]
✓ Learn about at least one type of complex ions [LO17]
✓ Get more familiar with collision blocks in StarLogo Nova [LO18]
✓ Become familiar with rate of a reaction and availability of reactants [LO19]

1

Teaching Guide

Materials, Resources and Preparation

For the Students
- StarLogo Nova modified model from Lesson 3
- Student Activity Sheet
- Experimental Design Form

For the Teacher
- Computer and projector
- Slide presentation document
- StarLogo Nova modified model from Lesson 3

Getting started – 10 min

1. **Ionic compounds, ionic equations and complexes**
   - Discuss a simple ionic compound and its equation: Silver nitrate, $Ag(NO_3)$ in water dissociates to one ion of Ag^+ and one $(NO_3)^-$ ion. Review the definition of an ion [An ion is an atom or molecule with a net electric charge, due to the loss or gain of one or more electrons.]
   - Discuss that the product copper nitrate, $Cu(NO_3)_2$ which was produced in our experiment, is also an ionic compound.
   - Copper nitrate is an ionic compound that is soluble in water. It dissociates to Cu^{+2} [or Cu(II) by convention] and two $(NO_3)^-$ ions. Review the definition of an ionic compound, "An Ionic Compound is made of positive ions (cations) and negative ions (anions) held tightly together" and the term "soluble" meaning it dissolves in water.
   - Copper ions, Cu(II), in water form a complex ion with 3 water molecules, which produces the blue hue (or color) in the solution. This complex can be referred to in many different ways:
     - $[Cu(H_2O)_3]^{+2}$
     - more conventionally referred to as $Cu(II).3H_2O$
     - simply referred to "hydrated copper ion complex"

   - It takes "colliding" with 3 different water molecules to form the "hydrated copper ion complex" or $Cu(II).3H_2O$. We can think of it as three stages going from $Cu(II).H_2O$ with one water molecule, to $Cu(II).2H_2O$ with two water molecules, to $Cu(II).3H_2O$, the final form with three water molecules attached.

Activity #1: Modifying the model further – 20 min

2. **Create hydrated copper ions**
   - Have students open and remix their modified model from Lesson 3.
   - Pose the goal of this activity, to implement the formation of the intermediary ionic compounds up leading to the hydrated copper ion $Cu(II).3H_2O$.
   - Ask students for suggestions on how this task might be approached given the StarLogo Nova tools and techniques they know of. [Hint: new breeds can be formed upon collision.]
   - If necessary, guide students in sketching out the model design using the Model Design

Form.

- Students will need to add 3 additional breeds, one for each of the hydrated copper ions: $Cu(II).H_2O$, $Cu(II).2H_2O$, $Cu(II).3H_2O$. Refer to Lesson 3 on how to add new breeds.
- Remind the students to check the Workspace area after they add the new breeds. Did new pages/tabs appear?
- Write the collision procedures for each of the intermediate ions, such that when a copper collides with a H_2O it becomes a $Cu(II).H_2O$, then when a $Cu(II).H_2O$ collides with a H_2O it becomes a $Cu(II).2H_2O$, and finally, when a $Cu(II).2H_2O$ collides with a H_2O it becomes a $Cu(II).3H_2O$.
- Remind student to check that they add the new collisions in the correct pages corresponding to the intermediary ionic compounds.

3. **Turn the solution blue**
   - Review that something special happened as the copper ions became fully hydrated. The solution turned blue! We are going to mimic this phenomenon in the model.
   - We are going to change the code within the collision blocks to create the agents with their own traits (specifically color):

     $Cu(II).H_2O$: Shape is sphere, color is cyan and size is 1
     $Cu(II).2H_2O$: Shape is sphere, color is sky blue and size is 1
     $Cu(II).3H_2O$: Shape is sphere, color is blue and size is 1

   Teaching Tip *It is possible to drag a selection box around a group of blocks on one page, and "copy and paste" them to a new page. This is a real time-saver.*

   - In the copper breed page, we create $Cu(II).H_2O$ and change the color of the agent to cyan.

   - Make similar collision blocks for the breeds $Cu(II).H_2O$ and $Cu(II).2H_2O$ and set the color of the new agent according to the specifications above.
   - Check your code and test your model. Did something get changed? Does the model execute correctly?
   - Ask the student what is missing from the code. Did they remember that these new agents are ions diffused in water? [Hint: They need to add a Wiggle Walk procedure to make the agents appear to be moving randomly.]

Activity # 2: Running experiments – 15 min

4. **Characterizing rates of reactions**
   - The rate of reaction is how fast the product is made or reactants consumed.
   - Let's add some instrumentation so we can graph how fast the products are made.
   - In order to collect and visualize quantitative data we need to add a line graph in StarLogo Nova. The graph will collect data on the time elapsed since the model started running and the cumulative number of products produced over time.
   - With this information we will be able to compare patterns in the collected data.
   - For this model, what products do we want to monitor?
   - Let's create a new line graph called "Products produced over Time."
   - Demonstrate how to create a line graph using the slide presentation or StarLogo Nova.
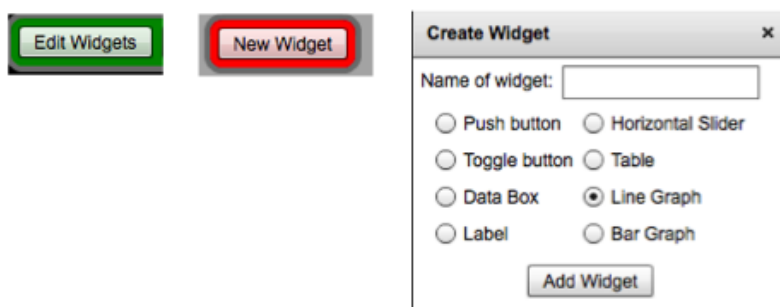

   - Drag the line graph off to the side of Spaceland.
   - Add new series to the graph by double clicking on New Series and changing the name and line color. For example,
     - Create a new series called "Silver" then select gray as its line color.
     - Create a new series called "Cu(II).1H2O" then select cyan as its line color.
     - Do the same for the other products you want to monitor.
   - Finally, click "Edit Widgets" to leave editing mode and return to play mode.
   - Next, we want "The World" to update the line graph each time through the forever loop, so we need to add a while forever toggled command to the page labeled "The World."
   - Notice that we need the "clock" along the x-axis and the count of agents of different breeds on the y-axis. We can get the count of agents with different characteristics using the count command. Since the whole Spaceland is less than 150 steps square, saying "within 150 steps" will get us the number of turtles that fit this criterion across all of Spaceland. See the example below.
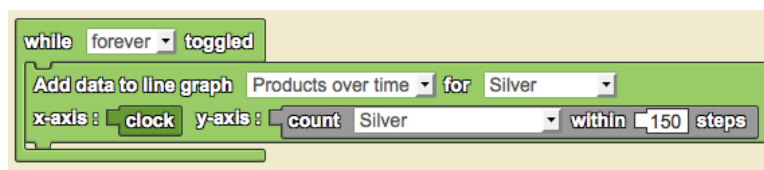
   - Add in similar "Add data to line graph" command blocks to the "while forever toggled" loop for each of the other products you would like to monitor in the line graph.

Test your model
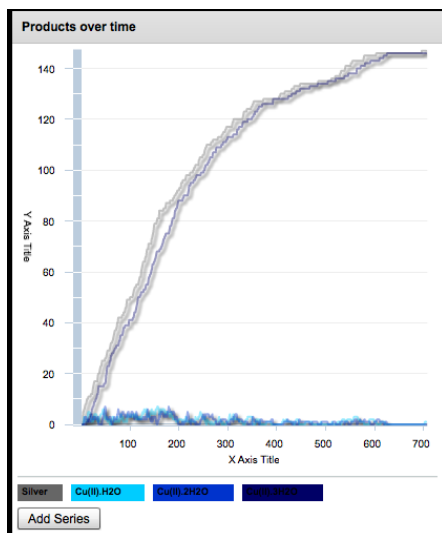
- Does your line graph work? [If not, save the model and return to your galleries by clicking on "my profile." Select and reopen the model.]

- What patterns can you now see that were difficult to see without a line graph?
- In our current model, various factors may impact the speed at which the product is made.
- One is the availability of reactants. Using the Experimental Design form, design an experiment to determine the impact of the availability of reactants on the rate of production.
- Ask students to compare their results of their experiments and suggest reasons why the shape of the products curve is what it is.

Wrap-up – 5 min

5. Using computer models in scientific investigations.
   - How is this computer model helping in figuring out the impact of availability of reactants and the rate of reactions in this experiment?
   - If time allows, have some students volunteer to present their models and point out any new learning/code they are proud of.

Assessment Questions

- What is an example of an ionic compound?
- Describe what happens to ionic compounds in solution.
- In the experiment we did today, what determines the rate of silver production?
- In your own words, describe the shape of the silver production curve and what caused it to have that shape.

Standards Addressed

NRC Scientific and Engineering Practice Standards

Practice 1: Asking questions and defining problems
1A: Ask questions that arise from careful observation of phenomena, models, or unexpected results.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument.
1C: Ask questions to determine relationships between independent and dependent variables and relationships in models.
1D: Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.
1E: Ask questions that require sufficient and appropriate empirical evidence to answer.
1F: Ask questions that can be investigated within the scope of the classroom, outdoor environment, and based on observations and scientific principles.
1G: Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.

Practice 2: Developing and using models

2A: Evaluate limitations of a model for a proposed object or tool.

2B: Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.

2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.

2D: Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.

2E: Develop and/or use a model to predict and/or describe phenomena.

2G: Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Practice 3: Planning and carrying out investigations

3A: Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

3D: Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Practice 4: Analyzing and interpreting data

4D: Analyze and interpret data to provide evidence for phenomena.

4F: Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).

4G: Analyze and interpret data to determine similarities and differences in findings.

4H: Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.

Practice 5: Using mathematics and computational thinking

5C: Create algorithms (a series of ordered steps) to solve a problem.

Practice 6: Constructing explanations and designing solutions

6A: Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.

6B: Construct an explanation using models or representations.

6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.

6E: Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.

6H: Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

Practice 8: Obtaining, evaluating, and communicating information

8E: Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

NRC Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

PS1.B: Chemical Reactions
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.

• Some chemical reactions release energy, others store energy.

NRC Crosscutting Concepts

1. Patterns:
1A: Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

3. Scale, Proportion, and Quantity
3A: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
3C: Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
3E: Phenomena that can be observed at one scale may not be observable at another scale.

4. Systems and Systems models
4B: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
4C: Models are limited in that they only represent certain aspects of the system under study.

5. Energy and Matter:
5A: Matter is conserved because atoms are conserved in physical and chemical processes.

6. Structure and Function
6A: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

CSTA K-12 Computer Science Standards

CT	Abstraction	3A-9	Discuss the value of abstraction to manage problem complexity.
CT	Abstraction	3B-10	Decompose a problem by defining new functions and classes.
CT	Connections to other fields	2-15	Provide examples of interdisciplinary applications of computational thinking.
CT	Data representation	2-8	Use visual representation of problem state, structure and data.
CT	Modeling & simulation	2-10	Evaluate the kinds of problems that can be solved using modeling and simulation.
CT	Modeling & simulation	2-9	Interact with content-specific models and simulations to support learning and research.
CT	Modeling & simulation	3A-8	Use modeling and simulation to represent and understand natural phenomena.
CPP	Data collection & analysis	2-9	Collect and analyze data that are output from multiple runs of a computer program.
CPP	Programming	2-5	Implement a problem solution in a programming environment using looping behavior, conditional statements, logic, expressions, variables and functions.

Student Activity #1 Guide:

Your Challenge: Alter your model to include the formation of hydrated copper ions.   First you will need to create additional breeds Cu(II).H_2O, Cu(II).$2H_2O$, Cu(II).$3H_2O$

Copper in water forms a complex with 3 water molecules which makes the solution slowly turn blue as the complex Cu(II).$3H_2O$ forms.

1.   Start with modified model from Lesson 3
2.   Remix the base model and change its name to include your name and your partner's name.

Reminder: Save and test your model every time you add a piece of code. Debug if needed. Save often.

3.   In the Interface (Spaceland) add 3 additional breeds:

<div align="center">

Cu(II).$1H_2O$
Cu(II).$2H_2O$
Cu(II).$3H_2O$

</div>

Hint: Refer to Lesson 3 on how to add new breeds.

Check the Workspace area. Did new pages/tabs appear?

4. Change the code using collision blocks to create the following agents with their own traits:

Cu(II).H_2O: Shape is sphere, color is cyan and size is 1. It is created when one copper nitrate agent collides with one water molecule.
Cu(II).$2H_2O$: Shape is sphere, color is sky blue and size is 1. It is created when one Cu(II).H_2O agent collides with one water molecule.
Cu(II).$3H_2O$: Shape is sphere, color is blue and size is 1. It is created when one Cu(II).$2H_2O$ agent collides with one water molecule.

The complex Cu(II).$3H_2O$ is the final ionic product created in the solution turning the solution blue.

Tip: It is possible to drag a selection box around a group of blocks on one page, and "copy and paste" them to a new page. This is a real time-saver.

Reminder: Execute your model every time you add a piece of code. Debug if needed. Save often.

5. These new agents are ions moving about in water.
Set up a Wiggle Walk procedure for each agent on its own page.

Student Activity #2 Guide:

Your Challenge: Add instrumentation to your model so you can observe the rate of reaction then characterize the rate of reaction.

Start with modified model from Activity 1 and add a new widget, a line graph.

On the line graph window, add a new series to the graph by double clicking on New Series and changing the name and line color. For example,

- o   Create a new series called "Silver" then select gray as its line color.
- o   Create a new series called "Cu(II).1H2O" then select cyan as its line color.
- o   Do the same for the other products you want to monitor.

Finally, add the corresponding commands to the World's page to update the line graph as time advances (clock tick).
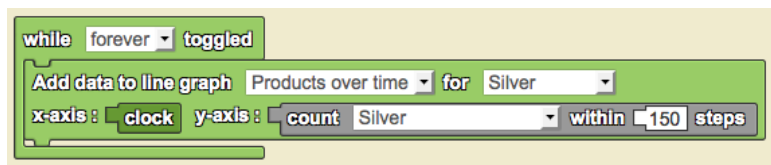
Use the experimental design form to design and document your experiment. Try to determine the impact of reactant availability on the rate of reaction (production of products).

What do you observe?
Did the rate of the reaction increase as the number of reactants increased? Or visa versa?

Experimental Design form

Name(s): _____Date: _____

Model name: _____

Question
What is your question?

Variables
What are the dependent and independent variables in your experiment?

Range
What is the range of values you will use for each variable?

Trials
How many trials will you run at each setting? Why?

Data Collection
What data will you collect?

Data Analysis
How will you analyze your data?

Interpretation

What is the answer to your question?

Interpretation

How does the analysis of your data help you answer your question?

4

Lesson 5

Factors that impact the Rate of a Chemical Reaction

50 minutes (1 day)

Lesson Overview

In this lesson students will make modifications to the model and run experiments to examine the effect of temperature on the rate of a chemical reaction.

Teaching Summary

Getting started – 10 minutes
1. Availability of reactants as a limiting factor

Activity #1: Factors impacting the rate of reaction – 15 minutes
2. Mixing – the simulation of movement
3. Step size – the simulation of kinetic energy

Activity #2: Running experiments – 15 minutes
4. Impacts of mixing or step size

Wrap-up – 10 minutes
5. Sharing results and conclusions

Lesson Objectives

The student will:
✓ Review findings on the rate of reaction from the last lesson [LO16]
✓ Learn how agent movement can impact outcome in simulations [LO17]
✓ Learn to simulate kinetic energy in an agent-based model [LO18]
✓ Run experiments to determine how kinetic energy impacts the rate of chemical reaction [LO19]
✓ Become familiar with rate of a reaction and kinetic energy effect [LO20]

Teaching Guide

Materials, Resources and Preparation

For the Students
- StarLogo Nova modified model from Lesson 4
- Student Activity Sheet
- Project Design Form

For the Teacher
- Computer and projector
- Slide presentation document
- StarLogo Nova modified model from Lesson 4

Getting started - 10 min

1. **Availability of reactants as a limiting factor in the rate of chemical reaction**
   - Discuss the shape of the silver production curve in the last lesson.
   - Discuss how, when the resources are limited, there are fewer to react and thus the reaction is slower.
   - Next we are going to examine other factors that can impact the rate of chemical reaction.

     Extension: If students have already completed the "Ecosystems" module, make the connection between a population growth curve in an ecosystem when there is a carrying capacity and this curve we see in the production of silver. This is an example of a negative or balancing feedback loop.

Activity #1: Factors impacting the rate of reaction – 15 min

2. **Mixing – the simulation of movement**
   - Have students open and remix their modified model from Lesson 4.
   - Pose the goal of this activity, to examine the impact of different movement in the model of the chemical reaction.
   - Ask students for suggestions on how this task might be approached given the StarLogo Nova tools and techniques they know of. [Hint: Wiggle walk can be altered to make agents walk in circles, wavy lines, or straight lines.]
   - If necessary, guide students in sketching out the model and experimental design using the Project Design form.
   - Students will need to manipulate the wiggle walk turn radius and bias. Discuss the mathematics involved, referring back to the Dice and Data activity from Module 1. Bias occurs when one direction is more likely than another. For example, a strong right bias can cause agents to walk in clockwise circles.
   - When agents walk in tight circles, there is not much mixing, whereas if agents walk mostly in a straight line, they tend to walk across SpaceLand.

- Compare the following three walks and determine what trail they would produce if repeatedly executed (in a forever loop).

3. **Step size – the simulation of kinetic energy**
   - We can simulate the kinetic energy of an atom or molecule by changing the number of forward steps it takes, from 1 to 2 to 3. By increasing the number of forward steps it takes, we are increasing the speed of the agent. In the real world, this is usually accomplished by increasing the temperature of the reaction. This increase in kinetic energy of reactants causes the rate of the reaction/speed to increase. In other words, the reactants are consumed faster.
   - Have students open and remix their modified model from Lesson 4.
   - Pose the goal of this activity, to examine the impact of different movement in the model of the chemical reaction.
   - Allow students some time to experiment informally with the step size the agents take.

Activity # 2: Running experiments – 15 min

4. **Impacts of mixing or step size**
   - Starting with modified model from Activity 1 or 2 above, have the students focus on an experimental design.
   - Guide students in sketching out the model modifications and experimental design using the Project Design form.
   - Run experiments at different kinetic energies or different movement (wiggle walks).
   - Capture data on the rate of reaction as seen in the production of products.
   - Remind students that in their experimental designs, the initial amount of copper and silver nitrate should remain the same throughout the experiment.
   - Run multiple trials of the experiment. For example, if experimenting with different step sizes, you may first run the experiment with forward step size set to 1 and record the time when about **half the copper** is used up. Since we are starting with 150 copper agents, click the forever button to stop the simulation when the copper count goes down to about 75 atoms. Run this same experiment 5-10 times if possible before changing the step size to 2, then 3. [Note to teacher: step sizes of greater than 3 will not work in this model. See teaching tip below.] In this experiment, students may observe that the reaction arrives at the half point faster when the kinetic energy increases.

     Teaching Tip *This simulation will not work for a number of steps over three because the width of the copper bar is 3 agents wide, and the agents would jump over the bar if the forward step was higher than 3. There is a solution, but it would require adding a repeat loop outside the Wiggle Walk*.

Wrap-up – 10 min

5. Sharing results and conclusions
   - Have students discuss their experiments and conclusions with another pair.
   - Have students discuss whether their results were in conflict or agreement with the findings of the other pair.

Assessment Questions

- What are some factors that impact the rate of reaction?
- How would you design an experiment to determine the impact of one of the factors?
- How was an increase in kinetic energy simulated in this lesson?
- Describe a feedback loop in the chemical reaction studied.

Standards Addressed

NRC Scientific and Engineering Practice Standards

Practice 1: Asking questions and defining problems
1A: Ask questions that arise from careful observation of phenomena, models, or unexpected results.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument.
1C: Ask questions to determine relationships between independent and dependent variables and relationships in models.
1D: Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.
1E: Ask questions that require sufficient and appropriate empirical evidence to answer.
1F: Ask questions that can be investigated within the scope of the classroom, outdoor environment, and based on observations and scientific principles.
1G: Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.

Practice 2: Developing and using models
2A: Evaluate limitations of a model for a proposed object or tool.
2B: Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.
2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.
2D: Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
2E: Develop and/or use a model to predict and/or describe phenomena.
2F: Develop a model to describe unobservable mechanisms.
2G: Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Practice 3: Planning and carrying out investigations
3A: Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
3B: Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
3D: Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Practice 4: Analyzing and interpreting data
4D: Analyze and interpret data to provide evidence for phenomena.
4F: Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).
4G: Analyze and interpret data to determine similarities and differences in findings.
4H: Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.

Practice 5: Using mathematics and computational thinking
5C: Create algorithms (a series of ordered steps) to solve a problem.

5D: Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.

Practice 6: Constructing explanations and designing solutions
6A: Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
6B: Construct an explanation using models or representations.
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
6E: Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
6G: Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
6H: Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

Practice 8: Obtaining, evaluating, and communicating information
8E: Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

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- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

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- The total number of each type of atom is conserved, and thus the mass does not change. Some chemical reactions release energy, others store energy.

NRC Crosscutting Concepts

1. Patterns:
1A: Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
1D: Graphs, charts, and images can be used to identify patterns in data.

2. Cause and Effect:
2B: Cause and effect relationships may be used to predict phenomena in natural or designed systems.

3. Scale, Proportion, and Quantity
3A: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
3C: Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
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7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

CSTA K-12 Computer Science Standards

CT	Abstraction	2-12	Use abstraction to decompose a problem into sub problems.
CT	Abstraction	3A-9	Discuss the value of abstraction to manage problem complexity.
CT	Abstraction	3B-10	Decompose a problem by defining new functions and classes.
CT	Algorithms	2-4	Evaluate ways that different algorithms may be used to solve the same problem.
CT	Connections to other fields	2-15	Provide examples of interdisciplinary applications of computational thinking.
CT	Data representation	2-8	Use visual representation of problem state, structure and data.
CT	Modeling & simulation	2-10	Evaluate the kinds of problems that can be solved using modeling and simulation.
CT	Modeling & simulation	2-11	Analyze the degree to which a computer model accurately represents the real world.
CT	Modeling & simulation	2-9	Interact with content-specific models and simulations to support learning and research.
CT	Modeling & simulation	3A-8	Use modeling and simulation to represent and understand natural phenomena.
CPP	Data collection & analysis	2-9	Collect and analyze data that are output from multiple runs of a computer program.
CPP	Programming	2-5	Implement a problem solution in a programming environment using looping behavior, conditional statements, logic, expressions, variables and functions.
CPP	Programming	3A-3	Use various debugging and testing methods to ensure program correctness.
CPP	Programming	3A-4	Apply analysis, design and implementation techniques to solve problems.

Project Design Form

Name(s): _____Date: _____

Model name: _____

PROJECT DESCRIPTION
What question do you seek to answer?
What observation of phenomenon, model, or unexpected result led you to this question?

MODEL DESCRIPTION
What will be modeled?
What question do you seek to answer?
How will it be modeled? What abstractions are used?
Who are the <u>Agents</u>?   What is the <u>Environment</u>?   What are the <u>Interactions</u>? What do ticks represent?   *What are the parameters of interest?*

EXPERIMENTAL DESIGN

Variables

What are the dependent and independent variables in your experiment?

Range

What is the range of values you will use for each variable?

Trials

How many trials will you run at each setting? Why?

Data Collection

What data will you collect?

Data Analysis

How will you analyze your data?

Interpretation

What question do you seek to answer?

Interpretation

How does the analysis of your data help you answer your question?

Scientific Practices with Computer Modeling & Simulation

Name: Date:

The table below lists scientific practices.   Please provide an example of what you did that matches the practice.

Practices:	
Asking questions and defining problems	
Develop and use a model	
Plan and carry out an investigation	
Analyze and interpret data	
Use mathematics and computational thinking	
Construct explanations and design solutions	
Engage in argument from evidence	
Obtain, evaluate, and communicate information	