Lesson 11: Teacher Reference

Elements to look for in students' responses to the summative assessment

Look for the *following elements in students' responses* in *Explaining the anchoring phenomena (assessment part 1)*

Look for a claim similar to the following:

- *A chemical reaction produces a gas, which was a new substance, without changing the total mass of the substances in a closed system.*

Look for references to the results from previous investigations that include:

- *No gas was released from the bathbomb when we crushed it up (Lesson 2)*
- *The total mass of the matter we started with and ended with didn't change when we mixed everything together in a closed system and got the gas to appear (it was 105.5g). But when we opened the system and released the gas, the mass decreased by 1.2 g. (using the actual mass data collected from Lesson 2)*
- *The bubbles that formed contained a gas, but the three substances that caused this (baking soda, citric acid, and water), were not a gas at room temperature, and the temperature of the system didn't increase during this process. (Lesson 3 and 4)*
- *We tested the flammability and density of the gas from the bath bomb and it extinguished a flame and sank downward. To do this, we released the gas from a container it was trapped in. (Lesson 5)*
- *Water molecules can be turned into hydrogen gas and oxygen gas when provided energy from electricity. Dalton and other scientists found similar things happened when testing other substances too. (Lesson 9 & 10)*

Look for the use of these scientific principles:

- *All matter has mass.*
- *Different substances have different properties (density, flammability, state of matter at room temperature, etc...)*
- *Different substances are made of different numbers, types, and combinations of atoms.*
- *In a chemical reaction the atoms that make up the molecules of substances that you start with (the reactants) break apart from each other and rearrange to form new types of molecules (products).*
- *Gases or liquids that are denser than the surrounding gas or liquid will sink, and ones that a less dense will rise upward.*
- *The type and number of atoms remain unchanged in a chemical reaction.*
- *In a chemical reaction, new substances with new properties are formed from the atoms that are in the reactants.*

Look for some of these **connections** between the data collected and the scientific principles:

- *No gas was released from the bathbomb when we crushed it up.* ***This told us the gas wasn't trapped in the solid bathbomb to start with.***
- *The total mass of the matter we started with and ended with didn't change when we mixed everything together in a closed system and got the gas to appear (it was 105.5g). But when we opened the system and released the gas, the mass decreased by 1.2 g.* ***This told us the matter that made up the gas came from the matter we started with.***
- *The bubbles that formed contained a gas, but the three substances that caused this (baking soda, citric acid, and water), were not a gas at room temperature, and the temperature of the system didn't increase during this process.* ***We know properties never change for a given type of substance and state of matter at room temperature is a property. Since the substance in the bubble is a different state of matter (a gas) than the baking soda or citric acid (both solids), or water (a liquid), that means it must be different substance than any one of the starting substances.***
- *We tested the flammability and density of the gas from the bath bomb and it extinguished a flame and sank downward when released from a container it was trapped in.* ***This told us the gas from the bath bomb was denser than the surrounding air. Since flammability and density are properties, and***

different substances have different properties, we eliminated many common gases that didn't have these properties. The only three gases that had matching properties (flammability and density) were carbon dioxide, nitrogen, and argon.

Look for these connections between the **specific phenomena** we are trying to explain and scientific principles:

- ***We eliminated argon and nitrogen as candidate gases that were produced, because none of the types of atoms that make up these gases, were types of atoms found in the molecules of the reactant, and we know*** *the type and number of atoms remain unchanged in a chemical reaction.*
- ***Carbon dioxide gas was produced as a product from a chemical reaction between the citric acid, baking soda and water. The carbon and oxygen atoms that made up the molecules of the citric acid and baking soda****, broke apart from each other, and rearranged to form new combinations of those atoms to make new molecules* ***of carbon dioxide gas.*** *No types or number of atoms changed in this process, which is why the mass didn't change when this happened in a closed system. (*students may also mention water as a potential source of oxygen atoms for this chemical reaction)*

Look for the *following elements in students' responses* in *Explaining new aspects of the anchoring phenomena (assessment part 2)*

Q1) A group of students in another class investigated why bath bombs behave the way they do. In one of their investigations they added baking soda to citric acid and water. They poured these substances into a container, put the lid on the container, and sealed it airtight. After sealing the container, they weighed the container and it's contents and recorded the mass of the entire system in the table below.

They made observations of what was happening inside the container for five minutes. They noticed bubbles forming. At five minutes, they weighed the system a second time. Lastly, they opened the container and weighed it a third time.

Mass of the closed container the first time they weighted it (just after it was sealed)	Mass of the closed container the second time they weighted it (~5 minutes after it was sealed)	Mass of the opened container the third time they weighted it
285.3 g	285.3 g	285.0 g

Why would the mass of the container remain unchanged between the first time they measured it and the second time they measured it?

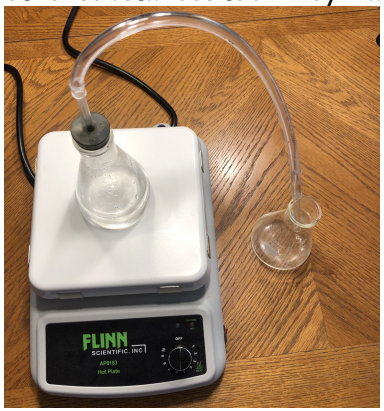
Matter has mass.
The amount of matter doesn't change in a physical change or chemical reaction.
Since this is a closed system, no matter can get in or out of it, so its mass shouldn't change.

Q2) After collecting this data, the students concluded that the gas that was produced was due to a chemical reaction between the citric acid and baking soda. Based on property measurements, they determined that the gas was carbon dioxide. But one of the students was still wondering why the system lost mass between the first measurement and the third measurement.

If carbon dioxide gas was produced due to a chemical reaction, then why would the mass of the system decrease after they opened the container?

Matter has mass.
Some of the gas probably escaped, when the lid was removed.
Since gas is matter, the system lost mass when this happened.

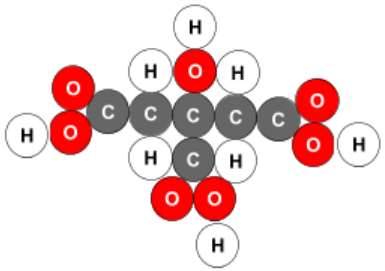
Q3) Though they had evidence that they produced carbon dioxide gas, this group of students wondered if the chemical reaction in the container produced other substances too. They wanted to test the liquid left in the container to figure this out.

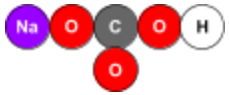


To do this, they boiled the liquid left over in the container and captured the gas from this. As the gas they captured cooled back down, it became a clear liquid. They measured the density of the liquid they collected and determined that it is the same as water. They were surprised, however, to find that they had 4.3 grams more water now than they had at the start (before mixing everything together).

Is it possible that the chemical reaction between baking soda and citric acid could also have produced some new water molecules? Use the models below to support your explanation.

- *In a chemical reaction new molecules (products) are made from the atoms that make up the old molecules (reactants).*
- *Since two types of atoms, hydrogen and oxygen, that are needed to make a water molecule are found in the reactant molecules (citric acid and baking soda), new water molecules could have been produced in this chemical reaction.*

Substance	Molecular formula	2D model
Water	H_2O	
Citric Acid	$C_6H_8O_7$	

Baking Soda	$NaHCO_3$	

Q4) After boiling off the water, there was a whitish powder left in the bottom of the container. One group member claimed this is either citric acid or baking soda. Another group member disagreed and claimed that this must be a third new substance that was produced in the chemical reaction.

They test the properties of the unknown powder left over and compare it to samples of citric acid and baking soda to try to determine which claim is correct.

sample	State of matter at room temperature	Color	Density	Solubility In water	Solubility in alcohol
Baking soda	solid	white	2.20 g/cm^3	Very soluble	Slightly soluble
Citric acid	solid	white	1.66 g/cm^3	Very soluble	Very soluble
Unknown powder left over	solid	white	1.70 g/cm^3	Very soluble	Not soluble

Construct a scientific explanation to answer the question: **Is the unknown powder left over in the container a new substance?** Remember to use evidence and scientific principles to support your claim.

Look for a claim similar to the following:

- *The unknown powder left over in the container is a new substance.*

Look for references to the data table that includes:

- *Students should make reference to the data from at least one of these property differences:*
  - *The density of the unknown powder (1.70 g/cm^3) is different than citric acid (1.66 g/cm^3) and it is different than baking soda (2.20 g/cm^3)*
  - *The solubility of the unknown powder in alcohol (not soluble) is different that the solubility of citric acid in alcohol (very soluble) and it is different than the solubility of baking soda in alcohol (slightly soluble).*

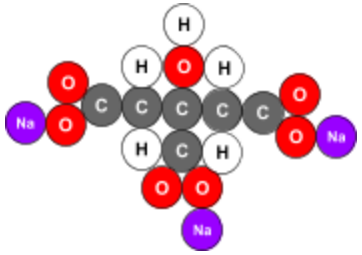
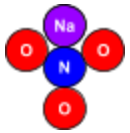
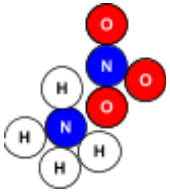
Look for the use of these scientific principles:

- *Different substances have different properties; two of these properties are density and solubility.*
- *In a chemical reaction, new substances with new properties are formed from the old substances.*

Look for these **connections** between the data collected and the scientific principles:

- *Since at least one of the properties of the white power (its density and/or its solubilty in alcohol) is different that citric acid and is different than baking soda, it is not the same substance as them, because different substances have different properties*

Q5) Another student claims that a chemical reaction can produce more than one new substance. Here are three substances that this student says could have been produced in a chemical reaction between baking soda, citric acid, and water:

Substance	Molecular formula	2D model
Sodium citrate	$Na_3C_6H_5O_7$	
Sodium nitrate	$NaNO_3$	
Ammonium nitrate	NH_4NO	

Use the space below to show why it is impossible to make <u>two</u> of the substances listed in the table above in a chemical reaction between baking soda, citric acid, and water.

This model or argument explanation should show that since there are no nitrogen atoms in citric acid, baking soda, or water, there is no way they can be the reactants in a chemical reaction that would be needed to produce sodium nitrate or ammonium nitrate molecules. This is because one type of atom is missing from these two reactant molecules - nitrogen.

Sodium citrate is made of the same four types of atoms (sodium, carbon, oxygen, and hydrogen) that can all be found in the reactant molecules, so it should be a possible product.
Note: Some students may claim that you can't make sodium citrate from the reactants either, because based on the molecular models shown, there would not be enough of each type of atom shown in one molecule of each of the reactants to make one molecule of sodium citrate. This is an excellent argument and is an appropriate middle school level explanation that there should be atom conservation in chemical reactions. This alternate argument lays a good foundation for mathematical models students will develop in high school that will help them determine the proportion of reactant molecules that must be available to produce a certain proportion of product molecules. Those mathematical models are sometimes referred to as stoichiometry or balancing equations and are beyond the middle school grade band.