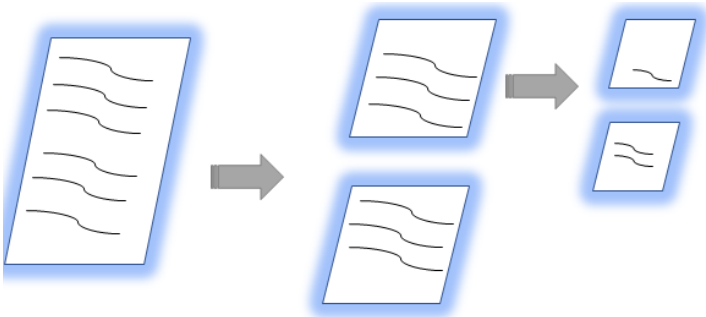
Subject Code Chem 1 **Chemistry 1**
Module Code 1.0 **Introduction and Review**
Lesson Code 1.3 **Dalton's Atomic Theory**
Time Frame 30 minutes

Components	**Tasks**	**TA[1] (min)**	**ATA[2] (min)**
Target	After working on this module, you are expected to: 1. Apply the different laws of chemical combinations in solving problems • Law of Conservation of Mass • Law of Definite Composition • Law of Multiple Proportions 2. Relate the importance of this chemistry concept to everyday life	1	
Hook	In the previous modules, we learned to differentiate the properties of matter either extensive or intensive properties, physical and chemical properties. We also classify matter as an element, a mixture or a compound. This means that a matter can exist as an element which is composed of one type of atom, a compound that is composed of two or more elements in a chemical combination. However, have we really tried to understand what an atom is? Let us start by giving you a challenge. Get a piece of paper try dividing the piece of paper in half as you go along. Then divide the half-piece of paper again in half. Then, you repeat the process.  Figure 1. Illustration for the paper dividing challenge. How many divisions will you take to cut that paper until you can't cut it no more? Can you divide it forever? Would you eventually run into very basic particles that are no longer divisible, not because of their minute sizes but you are now dealing with the fundamental nature of matter itself?	5	

[1] Time allocation suggested by the teacher.
[2] Actual time allocation spent by the student (for information purposes only).

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<td>That was the fundamental question that an English scientist and a school teacher, John Dalton was trying to understand. During this time, Dalton formulated a precise definition of the building blocks of matter we call atoms. This was then called Dalton’s Atomic Theory</td>
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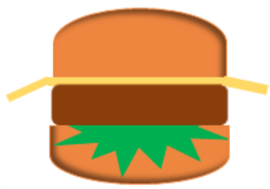
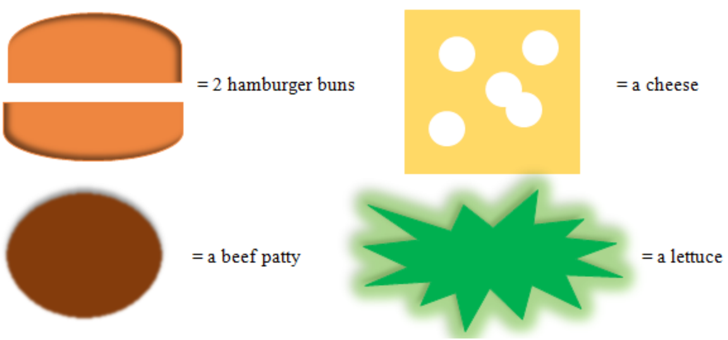
<td>Dalton’s work can be summarized as: (Brown et. al, 2012)

1.) Each element is composed of extremely small particles called atom.
2.) All atoms of a given element are identical, but the atoms of one element are different from the atom of different element.
3.) Atoms of one element cannot be changed into atoms of a different element by chemical reactions; atoms are neither created nor destroyed in chemical reactions.
4.) Compounds are formed when atoms of more than one element combine; a given compound always has the same relative number and kind of atoms.

This time, let us illustrate the Dalton’s atomic theory by making a cheese hamburger with a delicious brown beef patty and a bit of lettuce. In this case, the cheese burger is the product, each individual ingredient is the reactant and the process of making the cheese burger is the chemical reaction.



To create this hamburger we segregate each ingredient.



Postulate 1: Each element is composed of extremely small particles called atom.

In the case of our cheese burger, every ingredient represents an individual atom of every element.</td>
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	Postulate 2: All atoms of a given element are identical, but the atoms of one element are different from the atom of different element. First of all let us base this on the premise of our hamburger. In a standardized production, like in fast food chains. Every burger that these fast food chains serve should have the same quality of hamburger buns, cheese, lettuce, and burger patty. Let us focus on cheddar cheese for example. For it to be called a cheddar cheese, it should have the same properties as other cheddar cheese -- color, taste, texture, etc. Its properties are different from other cheese like mozzarella and parmesan. Even though they are of the all called cheese, they are not the actually the same. This concept is the same as comparing gold to silver. Silver and gold belong to the same family in the periodic table. This means that atoms of gold and silver may have similar properties. However because of the difference in the number of protons, neutrons and electrons, these two actually have different properties such as density, melting point, and so on. As you can see every ingredient represents different kinds of elements. If they are of different element, then they must differ in properties. Like in the case of your cheese burger, the taste of one ingredient is different from the other ingredients. **Postulate 3:** Atoms of one element cannot be changed into atoms of a different element by chemical reactions; atoms are neither created nor destroyed in chemical reactions. In the case of our burger, we cannot magically change a lettuce in to a beef patty, nor change a beef patty into a lettuce. That is why the field of alchemy for finding the "philosopher stone" that will turn every element into gold did not succeed. Simply because you cannot convert metals like mercury, silver or lead into gold. In this case you cannot create this ingredient nor destroy the ingredients. However, is this always the case? You will find out later in succeeding modules that this is not always the case since these atoms can be split into its elementary particles. Like the every ingredients of the burger wherein it can also be sliced into smaller pieces. **Postulate 4:** Compounds are formed when atoms of more than one element combine; a given compound always has the same relative number and kind of atoms.		

As we initially said, the cheese burger is the product, the ingredients are the reactants and the process of making the cheese burger is the reaction. In the process of making the cheese burger every ingredient is combined to form the cheese burger. If we use a different ingredient then it is a different burger.

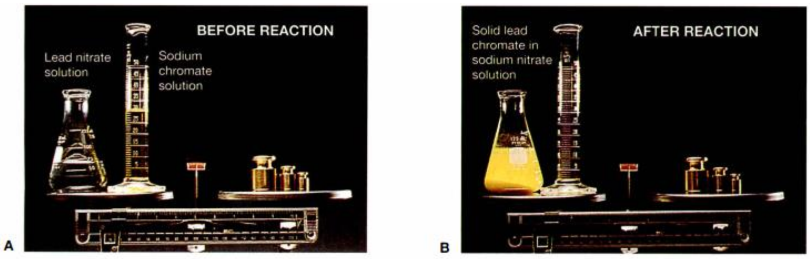
Think of a compound which originally has atoms A and B. If we use a different atom or we increase the number of either atom A or B, then that resulting compound is a different from the original compound.

Now, let us use the postulates of John Dalton to explain the different Mass Laws. These are the laws that led to the development and the acceptance of Dalton's Atomic Theory. These laws are:

Law of Conservation of Mass

"In a reaction matter is not created nor destroyed"

This means that in a chemical reaction the total mass of the substances in the product has the same total mass as your reactants. This means that when you combine the two substances together to form a product the sum of the individual masses of your reactant is the same as the total mass in the product. Just like the example in figure 1.



Silberberg, 2006

Figure 1. **The total mass of lead nitrate solution and sodium chromate solution before they react (A) is the same as the total mass after they have reacted (8) to form lead chromate (yellow solid) and sodium nitrate solution.**

If we look back to our cheese burger the total mass of the ingredients if weighed will become the total mass of the cheese burger.

Law of Definite Proportions

"All compounds, regardless of source or how they are prepared have the same proportions of their basic elements"

This means that all elements composing a given compound occurs in a fixed (definite) composition in all samples of that specific compound, regardless of where it is found or the process of making that compound. Let say for example carbon dioxide, the gas that we release in respiration, is also the same gas that is being released when we mix baking soda and vinegar to make baking soda volcano. The carbon dioxide which heats up the Earth's atmosphere have the same elemental proportions as the carbon dioxide that heats up the atmosphere of Mars and Venus.

If we are to prove it mathematically through mass ratios: (Tro, 2017)

Two samples of carbon dioxide are decomposed into their constituent elements. A sample produced from the atmosphere produced 26.7g of oxygen and 10.0 g of carbon. Another sample from that was collected from the forested areas of the Philippines produced 8.54 g of oxygen and 3.20 g of carbon. Shows that the carbon dioxide collected from both sampling sites have the same elemental proportions.

$\boldsymbol{For\ the\ first\ sample}$:

$$\frac{mass\ of\ oxygen}{mass\ of\ carbon} = \frac{26.7\ g}{10.0\ g} = \boxed{2.67\ or\ 2.67{:}1}$$

$\boldsymbol{For\ the\ second\ sample}$**:**

$$\frac{mass\ of\ oxygen}{mass\ of\ carbon} = \frac{8.54\ g}{3.20\ g} = \boxed{2.67\ or\ 2.67{:}1}$$

Carbon dioxide, CO_2 is always made up of 1 carbon atom and 2 oxygen atoms. This is always true regardless of the compounds source.

We can also prove this mathematically using the process of percent by mass or the fraction by mass (Silberberg, 2006), wherein it is expressed as the part of the compounds mass contributed by the element. It is obtained by dividing the mass of each element by the total mass of the compound.

Let us consider a sample of calcium carbonate. Calcium carbonate has many sources. It can be from the limestone that were deposited in a cave or it can be from the shell production of seashells.

Two samples of calcium carbonate where collected from different sources: a 20.0g sample and a 1.00g sample.

The table below shows the elemental mass composition of the sample of calcium carbonate

Table 1. Elemental and percentage composition from a sample of calcium carbonate.

Analysis by mass (grams/20.0g)	Analysis by mass (grams/1.00g)	Percent by mass
8.0g calcium	0.40 g calcium	40% calcium
2.4g carbon	0.12 g carbon	12% carbon
9.6g oxygen	0.48 g oxygen	48% oxygen
Total: 20.0g	Total: 1.00g	Total: 100%

As you can see the two different mass samples have the same percentages for each element in a pure sample of calcium carbonate. The Law of Definite Proportions tells us that pure samples of calcium carbonate always contain the same percent by mass.

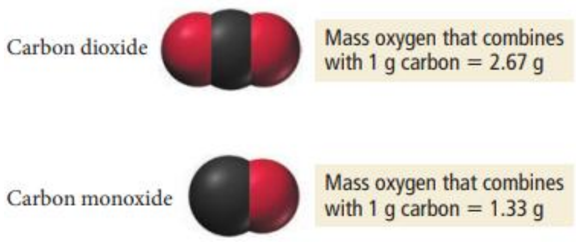
Law of Multiple Proportions

"If two elements A and B combine to form more than one compound, the masses of B that can combine with a given mass of A are the ratio of small whole numbers"

During this time Dalton suspected that an element A can combine with an element B multiple times to form more different compounds. This means that the masses of B that react with a fixed mass of A are always related to one another as small-whole number ratios. Let us consider carbon monoxide and carbon dioxide. The ratio of oxygen to carbon in carbon dioxide is 2.67 g of oxygen per 1.00 g of carbon. On the other hand, another experiment suggests that the ratio of oxygen to carbon is 1.33 g of oxygen per 1.00 g of carbon. If we are to compare the ratios of the oxygen of both carbon dioxide and carbon monoxide this will become

$$\frac{mass\ oxygen\ to\ one\ gram\ carbon\ dioxide}{mass\ oxygen\ to\ one\ gram\ carbon\ monoxide} = \frac{2.67\ g}{1.33\ g}$$
$$= 2\ or\ 2:1$$

This means that in carbon dioxide, there are two oxygen atoms while in carbon monoxide you only have one oxygen atom. (Silberberg, 2006)

	To prove that during the time of Dalton was very hard since they do not have the technology to visualize individual atoms. This time with the advent and usage of modern tools, have proven that carbon dioxide has one carbon atom and two oxygen atoms, while carbon monoxide contains only one atom of carbon and one atom of oxygen as shown in Figure 2.  Tro, 2017 **Figure 2. Space-filling model of carbon dioxide and carbon monoxide indicating the oxygen atom in red and oxygen atom in black.** These mass laws and the postulates of Dalton's Atomic Theory correlate with another in proving the existence of atoms and chemical reaction. This does not mean that the laws of chemistry should only focus on these laws and postulates. The proofs of disproving some of the postulates come in the recent century due to discoveries such as the existence of subatomic particles and nuclear reaction.		
Navigate 	Work on the following exercises to find out if you understood the lesson. 1.) Illustrate the different aspects of Dalton's atomic theory using everyday activities and real life analogies that is not related to atoms or molecules. (possible answers may include the illustration of making cheese burgers like the one in this module) Imagination is your limit. 2.) Two samples of carbon monoxide are decomposed into their constituent elements. One sample of liquid carbon monoxide used in the laboratory produced 2.00 g of oxygen then producing 1.50 g of carbon. Another sample taken from the atmosphere produced 11.7 g of oxygen and 9.0 g of carbon. Show that these results are consistent with the law of definite proportions.	4	
Knot 	Here are some of the significant key ideas that you should remember about Dalton's Atomic Theory and the mass laws that was derived or was proved from Dalton's Atomic Theory. ▪ . Every element is composed of atoms that are indestructible. ▪ Atoms of the same element have the same properties, while	2	

	of atom of a different elements are not. ▪ In a chemical reaction you can only combine, re-arrange, or separate elements. ▪ You can neither create nor destroy and atom. ▪ All compounds, regardless of source or how they are prepared have the same proportions of their basic elements. and; ▪ If two elements A and B combine to form more than one compound, the masses of B that can combine with a given mass of A are the ratio of small whole numbers.			

References

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