Activity: Physical, Chemical and Nuclear Changes

For the Teacher

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Summary
In this activity, students will analyze the representation of physical, chemical, and nuclear changes in four ways: submicroscopic (particle diagrams), symbolic (equations), macroscopic (observations), and linguistic (vocabulary words). This self-guided activity is designed to ensure that students internalize fundamental chemistry concepts that will serve as a meaningful basis for future learning about matter and its changes.

Grade Level
High School

NGSS Alignment
This activity will help prepare your students to meet the performance expectations in the following standards:

- **HS-PS1-8:** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
- **Scientific and Engineering Practices**:
    - Engaging in Argument from Evidence
    - Developing and Using Models

Objectives
By the end of this activity, students should be able to:

- Analyze particle diagrams and equations and determine whether they represent a physical change, chemical reaction, or nuclear reaction.
- Observe a change and determine whether it was a physical change, chemical reaction, or nuclear reaction.
- Define vocabulary words that are frequently used to describe physical, chemical, and nuclear changes and use these words correctly when describing changes in matter.

Chemistry Topics
This activity supports students' understanding of:

- Physical Changes
- Chemical Changes
- Chemical Reactions
- Nuclear Reactions
- Observations

Time
Teacher Preparation: 15 minutes
Lesson: 90–120 minutes

Materials
- Student handout

Safety
- No specific safety precautions need to be observed for this activity.

Teacher Notes

- This activity is designed to be used early in a physical science or chemistry course, and it will be effective even for students with minimal prior knowledge about these topics.
- Students should be familiar with the following before doing this activity:
    - Differences between an atom and a molecule.
    - Basic familiarity with the four main changes in state.
    - Basic familiarity with elements and their symbols.
- Note that the nuclear equations provided in this activity are oversimplified in order to allow for students to acquire a basic understanding of nuclear reactions early in a chemistry course. Teachers can use more detailed nuclear equations in a later unit to focus more specifically on topics of nuclear decay and radioactive isotopes.
- There are substantial reading passages in this resource, which are designed for students to read independently, at their own pace. Teachers can edit the student handouts to present the information in a different way for example through lecture notes or PowerPoint.
- Note that the author created each of the reading passages included in the student activity.
- Below are several suggestions for adjusting this activity, if needed, based on your school-wide, district, or state assessments:
    - If your assessments require students to know that specific terms like “rusting” or “tarnishing” are chemical changes, be sure to add those specific vocabulary words into Part 4.
    - If your assessments require students to know that a chemical change results in substances with new chemical properties, and a physical change results in substances with new physical properties, you’ll need to add that into Part 3. This lesson does not include, nor does it assume students know about, physical and chemical properties.
    - If your assessments require students to know the traditional “signs of a chemical change” (color change, formation of a gas, energy released or absorbed, etc.) then you will need to heavily modify Part 3 or just omit it entirely. These were not included in order to minimize misunderstandings since most of them can also be signs of physical changes and nuclear changes.
    - This lesson purposefully focuses on simple, easy-to-model changes. If your assessments require that students know that highly complex processes (e.g. cooking food, leaves changing color, a banana rotting) are chemical changes, you’ll need to add those types of examples to Part 3.
- An Answer Key document has been provided for teacher reference.

FOR THE STUDENT
Lesson

Physical, Chemical and Nuclear Changes

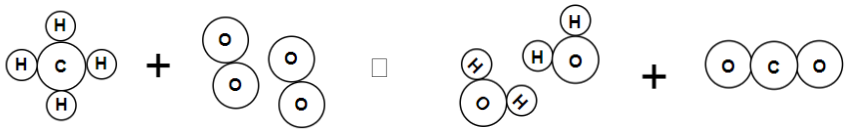
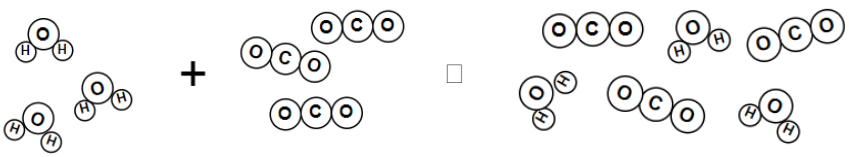
Part 1: Particle Diagrams

When a sample of matter undergoes a change, the type of change may be physical, chemical, or nuclear.

In a ***physical change***, the particles (atoms or molecules) in a substance get closer together or further apart from each other, but no actual chemical bonds are broken or formed. A common example of a physical change is a change in state, such as melting, freezing, vaporization, or condensation. During a change in state, the distance among the particles will increase or decrease, but no chemical bonds are broken or formed.

However, in a ***chemical change*** (or ***chemical reaction***), chemical bonds *are* broken and/or formed. Sometimes molecules are broken apart, sometimes atoms bond together to make new molecules, and sometimes both of these things occur during the chemical reaction. While the identity of the *atoms* remains the same, the structure of the *molecules* changes as chemical bonds are broken and/or formed among these atoms.

In a **nuclear change** (or ***nuclear reaction***), entirely new atoms of entirely new elements are formed. In some cases, one atom splits apart into smaller atoms of new elements. In other cases, multiple atoms fuse together to make one larger atom of a new element. The only way an element can be transformed into an entirely new element is through a nuclear reaction.

Particle Diagram	Physical, Chemical, or Nuclear Change?
	1.
	2.
	3.
	4.
	5.

Particle Diagram	Physical, Chemical, or Nuclear Change?
	6.
	7.
	8.
	9.

Part 2: Equations

Often, chemists use equations, rather than models, to depict changes in matter. In an equation, the state of matter of the substances is sometimes denoted with a letter in parentheses after the chemical formula:

(*s*) = solid (*l*) = liquid (*g*) = gas (*aq*) = aqueous (dissolved in water)

1. Analyze the equations below. Each one illustrates a chemical, physical, or nuclear change. Determine which equation represents which type of change.

*Equation A)*_____ $2\ H_{2\,(g)} + O_{2\,(g)} \rightarrow 2\ H_2O_{(l)}$

*Equation B)*_____ $H_2O_{(s)} \rightarrow H_2O_{(l)}$

*Equation C)*_____ $He_{(g)} + H_{(g)} \rightarrow Li_{(s)}$

2. Label each equation below as CHEMICAL, PHYSICAL, or NUCLEAR.

a. _____ $H_2S \rightarrow H_2 + S$

b. _____ $Li + He \rightarrow B$

c. _____ $Fe_{(s)} \rightarrow Fe_{(l)}$

d. _____ $U_{(s)} \rightarrow Ra_{(s)} + Be_{(s)}$

e. _____ $NaCl_{(s)}$ → $NaCl_{(aq)}$

f. _____ $2\ CuI_{(aq)} + Mg_{(s)} \rightarrow MgI_{2\,(aq)} + 2Cu_{(s)}$

3. During which type of change are new *elements* formed?

4. In what type of change do the atoms' identities AND their bonding structure remain the same?

5. In which equation in question #2 is a solid substance melting?

6. In which equation in question #2 is a solid substance dissolving?

Part 3: Observations

Instructions: Read each of the 6 statements in the Anticipation Guide below and make a prediction if the statement is true or false. Then read the short section of text provided. After reading the text, return to the Anticipation Guide and again decide if each of the 6 statements are true or false based on the reading.

Anticipation Guide		
Statements	Before Reading *TRUE or FALSE?*	After Reading *TRUE or FALSE?*
1. There are usually no major changes in appearance during a chemical reaction because the elements stay the same.		
2. Burning fuel, such as gasoline or a candle, is an example of a physical change.		
3. Most chemical reactions are endothermic, but some are exothermic.		
4. Changes in state, such a melting and vaporization, are examples of physical changes.		
5. Nuclear reactions release more energy than chemical reactions.		
6. The energy released by the sun is produced by chemical reactions going on inside of the sun.		

Part 3 Reading: Changes

Physical, chemical, and nuclear changes are occurring around us all the time; however, we often don't have a particle diagram or a chemical equation to help us make sense of these changes. Sometimes we need to classify these changes just by observing them. Here are some general descriptions of what these changes look like when observed in the lab or in your everyday life.

When a substance undergoes a *physical change*, its state, size, or shape may change, but the identity of the substance remains the same. The substance will still have the same color, taste, and smell after a physical change has occurred.

Changes in state (such as melting, freezing, vaporization, or condensation) are common examples of physical changes. Dissolving is also a common physical change. For example, if you dissolve sugar in water, the identities of the substances stay the same and their tastes stay the same; the only difference is that now they are evenly mixed together instead of separate.

Some physical changes are endothermic (absorb energy) or exothermic (release energy), but the amount of energy released or absorbed is generally small and not very noticeable.

During a *chemical change (chemical reaction)*, new substances are formed that often look totally different from the original substances. Even though the component elements stay the same during a chemical reaction, the change in their bonding structure can lead to a somewhat surprising change in appearance and properties. For example, sodium is a soft, gray, shiny, highly reactive metal and chlorine is a green, toxic gas that smells like bleach. When these two elements undergo a chemical reaction, they bond together to form sodium chloride (table salt) which looks completely different—totally new color, taste, and smell!

Another example of a chemical change is burning. Fuels, such as candle wax and gasoline, are made of molecules containing carbon atoms bonded to hydrogen atoms. When a fuel burns, those bonds break. The carbon atoms then bond with oxygen atoms from the air, forming carbon dioxide, and the hydrogen atoms bond with oxygen atoms from the air, forming water vapor. These are two clear, colorless gases that look nothing like the original fuel!

In terms of energy, chemical reactions, like physical changes, can be either exothermic or endothermic (however, they are more often exothermic). Sometimes the energy released or absorbed is not noticeable, but sometimes it is *very* noticeable, even dangerous.

During a *nuclear change* (nuclear reaction), totally new elements are formed. However, the physical appearance and properties of these new elements are often overshadowed by the overwhelming amount of energy that is released during a nuclear reaction. All nuclear reactions are EXTREMELY exothermic and release far more energy than exothermic chemical reactions. The reactions that occur in the sun, stars, and

nuclear weapons are all nuclear reactions. And before you ask, no, we will not be doing any nuclear reactions in class because they are too exothermic!

7. Fill in the first column below using the information you just read.

Type of Change	Energy Change	Observations
	LOTS of energy released	New element(s) are produced but are generally not noticed due to the overwhelming amount of energy released.
	Energy released or absorbed	New substance(s) are produced, and they often have a totally different appearance from the original substance(s).
	Little to no energy released or absorbed	No new substances are formed.

8. Think about what you would observe during each of the changes described below, then write PHYSICAL, CHEMICAL, or NUCLEAR change for each.

a. _____ Salt dissolves in water.

b. _____ A piece of iron rusts when left outside for a long time.

c. _____ A piece of iron is melted to form molten iron.

d. _____ The sun and stars emit heat and light.

e. _____ Baking soda and vinegar are combined to make a "volcano"

f. _____ Gasoline is used to power your car.

g. _____ A piece of plastic melts.

h. _____ A piece of plastic burns.

i. _____ An atomic bomb explodes.

j. _____ A stick of dynamite explodes.

k. _____ A piece of aluminum foil is torn in half.

Part 4: Vocabulary Words

In addition to knowing how to interpret particle diagrams, equations, and observations, it is also important to know the vocabulary words scientists use to describe common changes and to be able to classify these words as *physical*, *chemical*, or *nuclear* changes.

Using what you have learned in this activity and your background knowledge, try to match each vocabulary word with its definition. Each word will be used once.

FISSION	FUSION	REACTING
FREEZING	TEARING	RADIOACTIVE DECAY
MIXING	DISSOLVING	CONDENSATION
BURNING	MELTING	VAPORIZATION

1. _____ Ripping something apart.
2. _____ A liquid changes into a solid.
3. _____ Breaking and/or forming chemical bonds.
4. _____ Physically combining different substances without bonding them together.
5. _____ A liquid changes into a gas.
6. _____ Evenly mixing a substance throughout water or another substance.
7. _____ A gas changes into a liquid.
8. _____ A substance reacts rapidly with oxygen.
9. _____ A solid changes into a liquid.
10. _____ Atoms merge together to make a new, larger atom.
11. _____ Atoms split into new, smaller atoms.
12. _____ Atoms *spontaneously* split into smaller atoms.

13. Now classify each of the vocabulary words based on the type of change it describes:

PHYSICAL CHANGES	CHEMICAL REACTIONS	NUCLEAR REACTIONS

14. Look back at the particle diagrams #1-6 in Part 1:

a. Which diagram illustrates vaporization?
b. Which diagram illustrates dissolving?
c. Which diagram illustrates burning?
d. Which diagram illustrates nuclear fusion?
e. Which diagram illustrates nuclear fission?

15. Imagine that you are doing the following experiment in the lab:

> *You drop a piece of magnesium metal into a test tube of hydrochloric acid. The metal seems to disappear, and a gas forms. The gas bubbles rise to the top of the test tube. The test tube starts to feel warm as heat is released.*

a. Is this a physical change, chemical change, or nuclear change?

b. Based on what you have learned in this activity, should you use the term "*dissolving"* or "*reacting"* to describe what happened to the magnesium? Explain:

16. When someone rips a piece of paper, they often mistakenly think that they broke bonds. Based on what you observe when ripping a piece of paper, and based on what you have learned in this activity, how can you tell that you are definitely NOT breaking chemical bonds when you rip a piece of paper?

17. Many people mistakenly use the term *burning* to describe what's going on in the sun. Based on what you have learned in this activity, why is this incorrect?

18. Photosynthesis is a process you have learned about in your previous science classes.

a. Based on what you know about photosynthesis, is it an exothermic change (releases energy) or an endothermic change (absorbs energy)?
Hint: think about what plants need in order to do photosynthesis.

b. The equation for photosynthesis is:

$$6\ CO_{2\ (g)} + 6\ H_2O_{\ (l)} \rightarrow C_6H_{12}O_{6\ (s)} + 6\ O_{2\ (g)}$$

Based on this equation, is photosynthesis a physical change, chemical reaction, or nuclear reaction? Explain how you can tell.