Teacher Guide and Student Journal
Sample Activity and Planning Pages

Particles of Matter and Chemical Reactions MSPNG2

A Middle School Unit supporting Next Generation Science Standards and Michigan Science Standards

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A Middle School Unit supporting
Next Generation Science Standards
and the Michigan Science Standards

developed and written by
Battle Creek Area Mathematics and Science Center
for

CEREAL CITY SCIENCE
by BCAMSC

Particles of Matter and Chemical Reactions

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NEXT GENERATION SCIENCE STANDARDS

Disciplinary Core Ideas/Performance Assessments	Activity
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. (MS-PS1-1) • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-3, MS-PS1-2) • Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4) • 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. (MS-PS1-4) • Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1) • The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)	1, 2, 3, 4, 5, 6, 7, 8
MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.	2, 3
MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.	7
MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.	1, 2, 3
MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	6
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. (MS-PS1-3) • The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-5) • Some chemical reactions release energy, others store energy (MS-PS1-6)	6, 7, 8
MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	6
MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.	7
MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.	6
MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*	8

NEXT GENERATION SCIENCE STANDARDS

Disciplinary Core Ideas/Performance Assessments	Activity
PS3.A: Definitions of Energy • The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary to MS-PS1-4) • The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. (secondary to MS-PS1-4)	2, 3
MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.	2, 3
ETS1.B: Developing Possible Solutions • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (secondary to MS-PS1-6)	8
MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*	8
ETS1.C: Optimizing the Design Solution • Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design. (secondary to MS-PS1-6) • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (secondary to MS-PS1-6)	8
MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*	8

*The Performance Expectations marked with an asterisk integrate traditional science content with engineering through a Practice and Disciplinary Core Idea.

NEXT GENERATION SCIENCE STANDARDS

Science and Engineering Practices/Performance Assessments	Activity
Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to predict and/or describe phenomena. (MS-PS1-1),(MS-PS1-4) • Develop a model to describe unobservable mechanisms. (MS-PS1-5)	1, 2, 3, 4, 6, 7, 8
MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.	1,2,6,7,8
MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.	2, 3
MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.	6, 8
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 6–8 builds on K–5 experiences and progresses to evaluating the merit and validity of ideas and methods. • Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-PS1-3)	3, 6, 7
MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.	7
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2)	1, 2, 3, 5, 6,7, 8
MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	6, 7, 8
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories. • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. (MS-PS1-6)	1, 2, 3, 4, 5, 6, 7, 8
MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*	8

*The Performance Expectations marked with an asterisk integrate traditional science content with engineering through a Practice and Disciplinary Core Idea.

NEXT GENERATION SCIENCE STANDARDS

Connections to Nature of Science	
Scientific Knowledge is Based on Empirical Evidence • Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2)	6, 7, 8
MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	6
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena • Laws are regularities or mathematical descriptions of natural phenomena. (MS-PS1-5)	6
MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.	6

Crosscutting Concepts/Performance Assessments	Activity
Cause and Effect • Cause-and-effect relationships may be used to predict phenomena in natural or designed systems.	2, 3, 5, 6, 7
MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.	2, 4
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. (MS-PS1-1)	1, 2, 6, 8
MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.	1, 2
Structure and Function • Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS1-3)	3, 7
MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.	7
Patterns • Macroscopic patterns are related to the nature of microscopic and atomic-level structure (MS-PS1-2)	3, 6, 8
MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	6

*The Performance Expectations marked with an asterisk integrate traditional science content with engineering through a Practice and Disciplinary Core Idea.

NEXT GENERATION SCIENCE STANDARDS

Energy and Matter • Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5) • The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS1-6)	2, 5, 6, 7, 8
MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.	6
MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*	8
Connections to Engineering Technology and Applications of Science	
Interdependence of Science, Engineering, and Technology • Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-PS1-3)	7
MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.	7
Influence of Science, Engineering, and Technology on Society and the Natural World • The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology varies from region to region and over time. (MS-PS1-3)	7
MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.	7

*The Performance Expectations marked with an asterisk integrate traditional science content with engineering through a Practice and Disciplinary Core Idea.

UNIT AT A GLANCE

Activity	Time to Complete	Questions	Phenomena	Summary: Students Will…
1 **Developing a Kinetic Particle Model**	Preparation: 20 minutes Activity: 4 classes Lesson 1A: 55–60 min., 2 classes Lesson 1B: 55–60 min. Lesson 1C: 55–60 min.	What are odors? How does an odor travel through material?	**"Something Stinks in Here" phenomenon.** **Vanilla odor detected through a balloon.**	• Make observations of vanilla extract odor that travels through the walls of a balloon. • Make observations to determine that there is space between the particles of matter. • Make observations of what happens when two equal parts of water are combined. • Make observations of what happens when two equal parts of water and ethanol are combined. • Collect and analyze data when mixing different solids with water.
2 **Heating Things Up!**	Preparation: 15 minutes Activity: 4 classes Lesson 2A: 55–60 min. Lesson 2B: 55–60 min. Lesson 2C: 55–60 min., 2 classes	What are the particles that make up water? What happens when thermal energy is added or removed from water? How does shaking the balloon affect the strength of the odor detected through the balloon?	**The odor of the vanilla is stronger after shaking the balloon, but no liquid vanilla appears on the outside of the balloon.** **The liquid in a thermometer moves up the tube when thermal energy is applied and moves down the tube when thermal energy is taken away.**	• Investigate the behavior of food coloring in hot water and cold water. • Observe the behavior of a density rod in hot water and cold water. • Make observations of the liquid in a thermometer when thermal energy is applied and removed. • Collect data over time intervals of the temperature of icy water when thermal energy is added.
3 **Density Matters**	Preparation: 20 minutes Activity: 6 classes Lesson 3A: 55–60 min., 2 classes Lesson 3B: 55–60 min., 2 classes Lesson 3C: 55–60 min. Lesson 3D: 55–60 min.	How is density determined? How is density used to identify different substances? How are sinking and floating related to our ideas about particles that make up matter? Why does ice float? How does a hot air balloon lift off and float?	**A can of Coke sinks and a can of Diet Coke floats.** **Ice floating in water.** **An iceberg floating and flipping.**	• Make observations and collect data on sink and float objects. • Use an interactive simulation to explore the density of different materials. • Measure the volume and mass of a variety of objects. • Gather information from a simulation that explains why ice floats.

Students Figure Out How to:	Practices/Crosscutting	PE at Lesson Level and Assessment
• Develop a model to explain how the odor of the stinky socks filled the room. • Develop a model to explain how they can detect the odor of vanilla through the balloon. • Use observations and data to determine that there is space between the particles that make up matter. • Recognize patterns in data to develop a kinetic particle model that can be applied to future explanations of the behavior of matter. • Engage in productive Science Talk.	**Constructing Explanations and Designing Solutions** **Asking Questions and Defining Problems** **Developing and Using Models** **Analyzing and Interpreting Data** **Planning and Carrying Out Investigations** **Scale, Proportion, and Quantity**	**PE at Lesson Level** Explore the behavior of matter to develop a particle model that can be applied in explaining how an odor is detected through material. Plan and carry out investigations into the effect of mixing liquids and mixing liquids and solids. **Formative Assessment** Activity Pages initial models revisions to models Science Talk **Summative Assessment** Activity Pages final models
• Use evidence and information from investigations into the behavior of liquids and apply their thinking to gases. • Use evidence to determine that hot water is less dense than cold water. • Explain how a thermometer works based on their understanding of how thermal energy affects the motion of particles of matter. • Develop a model that explains why the shaking of the balloon increased the vanilla odor detected on the outside of the balloon. • Graph their data of the icy water. • Analyze and interpret their data from the icy water investigation.	**Asking Questions and Defining Problems** **Constructing Explanations and Designing Solutions** **Analyzing and Interpreting Data** **Developing and Using Models** **Cause and Effect** **Scale, Proportion, and Quantity** **Energy and Matter**	**PE at Lesson Level** Plan and carry out investigations into the effect of adding thermal energy to liquids. **Formative Assessment** Activity Pages Science Talk **Summative Assessment** Journal Entries final models consensus model
• Develop a model that explains why the Coke can sank and the Diet Coke can floated. • Use evidence and information from the interactive simulation to make revisions to their models. • Use measurement to calculate density. • Make connections between the density of objects and the effect of thermal energy on the behavior of particles. • Develop a model to explain why ice floats.	**Asking Questions and Defining Problems** **Developing and Using Models** **Using Mathematics and Computational Thinking** **Analyzing and Interpreting Data** **Constructing Explanations and Designing Solutions** **Obtaining, Evaluating, and Communicating Information** **Cause and Effect** **Structure and Function** **Patterns**	**PE at Lesson Level** Use data and computations to determine the density of material and how thermal energy affects density. **Formative Assessment** Activity Pages Science Talk class chart **Summative Assessment** Activity Pages Journal Entry final models Science Talk

UNIT AT A GLANCE

Activity	Time to Complete	Question	Phenomena	Students Will…
4 Layering Liquids - Density Challenge	Preparation: 15 minutes Activity: 4 classes Lesson 4A: 55–60 min., 2 classes Lesson 4B: 55–60 min., 2 classes	Why does oil float on water?	**When you shake the bottle of Italian salad dressing, the liquids layer in the bottle.**	• Investigate the layering of different liquids. • Determine the density of liquids and layer from greatest to least dense. • Investigate the viscosity of liquids compared to the density of liquids.
5 What About Gases?	Preparation: 20 minutes Activity: 3 classes Lesson 5A: 55–60 min., 2 classes Lesson 5B: 55–60 min.	How does the density of air change when thermal energy is applied and removed? What makes a helium balloon float?	**Flight of a hot air balloon.**	• Make observations of a hot air balloon taking off and in flight. • Investigate the effect of adding thermal energy and removing thermal energy to a soap bubble. • Make observations of a helium balloon. • Collect data that provide evidence of the effect of adding and taking away thermal energy. • Collect data to determine how much weight a helium balloon can carry.
6 Combustion of Gasoline	Preparation: 15 minutes Activity: 8-10 classes Lesson 6A: 55–60 min., 2 classes Lesson 6B: 55–60 min., 2 classes Lesson 6C: 55–60 min., 2–3 classes Lesson 6D: 55–60 min., 2–3 classes Lesson 6E: 55–60 min.	What happens to gasoline when it is burned? What happens when substances combine to form new substances?	**Scenario of filling up the family car with gasoline once a week.**	• Collaborate to develop a model of what happens to the gasoline in a car. • Make observations of a candle burning without and with a jar placed on top. • Use Universal Indicator to determine if CO_2 is a product of a candle burning. • Make observations of the oxidation of steel wool. • Obtain information about chemical change through text. • Collect data on temperature change during a chemical reaction.

UNIT AT A GLANCE

Students Figure Out How to:	Practices/Crosscutting	PE at Lesson Level and Assessment
• Develop a model to explain why the liquids in Italian salad dressing layer in the bottle and do not mix. • Apply understanding of density to layering of liquids. • Measure the mass and volume of liquids to calculate density. • Write a scientific explanation for the liquid layers using claim, evidence, and reasoning.	**Developing and Using Models** **Planning and Carrying Out Investigations** **Analyzing and Interpreting Data** **Constructing Explanations and Designing Solutions** **Patterns**	**PE at Lesson Level** Obtain information through investigation and analyzing and interpreting data about the effect of the density of liquids and how they layer in a bottle. **Formative Assessment** initial models Science Talk **Summative Assessment** Journal Entry Activity Pages Science Talk final models
• Develop a model of how a hot air balloon takes off and floats in the air. • Carry out an investigation to find out the effect of adding and taking away thermal energy on air in a system. • Use information from their investigations to revise models and develop explanations. • Use reasoning from their understanding of density and the effect of thermal energy to explain the hot air balloon. • Use mathematics to solve a problem.	**Developing and Using Models** **Asking Questions and Defining Problems** **Planning and Carrying Out Investigations** **Using Mathematics and Computational Thinking** **Analyzing and Interpreting Data** **Constructing Explanations and Designing Solutions** **Cause and Effect** **Energy and Matter** **Systems and System Models**	**PE at Lesson Level** Use their understanding of the effect of thermal energy on matter and density of matter to explain the hot air balloon and helium balloon. **Summative Assessment** Activity Page Science Talk Journal Entry models
• Identify the reactants in a burning candle. • Identify the products in a burning candle. • Develop a scientific explanation for the reactants and products of a burning candle using claim, evidence, and reasoning. • Using the chemical formula for the wax candle, write an equation that demonstrates the reactants and products. • Plan and carry out an investigation into the burning of a substance that is mainly made of carbon, oxygen, and hydrogen. • Provide evidence of a chemical change. • Determine when a reaction is exothermic or endothermic.	**Developing and Using Models** **Asking Questions and Defining Problems** **Constructing Explanations and Designing Solutions** **Engaging in Argument From Evidence** **Using Mathematics and Computational Thinking** **Analyzing and Interpreting Data** **Planning and Carrying Out Investigations** **Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** **Obtaining, Evaluating, and Communicating Information** **Energy and Matter** **Cause and Effect** **Scale, Proportion, and Quantity**	**PE at Lesson Level** Determine the reactants and products when a hydrocarbon burns. Determine when a reaction is exothermic or endothermic. **Formative Assessment** Activity Pages Science Talk Journal Entry **Summative Assessment** Activity Pages Journal Entries Science Talk model card activity revised models group charts class particles of matter statement

Activity	Time to Complete	Question	Phenomena	Students Will…
7 Synthetic Fuels	Preparation: 15 minutes Activity: 6–8 classes Lesson 7A: 55–60 min., 2–3 classes Lesson 7B: 55–60 min., 2–3 classes Lesson 7C: 55–60 min. Lesson 7D: 55–60 min.	How is E-85 fuel different from regular gasoline? What other types of fuel can be used in a car? What are the alternative fuels and how are they made?	**Some fuel pumps offer choices of E fuels and some fuel pumps offer regular and super gasoline.** **Bread dough rising.**	• Make observations of pictures of the different options on fuel pumps. • Read an article about e-diesel fuel made from water and air. • Research to answer their questions about synthetic and natural fuels. • Make observations of how ethanol is made from sugar. • Engage in argument about renewable and nonrenewable resources. • Investigate how to make ethanol and CO_2 from cereal and water.
8 Energy Change during a Chemical Reaction	Preparation: 20 minutes Activity: 3 classes Lesson 8A: 55–60 min., 2 classes Lesson 8B: 55–60 min.	Why do we use gasoline as fuel? How can we develop a model that demonstrates when energy is released or absorbed?	**Observation of temperature change in a chemical reaction.** **Engineering Challenge: Develop a device that can be placed in a fish tank to transport clown fish at 22°–26°C for 20 minutes.**	• Make observations of videos of chemical reactions that release a substantial amount of thermal energy. • Carry out investigations into temperature change in two different reactions. • Collect data on temperature change in two different reactions. • Carry out investigations into changing the variables to produce a greater change in temperature.

Students Figure Out How to:	Practices/Crosscutting	PE at Lesson Level and Assessment
• Raise questions about the different options of e-fuels and regular fuels. • Obtain information from text about e-diesel and synthetic fuels. • Classify fuels as synthetic and natural. • Present their research findings. • Determine the benefits and pitfalls of synthetic and natural fuels. • Analyze the reaction between sugar and water to make ethanol. • Plan and carry out an investigation to find out which cereal will produce the most CO_2 and ethanol. • Use evidence and reasoning to make a claim.	**Asking Questions and Defining Problems** **Obtaining, Evaluating, and Communicating Information** **Constructing Explanations and Designing Solutions** **Developing and Using Models** **Scientific Knowledge is Based on Empirical Evidence** **Engage in Argument from Evidence** **Planning and Carrying Out Investigations** **Analyzing and Interpreting Data** **Energy and Matter** **Interdependence of Science, Engineering, and Technology** **Influence of Science, Engineering, and Technology on Society and the Natural World** **Cause and Effect** **Scale, Proportion, and Quantity**	**PE at Lesson Level** Obtain information through investigation and text to identify synthetic fuels and natural fuels. **Formative Assessment** Activity Page Science Talk **Summative Assessment** Journal Entries Activity Pages Science Talk initial and final models group presentations
• Draw a model of what happened during the two different reactions. • Develop an understanding of the terms *endothermic* and *exothermic*. • Revise models based on new information. • Develop a model that explains how endothermic and exothermic reactions occur. • Develop a device that can be placed in a fish tank to transport clown fish at 22°–26°C for 20 minutes. • Analyze and interpret data to solve a problem.	**Developing and Using Models** **Scientific Knowledge Is Based On Empirical Evidence** **Planning and Carrying Out Investigations** **Constructing Explanations and Designing Solutions** **Engage in Argument from Evidence** **Analyzing and Interpreting Data** **Energy and Matter** **Scale, Proportion, and Quantity** **Patterns**	**PE at Lesson Level** Use information from investigations into temperature change during a chemical reaction to solve a problem. Construct, test, and modify a device that releases thermal energy by chemical processes. **Summative Assessment** Activity Pages Science Talk Journal Entry models heating devices presentations

Developing a Kinetic Particle Model

Teacher Background
In this series of activities, students will encounter various phenomena and use what they observe to produce a theory of matter on a particle level that they can use and apply throughout the lessons. Information is given on this theory in the Teacher Background Information on page 2.

In the fifth-grade unit *Structure and Properties of Matter*, students began to develop the concept that matter was made up of particles too small to see. They explored the properties of solids, liquids, and gases and phase change due to thermal energy. The conservation of matter during a phase change was also introduced in the fifth-grade unit.

Engage the learner
During the initial phase of learning, students are introduced to a phenomenon to raise questions and develop an initial model to explain what they think is happening in the phenomenon. The class will develop the driving questions that will guide further exploration.

Lesson 1A: Observations of Vanilla in a Balloon

Advance Preparation
Prepare a space for a What We Think chart that includes the driving question and an activity summary table. Plan to have the chart visible throughout the activities that relate to the "Something Stinks in Here" phenomenon.

Example What We Think chart

What We Think	What Questions Do We Have and How Can We Find Out?	What We Did	What We Found Out	How Does This Help Us to Figure Out the Phenomenon?
Student initial ideas about odors and gases.	Student initial questions about odors and gases. Develop the driving questions.	Lesson 1A: Made observations of the vanilla odor through the balloon. Developed an initial model of the phenomenon.	The odor of the balloon is stronger after you shake the balloon and distribute the vanilla throughout the balloon.	

Set up a materials table with eight balloons, vanilla extract, and a pipette. Do not prepare the vanilla balloons until you are ready to distribute them to the groups.

ESTIMATED TIME
Lesson 1A: 55–60 minutes, 2 classes
Lesson 1B: 55–60 minutes
Lesson 1C: 55–60 minutes

OBJECTIVE
Make observations and carry out investigations to find out how matter behaves and to develop a model of matter on a particle level.

KEY QUESTIONS
What are odors?

How does an odor travel through material?

PRE ASSESSMENT
- Give the Pre Assessment to assess the students' prior knowledge of the topics included in this unit.
- Additional time may be necessary beyond the estimated lesson time.
- This same assessment will be given at the end of the unit so the students' Pre and Post Assessment responses can be compared.
- Be consistent in administering the Pre and Post Assessment.
- The assessment and rubric are located in the Assessment section of the unit.

SAFETY TIP
This activity includes materials (chemicals) that require the inclusion of a Material Safety Data Sheet (MSDS). Please refer to Section 5: MSDS of your Teacher Guide for handling and guidelines of the chemicals in this activity.

LESSON 1A

MATERIALS NEEDED

For each student:

student pages

For each group of 4:

1 balloon with vanilla extract, inflated and tied

Something Stinks Here! *Card Set*

For the class:

8 balloons

2 pipettes

vanilla extract, 1 bottle

Teacher supplies:

chart paper

markers

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.
- 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.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

Procedure

Engage the learner.

Real-world phenomenon: *Something Stinks in Here!* Divide the class into groups of four students. Distribute the cartoon strip *Something Stinks in Here!*

In their groups of four, ask the students to discuss the phenomenon in the story. Ask students to explain to one another their ideas of how the odor from the stinky socks was able to travel and be detected in LaDonna's bedroom. Facilitate the group discussion by circulating among the students and listening to their initial ideas. To help students elaborate on their explanations and make connections with previous knowledge, ask:

- How does this relate to when you smell cookies baking in the oven? What about perfume or cologne from across the room?
- What do you know about odors that might help you figure out the "Something Stinks in Here" phenomenon?
- What questions do you have about odors that you might investigate?
- Why do you think that?
- How do you know?
- What do you mean when you say…?
- Tell me more about….
- How might you confirm or find out?

Have the students draw their initial ideas as a model of what is happening in the Student Journal.

1. *Use the space below to draw a model to explain where you think the odor is coming from and how it spread throughout the room.*

2. *Write your initial ideas and questions about the "Something Stinks in Here" phenomenon.*

After the groups have collaborated and developed a model in their Student Journals, distribute chart paper or whiteboards and markers and have them make their thinking visible. Allow sufficient time for each group to post their initial models and review the models of others. Remind students that they will come back and revisit their models in following lessons.

After they have had an opportunity to discuss their ideas about the stinky problem and develop and review their models, conduct a whole-class discussion. Turn the class attention to the What We Think column of the class chart. Ask students to share their ideas of how they think the odor of the stinky socks traveled throughout the room. Record their initial ideas on the chart. Remind students that there are no right or wrong answers at this point in their learning. From their initial ideas, have students develop questions they have about odors and how odors travel.Ask students for ideas of how they can find out the answer to their questions and record them on the chart. Encourage students to think of investigations they might be able to conduct that will give them evidence to support or refute their initial thinking.

Divide the class into their groups of four students and ask them to make observations of the balloon with vanilla extract.

Put a few drops of vanilla extract into one balloon for each group. Blow up the balloons and tie them off. Distribute one balloon to each group. Ask students to smell the air surrounding the balloon without putting their noses on the balloon itself. Then have students shake the balloon and smell again.

Allow sufficient time for all students in each group to make observations of the odor that surrounds the balloon. Encourage individual students to use the Student Journal to record their initial ideas.

1. *Develop and label a model that explains how the odor of the vanilla is detected on the outside of the balloon. Include in your model a representation before shaking the balloon and after shaking the balloon.*
2. *Write questions you have about the observation of the odor through the balloon.*
3. *Write how you think the vanilla in the balloon is similar to the "Something Stinks in Here" phenomenon.*

Facilitate group observations by circulating among the students and listening to their exchange of ideas. To help students make connections and draw on experiences, ask:

- Has anyone smelled popcorn from another room? What about cookies baking or strong perfume? How does detecting those odors relate to smelling the odor through the balloon?
- How is it similar? How is it different?
- Is there any liquid vanilla on the outside of the balloon? Then how can we smell the vanilla?
- Why can't I smell perfume when it is in a capped bottle?
- What do you think would happen if we used a mylar balloon?
- Can anyone explain the phenomenon of the odor through the balloon? Can you draw your ideas in the Student Journal?
- What do you mean when you say…?
- Tell me more about….
- What do you think will happen if we leave the balloon overnight or for several days? Will we still smell the vanilla? Why or why not?

After students have had sufficient time to develop their own models and collaborate within their groups, have the class come together and develop the driving questions that they have about the phenomenon. To help the students collectively raise questions about their observations, ask:

- What question or questions are we trying to answer about the vanilla in the balloon?
- What do you think about what ___________ said?
- Do the rest of you agree? Why or why not?
- Does anyone have a different question about the phenomenon?

TEACHING TIP

Take this opportunity to check for student understanding that matter is made up of particles too small to be seen from their fifth-grade unit *Structures and Properties of Matter*. Students should have developed an understanding that all matter is made of tiny particles, including gases.

DEVELOPING AND USING MODELS

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop a model to predict and/or describe phenomena.
- Develop a model to describe unobservable mechanisms.

TEACHING TIP

Take this opportunity to conduct an investigation into what will happen if the balloon is left overnight or for several days.

ASKING QUESTIONS AND DEFINING PROBLEMS

Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.

- Ask questions
  - that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
  - to clarify and/or refine a model, an explanation, or an engineering problem.

TEACHING TIP
Resist the temptation to conduct a mini-lecture or explain to the students what is actually going on in the phenomenon. In following lessons students will be given additional examples of how particles of matter behave to help explain the phenomenon.

DEVELOPING AND USING MODELS
Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
- Develop a model to predict and/or describe phenomena.
- Develop a model to describe unobservable mechanisms.

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.

Have students refer to their questions and models in the Student Journal to help add questions to the What We Think chart. Ask students to think of "what would happen if" questions and change a variable in the phenomenon. Look for questions that relate to:

How does the odor move through the solid barrier of the balloon?
What is the odor made of?
How can we smell the vanilla through the balloon?
Will other odors behave the same way as the vanilla?
What would happen if we added a solid that has an odor? (peppermint candy)
Does the substance in the balloon have to be a liquid to smell the odor through the balloon?
Would we still smell the vanilla if the balloon was only slightly inflated or not inflated?
Why is the smell of vanilla stronger after I shake the balloon?

Refer to the three final columns on the What We Think chart (What We Did, What We Found Out, and How Does This Help Us to Figure Out the Phenomenon?). Explain that as the class moves through the unit, the chart will serve as a record of what they did and what they found out to help them answer their questions about the phenomenon.

Have the students return to their groups. Distribute chart paper and markers or whiteboards to each group and ask them to collaborate to develop a model that explains the vanilla odor through the balloon. Explain that each group will be given the opportunity to share their ideas with the rest of the class. Encourage students to refer to their initial models in their Student Journal. Facilitate the development of the models by circulating among the groups, observing their progress and listening to their ideas. To check for understanding of particles that make up matter, ask:

- What are the different substances that you will represent in your model?
- How are you representing the balloon? Air? Vanilla?
- What do you already know about matter that will help you explain the vanilla odor and develop your model?
- Is anything moving in your model? How will you show that?
- What do you mean when you say…?
- Tell me more about the walls of the balloon. What makes you think that?
- How will you represent why there is an increase in the odor when we shake the balloon? Where did the odor come from? Can you show that in your model?

Allow sufficient time for groups to complete their models. Check for models that represent the vanilla liquid, vanilla gas (odor), and balloon as matter that is made up of tiny particles. Students may represent the particles as dots or circles. They may also choose to use different colors to represent the walls of the balloon, air, and vanilla. Check for ideas that there is space between the particles that make up matter, which can help to explain how the odor is detected through the balloon.

Science Talk
Invite students to come together with their models and form a circle to explain their models and share their ideas. Encourage lively discussion and questioning about their initial ideas. To start the sharing of ideas, ask students to briefly take a look at each of the models and look for some common features in the majority of models. Ask a group to volunteer to share their thinking on the model. Encourage groups to exchange ideas and share their reasoning with one another. Ask students in each group to explain how they represented the walls of the balloon, air in the balloon, liquid vanilla, and vanilla gas (odor).

Ask if the sharing of ideas has given groups ideas for revisions, additions, or adjustments to their models. Allow time for students to make any adjustments and have them save their models to revisit at another time.

Inform the class that the following lessons will provide further information and evidence about the behavior of matter and students will be given the opportunity to revise the models as they gather more information.

Revisit the Questions We Have column of the What We Think chart with the collection of student questions and post the driving question:

What are odors and how do they travel through different materials?

Assessment: Formative
Use the initial models and Science Talk to assess the students' initial thinking about what matter is made of and how particles of matter behave.

SCIENCE TALK
Science Talk is a conversation among the students that allows them to have the opportunity to orally express their ideas and listen to the ideas of others. Allow sufficient time for each student to express ideas and opinions. Create a classroom culture where all ideas are respected and considered.

Lesson 1B: Observations of How Matter Behaves

Teacher Background
In the previous lesson, students made observations and raised questions about the vanilla odor that could be detected through the balloon. The phenomenon of the balloon and vanilla is designed to make students wonder about the structure of matter and the tiny particles that make up matter. They begin to wonder if there are spaces between the particles.

To provide further evidence of space between molecules, students combine two different liquids, water and ethanol. Students measure 50 mL of ethanol and 50 mL of water and predict what the combined mixture will measure. Then they combine the water and ethanol and measure the result. It's about 47 to 48 mL total. Students wonder what happened to the 2 to 3 mL of liquid.

Explore the Concept
During this phase of their learning, students explore a variety of investigations that provide evidence about the structure of matter, that matter is made of particles too small to see, and that there are spaces between the particles.

Advance Preparation
Display the class What We Think chart from the previous lesson.

Prepare 8 squeeze bottles with 27-28 mL ethanol (students will measure 25 mL of the ethanol).

For the water and ethanol investigation, each group will need one 100 mL graduated cylinder, two 25 mL graduated cylinders, 2 pipettes, 1 squeeze bottle with 27-28 mL ethanol, and one beaker with approximately 100 mL distilled water (students will measure 25 mL water from the beaker three times).

Fill a gallon bucket 1/2 full of water. At the conclusion of the ethanol/water investigation, have students empty the graduated cylinder into the bucket of water and discard down the sink.

Preview the water and ethanol simulation:

https://lab.concord.org/embeddable.html#interactives/interactions/Mixing-polar-nonpolar-particle.json

Write the following headings at the top of four pieces of chart paper:

1. Asking Clarifying Questions
2. Asking a Probing Question
3. Adding to an Idea
4. Respectfully Disagreeing with an Idea

MATERIALS NEEDED

For each student:
- student pages
- goggles

For each group of 4:
- Squeeze bottle,28 mL ethanol
- Beaker, 100 mL distilled water
- 100 mL graduated cylinder, 1
- 25 mL graduated cylinder, 2
- Pipettes, 2
- Stir rod, 1

For the class:
- 8 oz. deli containers, 2
- 16 oz. deli container, 1
- sand, 1 cup
- marbles, 1 cup
- graduated cylinders, 2

Teacher provides:
- paper towel
- distilled water
- chart paper and markers
- goggles
- bucket of water

TEACHING TIP
When assembling the graduated cylinders to their bases, be sure the cylinders are level and secure in their bases.

Groups will need a little more than the 75 mL of water and 25 mL of ethanol because not all the liquid will transfer from the containers to the graduated cylinder.

TEACHING TIP
This unit calls for the use of safety goggles, the periodic table of the elements, and precision balances. These items are NOT included in the unit as most middle school classrooms are equipped with these items. If you do not have safety goggles, a periodic table, or precision balances, they can be can be ordered through the Battle Creek Area Mathematics and Science Center, (269) 213–3904.

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.
- 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.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

TEACHING TIP

Take this opportunity to demonstrate how to measure liquids. Teach about the meniscus and to bring the bottom of the meniscus to the 25 mL mark or needed quantity in any investigation.

Accurate measurement is key in getting students to question why they get a slightly smaller volume when they mix the water and ethanol than when they mix water and water.

Procedure

Explore the concept.

Review the students' initial ideas about the balloon and vanilla from the previous lesson. Ask students if they have any additional thoughts or questions about the phenomenon at this time. Write any new ideas or questions on the What We Think chart. At this point in their explanations, students should have an understanding that all matter is made up of particles that are too small to see. Refer to ideas that describe the odors as a gas. Explain that because gases cannot be seen, the class will use liquids to gather further information about how particles behave and then apply their findings to gases.

Demonstrate how to accurately measure 25 mL of water into two 25ml graduated cylinders. Use the pipette to measure as accurately as possible. Hold up the two 25mL graduated cylinders, each with 25 mL water. Ask students what they think will happen when the two cylinders of water are combined and why they think that.

Explain that the class will carry out an investigation to find out what happens when the two graduated cylinders of water are combined and then what happens when two graduated cylinders, one with water and one with ethanol, are combined.

Divide the students into their groups of four and distribute goggles to each student and the investigation materials to each group. Allow time for the groups to practice measuring 25 mL of water into the 25mL graduated cylinders, and then combining to measure 50 mL. When you are satisfied with their measuring technique, have the groups follow the procedure in the Student Journal.

Combining equal amounts of water: What will happen if we combine 25 mL of water with 25 mL of water?

Note: To accurately measure 25 mL, use the small 25 mL graduated cylinder.

1. *Measure 25 mL of water into one 25 mL graduated cylinder*
2. *Measure 25 mL of water into the second 25 mL graduated cylinder*
3. *Predict how much liquid you will have when combined.*
4. *Combine the 25 mL graduated cylinders of water into the 100 mL graduated cylinder.*
5. *Record your results.*

Combining equal amounts of water and ethanol. What will happen if we combine 25 mL of water with 25 mL of ethanol?

1. *Measure 25 mL of water into one 25 mL graduated cylinder.*
2. *Measure 25 mL of ethanol into the second 25 mL graduated cylinder.*
3. *Predict how much liquid you will have when combined.*
4. *Combine the 25 mL graduated cylinders of water and ethanol into the 100 mL graduated cylinder and stir.*
5. *Record your results.*

Discussion Questions:

1. *Was the quantity of combined liquids what you predicted?*
2. *Why do you think the results are different when combining equal amounts of water and equal amounts of water and ethanol?*
3. *What do you think happened to the missing liquid?*
4. *What do your results tell you about the amount of space between the particles of matter in a liquid?*
5. *Draw a model of what is happening when the water and ethanol are combined.*

Facilitate the group investigation by circulating among the students, observing their results and listening to their reasoning. To help students reason scientifically, ask:

- What did you predict would happen when the two liquids were combined? What makes you think that? Does that make sense?
- What do you think is happening? What happened to the rest of the liquid?

Science Talk
Explain the concept and define the terms.
After the groups have completed the combining ethanol and water experiment, ask them to share their data and models of what they think is going on. Record their ideas on the What We Think chart. Listen for ideas that find commonalities among their investigations and models. Students may begin to suggest or wonder about the particles that make up matter and how they behave. Listen for ideas that all matter is made up of particles and that the particles have spaces in between. Check for a reference to spaces in between the particles that make up the gases and the balloon.

Discuss how the investigations gave them evidence that there is something different about the structure of the ethanol and the structure of water. Conduct a teacher demonstration using the marbles and sand. Explain that the two 8 oz. deli containers are equal in volume to the one 16 oz. deli container. Show the students an 8 oz. deli container filled to the top (1 cup) with marbles and another 8 oz. deli container with sand filled to the top (1 cup). Ask students if adding the sand will give them a mixture of sand and marbles that measures 16 oz. or 2 cups. Why or why not?

Pour the sand into the marbles and ask a student to read the combined volume. Ask why the sand did not fill the container to the top or 2 cups. Listen for an explanation that there are spaces between the marbles that are filled by the sand and therefore the volume of the mixture is nonadditive. Ask students to relate the sand and the marbles to the water and ethanol. Listen for ideas that the loss of volume can be explained if water and ethanol are actually made of a collection of particles that may vary in size, but are too small to be seen.

DEVELOPING AND USING MODELS

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop a model to predict and/or describe phenomena.
- Develop a model to describe unobservable mechanisms.

TEACHING TIP

Compare the mixing of the water and ethanol to a truck driver who had to get a load of watermelons and a load of ping-pong balls to the same destination. The driver decides they will all fit if he just puts the ping-pong balls into the truck to fit between the watermelon spaces. At this grade level, students are not expected to understand the electrical interactions among the molecules that are an important part of the explanation. The attraction among molecules will come at a later grade.

ANALYZING AND INTERPRETING DATA

Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Analyze and interpret data to determine similarities and differences in findings.

TEACHING TIP
Some students may be using the terms *atoms* and *molecules* when they describe what they think is happening. Ask them to describe what they mean by atoms and molecules. Do not try to define the terms at this time. Allow time for all students to express their initial ideas about atoms and molecules. Explain that as the unit progresses, they will have the opportunity to look deeper into the behavior of atoms and molecules (the particles that make up matter).

Elaborate on the concept.
Take this opportunity to have students interact with a simulation model of what is happening to the particles that make up water and ethanol. Allow sufficient time for students to compare their investigation results to the simulator.

https://lab.concord.org/embeddable.html#interactives/interactions/Mixing-polar-nonpolar-particle.json

Evaluate the students' understanding of the concept.
Ask students to relate the ethanol and water to the vanilla in the balloon phenomena. Listen for student ideas that consider space between the particles that make up matter as solids, liquids, and gases.

Return to the What We Think chart and record what the class did, what they found out, and how the new information helps them to figure out the phenomenon. Allow sufficient time for students to return to their initial models of the balloon and vanilla and make adjustments based on their new information. Allow time for students to share their revisions and critique the balloon and vanilla models of others.

In order to conduct a friendly, nonthreatening critique, ask the class to establish some guidelines and rules for their critiquing methods. Ask students to create four anchor posters that will guide the class throughout the unit. Display the four charts with the questioning and critiquing categories (see p. 45 - Advanced Preparation). As a class, have students suggest how they might start a question that asks a group to clarify, probe or dig deeper, disagree with, and add to an idea.

Example charts:

Respectfully Disagreeing With an Idea

- I agree with… but…
- I disagree with… because…
- I agree with part of your model but disagree with this part…
- I respectfully disagree because…
- I understand where you are coming from, but I have a different idea.
- I agree with you but also think…
- I see your reasoning, but I disagree with some of the ideas because…

Asking a Clarifying Question

- What do you mean by…?
- Can you be more specific about…?
- What makes you think that?
- What evidence do you have that supports that?
- How do you know?
- Can you tell us more about…?
- What do you mean by…?

Asking a Probing Question

- What do you mean by…?
- What makes you think that?
- If that were true, then wouldn't __________ be true?
- Where did you get this idea?
- How did you come up with…?

Adding to an Idea

- I agree with you, but also…
- I would like to add…
- I agree but also think…
- I agree with this part, but could you add…?
- Do you think adding ______ would make it more clear?
- I agree but have an idea that might add more clarity or information.
- Would it make it more clear if you added…?

After the class has completed their questioning anchor guidelines, do a whole-class gallery walk and invite each group to explain their models and the thinking behind their models. Encourage students to ask questions of one another and make suggestions. If groups are hesitant to ask questions or make suggestions, begin the conversation by asking:

- Can you tell us more about this representation in your model?
- Do the rest of you agree? Why or why not?
- How is this model different from or similar to the previous model we reviewed?
- What information from this model might you use to improve your own model?
- Does the model provide further information that might help explain the "Something Stinks in Here" phenomenon?
- What ideas will you add to your initial model?
- How did combining ethanol and water give us information about the behavior of matter?

At the conclusion of the Science Talk, ask the class what more they need to know about matter, the particles that make up matter, and how they behave to help them to better explain the stinky socks and balloon and vanilla phenomena. Write their ideas on the What We Think chart. Explain that in the following lessons, the class will be exploring motion of particles in a variety of investigations that will give them more information for their models to help explain the phenomena. Discuss how the mixing of the liquids relates to the odor in the phenomenon. What is mixing in the room? What is mixing with the vanilla odor through the balloon? What ties the ideas together? Listen for ideas that relate to:

- Matter as a solid, liquid, or gas is made of tiny particles too small to see.
- The particles of matter as a solid, liquid, or gas have space between them.

CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Analyze and interpret data to determine similarities and differences in findings.
- Construct an explanation that includes qualitative and quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
- Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.

Assessment: Formative
Use the Activity Pages and revisions to models to assess the students' understanding that matter is made up of particles and the space between particles has an effect on the behavior of matter.

Use the Activity Pages and models to assess the students' initial ability to develop a model to explain a phenomenon.

Lesson 1C: Making Mixtures Using Solids and Water

Teacher Background Information
This lesson is a follow-up on the previous lesson where students observed what happened when ethanol and water were mixed. The previous lessons provided some evidence that there is space between the particles of a liquid. In this lesson, students explore the physical mixing of different solid substances in water, resulting in the formation of a solution or a suspension, and develop models to explain their results.

Advance Preparation

Prepare a materials table with 32 test tubes, 8 test tube holders, 8 soufflé cups with 1 tsp. kosher salt, 8 soufflé cups with 1 tsp. cornstarch, 8 soufflé cups with 1 tsp. drink mix, 8 soufflé cups with 1 tsp. sodium polyacrylate, 8 25ml graduated cylinders, 8 hand lenses, 8 stirring rods, 32 smart spatulas, goggles, and beaker of distilled water. Label the soufflé cups to identify the material in each cup.

Do a Google search and review a video of pouring a soda into a glass. Preview a site that shows how beverages become carbonated. Examples:
https://www.livescience.com/32492-why-does-soda-fizz.html
https://wonderopolis.org/wonder/why-are-some-drinks-bubbly

Conduct a Google search using the terms "video of pouring soda into a glass." Look for pictures of beverages to be projected (cola, lemon-lime soda, lemonade, iced tea, Kool-Aid, etc.)

Prepare a Class Data Table:

Name of substance added to water	Description of the mixture formed after shaking for one minute	Description of the mixture undisturbed for five minutes
Kosher salt		
Cornstarch		
Drink mix		
Sodium polyacrylate		

Procedure
Elaborate on the concept.
Review the previous lesson and what happened when they combined two different liquids and new ideas gained from combining the water and the ethanol. Discuss how the discovery that there is space between the particles and that particles are different sizes helps to explain the stinky socks and vanilla in balloon phenomena. Ask students for their ideas of what happens when they combine some solids with liquids. Ask students if they have ever made Kool-Aid or added flavoring to their water. Discuss what happens to the solid they are adding to the water.

MATERIALS NEEDED

For each student:
- student pages
- goggles

For each group of 4:
- test tube holder
- 25x150 cm test tubes, 4
- Smart spatulas, 4
- cornstarch, 1 tsp.
- kosher salt, 1 tsp.
- drink mix (such as unsweetened Kool-Aid), 1 tsp.
- sodium polyacrylate, 1 tsp.
- stirring rods, 4
- graduated cylinder, 25 mL
- soufflé cups (with 1 tsp. of each substance students are testing), 4
- hand lens, 1
- distilled water, 150 mL
- beaker (for 150 mL of water)

For the class:
- 100 mL graduated cylinders, 4
- coffee filters, 4
- glass funnels, 4
- test tube brush
- measuring teaspoon, 1

Teacher provides:
- chart paper
- markers
- paper towel
- sticky notes
- distilled water
- goggles
- pictures of beverages (cola, lemon-lime soda, lemonade, iced tea, Kool-Aid),

TEACHING TIP
Sodium polyacrylate disposal: Do not dispose of the sodium polyacrylate down the drain. It is safe to dispose of it in the wastebasket or go outside and pour it into the soil. Hint: Use the kosher salt water to rinse the sodium polyacrylate out of the test tube.

TEACHING TIP
To ensure that all four substances are represented in models, you may want to assign a substance for modeling or, as you facilitate the group activity, encourage groups to choose one of the substances that is not yet being represented.

TEACHING TIP
You may need to remind students how to measure volume of liquids using a graduated cylinder. Students may also need a demonstration of how to use the spatulas to add the solids to the test tubes.

PLANNING AND CARRYING OUT INVESTIGATIONS
Planning and carrying out investigations in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.

- 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.
- 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.
- Evaluate the accuracy of various methods of collecting data.

Ask students to share their favorite beverages. Project different images of common beverages and ask students if they know how the different drinks are made. Ask students if they have ever used the “flavor shots” button when getting a soda at a restaurant or gas station. To help students raise questions and inspire ideas, show a video of pouring a soda into a glass. Allow time for students to share ideas and experiences with a partner or within a group and then share their ideas with the rest of the class.

Allow time for students to complete the entry in their Student Journals. Explain that they will be able to revisit their initial models at the end of the lesson.

Draw and label a model of a soda. Include the arrangement of the ingredients of the beverage in the can.

Write a list of questions you have about soda and how it is made.

After the students have had sufficient time to complete the Activity Page, divide the class into groups of four and have students share their questions about soda. Distribute sticky notes to each group and encourage them to develop at least three or four questions they have about soda and how it is made. Have the groups place their questions on the What Questions Do We Have section of the What We Think chart. When the groups have posted their questions, as a class, categorize similar questions. Categories may include: bubbles/fizz, color, flavor, ingredients.

Inform the class that they are going to conduct an investigation into how some substances mix together to try to answer some of their questions about how the sodas and other beverages are made. Explain that the class is looking for patterns in the behavior of particles that make up matter to understand how matter behaves and to further explain the "Something Stinks in Here" phenomenon. Review what they have already discovered in the mixing of water and ethanol and their evidence that there is space between particles or molecules.

As a class, review the Activity Pages in the Student Journal. Explain that each group will be investigating four different substances and how they behave when they are mixed with water. Each group should select only one of the substances for their models.

1. *Write the question you are investigating.*
2. *Write what you already know about mixing solids with water.*
3. *Write what you think you will find out:*
4. *List the materials you will use.*
5. *Draw and write how you will set up your investigation.*

6. Complete the chart to record your observations and data.

Name of substance added to water	*Description of the mixture formed after stirring for one minute*	*Description of the mixture undisturbed for five minutes.*
Kosher salt		
Cornstarch		
Drink mix		
Sodium polyacrylate		

7. Write what you found out.

Show the class the materials table. Instruct the class on how to use the small end of the Smart spatula and scoop a small amount of each solid to be combined with water. Each soufflé cup has 1 teaspoon of the solid, and students are to add only a small amount to the water. Remind students that they must clear their procedures with you before retrieving material.

Allow sufficient time for students to plan their investigations. Take time to review each plan to check for proper use of materials and procedures for mixing the solids in water in the test tubes. Check investigations to make sure they include:

1. amount of water in each test tube.
2. use of small amount of the solid.
3. use of the stirring rod to stir the mixture.
4. record of observations before, during, and after mixing.

After groups have presented a workable plan for their investigation, have one person from the group collect the necessary materials from the table. Distribute goggles to each student.

Facilitate the group investigations by circulating among the students, listening to their ideas and observing their data collection. To check student progress, ask:

- Can someone explain what you have done so far?
- When making a comparison among the substances, what variable do you need to keep the same? How much water are you putting in the test tubes? How much of each sample are you testing? Why is it important to keep these variables the same? How long are you stirring the solution? When do you know to stop stirring?
- What observations have you made so far of the four different solids?
- What differences have you observed? How do you think those differences might affect the way they mix with water?
- What do you predict will happen when they are mixed with water? Will they all mix the same? Why or why not?
- What do you mean when you say…?
- Tell me more about….
- Which substance has your group chosen to develop a model of what happens when the substance is mixed with water? What are you predicting? What makes you think that?

TEACHING TIP

Ask one or two groups to save their test tubes with the solutions and suspensions to use in the filtering demonstrations later in the lesson.

ANALYZING AND INTERPRETING DATA

Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Analyze and interpret data to determine similarities and differences in findings.

TEACHING TIP

As you facilitate the student investigations, check procedures and make sure students are stirring the solution until it is uniform in appearance.

TEACHING TIP

This unit calls for the use of safety goggles, the periodic table of the elements, and precision balances. These items are NOT included in the unit as most middle school classrooms are equipped with these items. If you do not have safety goggles, a periodic table, or precision balances, they can be ordered through Cereal City Science by Battle Creek Area Mathematics and Science Center, (269) 213–3904.

DEVELOPING AND USING MODELS

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop a model to predict and/or describe phenomena.
- Develop a model to describe unobservable mechanisms.

CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Analyze and interpret data to determine similarities and differences in findings.
- Construct an explanation that includes qualitative and quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
- Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.

After the groups have completed their observations of the solids and observations of mixing the solids with water, allow sufficient time for each group to analyze their data and develop their models of what they think is happening in one of the substances. Distribute chart paper and markers or whiteboards to each group and ask students to develop a model of what is happening to one of the substances to share with the rest of the class. Encourage groups to choose a substance and then check to make sure all mixtures are represented.

Science Talk

Ask the groups to bring the data collected from their investigations and their models and convene in a circle. Display the class data table and allow each group to record their results. Conduct a Science Talk among the groups that focuses on results in the data table and discuss the behavior of the particles or atoms and molecules. Ask the groups to look at the class collective data and look for patterns in the data or common outcomes. Review the anchor charts from the previous lesson and encourage groups to respond to discrepancies and commonalities in their data. Ask students if they were surprised or have questions about their results. If groups are hesitant to ask questions, make suggestions or comments. Begin the conversations by asking:

- Can someone explain the difference between mixing the cornstarch and the salt?
- Do the rest of you agree? Why or why not?
- What information can we conclude from our data?
- ______________, I heard you use the term *dissolved*. What do you mean by that? Which substances that you tested dissolved?
- Does anyone have a similar or different idea about dissolving?
- Can we apply what we have learned so far about the behavior of particles that make up matter to our data?

After the class has evaluated the collective data, ask each group to share their model of what is happening to produce their results. Ask students to compare what is happening between the different substances. Listen for students to use the term *dissolve* in their explanations and ask them to explain what it means when something dissolves in a liquid.

Elicit from students that a solution is formed as one substance, the solute (kosher salt and drink mix), dissolves in the solvent (water). The particles of the mixture are no longer visible in a solution. Solutions are clear and can have a color. They are never cloudy. Write the term *solution* on the board. Ask students if they created any solutions in their investigations and how they know when something is a solution.

Review the models of kosher salt and drink mix and check for understanding that in a solution the particles of one substance are distributed evenly between the particles of the other substance.

Review the models of the corn starch and sodium polyacrylate. Check that in the models that suspensions are formed in the presence of undissolved substances dispersed in the mixture.

Continue the Science Talk as you move toward developing a consensus model of a solution and a suspension. Ask students to compare their ideas with the previous lesson and mixing the water and ethanol and how that compares with mixing the solids with the water. As students express their ideas, draw their consensus model of the behavior of particles in a solution and a suspension.

Ask students what they think will happen if they try to filter each of the mixtures. Ask:

- Will we get the kosher salt, drink mix, sodium polyacrylate, or cornstarch back?
- What makes you think that?
- What about the soda?

Conduct a demonstration using the graduated cylinders, coffee filter, and glass funnel. Display the saved samples of the mixtures from the lesson. Ask students to gather around and observe the demonstration of the filtration process. Filter each substance through the coffee filter. Ask students to explain why the solution did not leave any matter behind and the suspension left matter on the filter paper.

Return to the consensus model and ask students if filtering the liquids in the test tubes helps them in representing what is happening with the particles that make up the water and the different solids.

Have students return to their groups of four and revisit their initial models of the soda. Ask them to discuss within their groups how their models have changed and develop an explanation of how substances behave in water. Facilitate the group discussion by circulating among the students and listening to their ideas. To help the students self-assess and evaluate their developing ideas, ask:

- Can someone explain what was revised on your new model showing how the components are distributed in a soda? What new evidence did you consider?
- Does your new model support the observations made and the claims generated as you conducted the investigations? Tell me more about….
- In what ways will your final model help someone understand the phenomenon of mixing substances in water?
- What limitations do you see in your final model? Are all the components of the mixture represented? How are you representing the particles that make up the components? How is that different from what is really happening?

After students have made comparisons of their initial and final models, check for how they made sense of the phenomenon of making solutions and if they are able to use evidence from their investigations to support their ideas. Check for the students' use of the terms *mixture*, *solution*, *dissolve*, and *solute*. Write the terms on the board or chart paper and take this opportunity to discuss the terms as a class and develop a definition for each term. After the class is satisfied with their definitions, have them write them in the Key Terms of the Student Journal.

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.
- 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.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

TEACHING TIP
If you teach more than one section of science, instruct the students to return their soufflé cups with chemicals to the materials table and to rinse their test tubes and return the holder, test tubes, spatulas, and beakers to the table. Have them dispose of the sodium polyacrylate and water in the trash or outside into the grass. All other test tube mixtures can be poured down the drain.

Return to the students' initial questions about sodas and beverages. Focus on their questions or ideas about the bubbles or carbonation in sodas. Ask students how they think the bubbles or fizz got in there and what are they made of. Allow time for students to research the carbonation of beverages using a couple of Internet sites. Encourage students to share their findings from their research. Discuss how they would classify a soda: a solution or a suspension?

https://www.livescience.com/32492-why-does-soda-fizz.html
https://wonderopolis.org/wonder/why-are-some-drinks-bubbly

Return to the class What We Think chart and record their activity and new understandings in the appropriate columns. Ask students if their new information about solutions and suspensions and the behavior of the solids and liquids when combined gave them ideas of how to explain the stinky socks and balloon and vanilla phenomena. Record student ideas about what makes up matter and how it behaves. At this point in their learning, students should recognize that:

- All matter is made up of small particles that are too small to be seen.
- In all states of matter (solids, liquids, and gases), the tiny particles that make up matter have spaces in between.
- Solids can combine with liquids to make solutions and suspensions.

Assessment
Use the Activity Pages and final models to assess the students' understanding of the behavior of the particles of different substances when combined.

ENGINEERING DESIGN PROCESS

The Engineering Design Process provides students with a series of steps to guide them as they solve problems and design and test products, models, and solutions. The process is cyclical, yet not necessarily in an order. Students are encouraged to evaluate as they progress through the process, revisit the mission often, and revise thinking and their plan multiple times as the process unfolds.

Engineers do not always follow the Engineering Design Process steps in order, one after another. It is very common to design something, test it, find a problem, and then go back to an earlier step to make a modification or change the design. Engineers must always keep in mind the mission or problem they are trying to solve and the limitations (cost, time, material, etc.) that are part of the solution to the problem. Two key elements in working as an engineer are teamwork and design-test-and-redesign.

Mission
- Defines the problem and what the engineers are trying to design or build.
- Describes the limitations within which the engineers must solve the problem.

Brainstorm Ideas
- Imagine, discuss, and sketch possible solutions.
- Conduct research into what has already been done.
- Discover what materials are available, time frame, and other limitations.

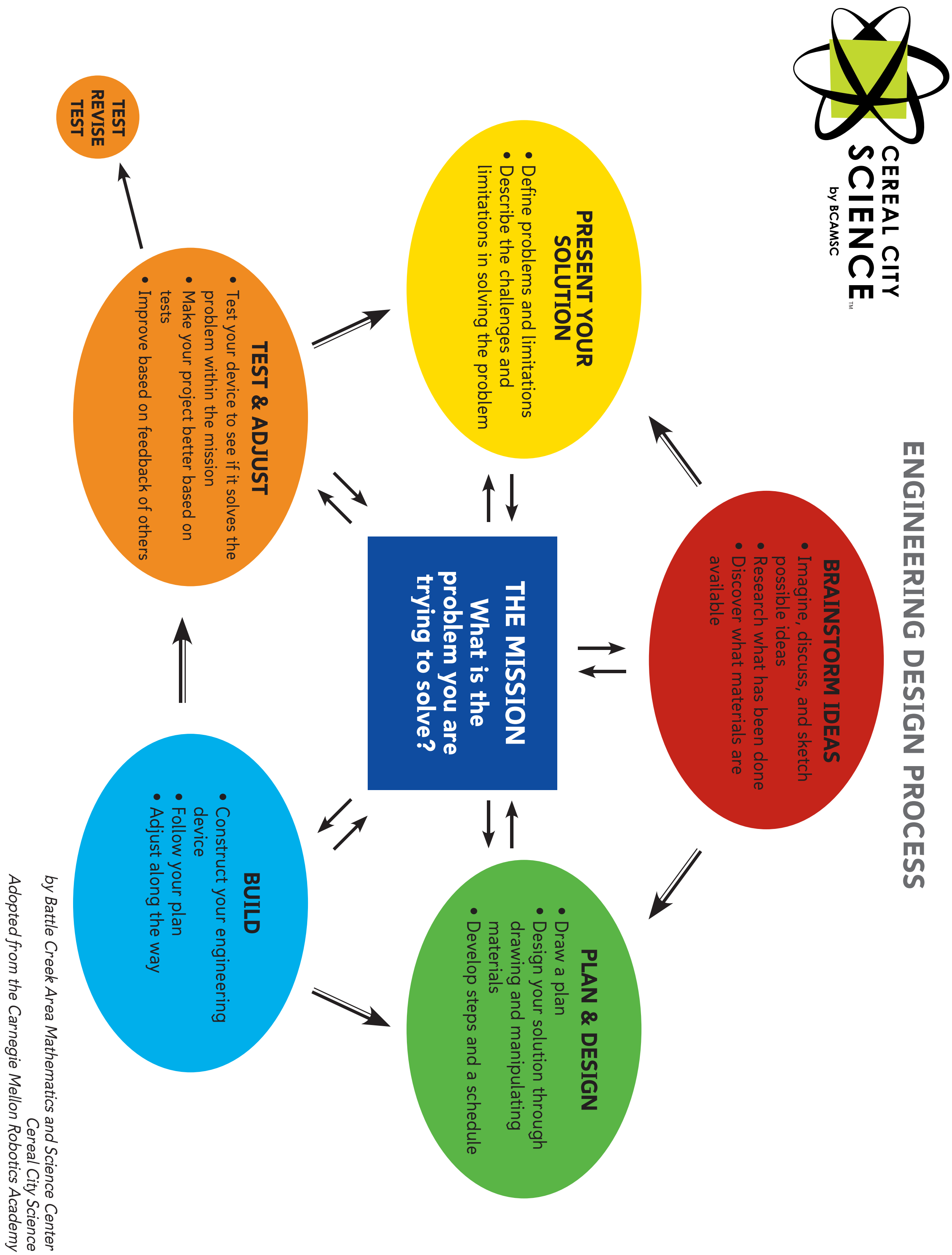
Plan and Design
- Draw and write a plan.
- Design your solution through drawing and manipulating materials.
- Develop a plan or steps and a schedule.

Build
- Construct your engineering device or project.
- Follow your plan.
- Adjust and test along the way.

Test and Adjust
- Test your device to see if it solves the problem within the mission and limitations.
- Make your project better based on tests: Test → Revise → Test.
- Improve based on feedback of others.

Present Your Solution
- Demonstrate how your solution solves the problem.
- Define problems and limitations.
- Describe the challenges and limitations in solving the problem.
- Describe additional revisions that could improve the device or project.

ENGINEERING DESIGN PROCESS



Particles of Matter and Chemical Reactions MSPNG2

A Middle School Unit supporting Next Generation Science Standards and Michigan Science Standards

Name: ____________________________

A C T I V I T Y **1A**
Observations of Vanilla in a Balloon

Date: ____________________________

1. Use the space below to draw a model to explain where you think the odor is coming from and how it spread throughout the room.

2. Write your initial ideas and questions about the “Something Stinks in Here” phenomenon.

1A ACTIVITY
Observations of Vanilla in a Balloon

Name: ______________________

Date: ______________________

1. Develop and label a model that explains how the odor of the vanilla is detected on the outside of the balloon. Include in your model a representation before shaking the balloon and after shaking the balloon.

Name: ______________________________

Date: ______________________________

2. Write questions you have about the observation of the odor through the balloon.

3. Write how you think the vanilla in the balloon is similar to the “Something Stinks in Here” phenomenon.

Name: ____________________

Date: ____________________

Combining equal amounts of water: What will happen if we combine 25 mL of water with 25 mL of water?

1. Measure 25 mL of water into one 25 ml graduated cylinder.
2. Measure 25 mL of water into the second 25 ml graduated cylinder.
3. Predict how much liquid you will have when combined. ____________________
4. Combine the 25 mL graduated cylinders of water into the 100 mL graduated cylinder.
5. Record your results. ____________________

Combining equal amounts of water and ethanol: What will happen if we combine 25 mL ethanol and 25 mL water?

1. Measure 25 mL of water into one graduated cylinder.
2. Measure 25 mL of ethanol into the second 25 mL graduated cylinder.
3. Predict how much liquid you will have when combined. ____________________
4. Combine the 25 mL graduated cylinders of water and ethanol into the 100 mL graduated cylinder and stir.
5. Record your results. ____________________

Discussion Questions:

1. Was the quantity of combined liquids what you predicted?

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2. Why do you think the results are different when combining equal amounts of water and equal amounts of water and ethanol?

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Name: ______________________

Date: ______________________

3. What do you think happened to the missing liquid?

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4. What do your results tell you about the amount of space between the particles of matter in a liquid?

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5. Draw a model of what is happening when the water and ethanol are combined.

1C ACTIVITY
Making Mixtures Using Solids and Water

Name: ______________________________

Date: ______________________________

Draw and label a model of a soda. Include the arrangement of the ingredients of the beverage in the can.

Write a list of questions you have about soda and how it is made.

Name: ______________________

Date: ______________________

1. Write the question you are investigating.

2. Write what you already know about mixing solids with water.

3. Write what you think you will find out:

4. List the materials you will use.

Name: ______________________________

Date: ______________________________

5. Draw and write how you will set up your investigation.

Name: ______________________________

Date: ______________________________

6. Complete the chart to record your observations and data.

Name of substance added to water	Description of the mixture formed after stirring for one minute	Description of the mixture undisturbed for five minutes
Kosher salt		
Cornstarch		
Drink mix		
Sodium polyacrylate		

7. Write what you found out.

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