Remote Learning Packet

Please submit scans of written work in Google Classroom at the end of the week.

May 4-8, 2020
Course: Nature of Science
Teacher(s): Mr. Brandolini (david.brandolini@greatheartsirving.org); Mr. Mooney (sean.mooney@greatheartsirving.org); Mr. Schuler (david.schuler@greatheartsirving.org)

Weekly Plan:

Monday, May 4
☐ Watch the short video on Google Classroom before beginning the week's work
☐ Read Monday's lecture on Antoine Lavoisier and Read *Nature of Science* pp. 121-122
☐ Complete the Reading questions

Tuesday, May 5
☐ Read Tuesday's lecture on Charles' Law & Boyle's Law and pp. 123-124 in *Nature of Science*
☐ Complete the Reading questions

Wednesday, May 6
☐ Read Wednesday's lecture on John Dalton and pp. 125-126 in *Nature of Science*
☐ Complete the Reading questions

Thursday, May 7
☐ Read Thursday's lecture on John Dalton and pp. 126-127 in *Nature of Science* (and also review Dalton's charts on pp. 128-129!)
☐ Complete the Reading questions

Friday, May 8
☐ Attend office hours at 11:30am
☐ Catch-up or review the week's work

Statement of Academic Honesty

I affirm that the work completed from the packet is mine and that I completed it independently.

____
Student Signature

I affirm that, to the best of my knowledge, my child completed this work independently

____
Parent Signature

Monday, May 4

1. Watch the introductory video on Google Classroom.
2. Then, read the lecture document below.
3. Next, read pp. 121-122 of *Nature of Science*.
4. Finally, complete the reading questions worksheet for today's readings.

Antoine Lavoisier, *Elements of Chemistry*

Our next scientific thinker is the Frenchman Antoine Lavoisier. His *Elements of Chemistry*, published in France in 1789 and translated into English in 1790, continues to build off of many of the ideas we've seen in previous thinkers. Much like Democritus, Lucretius, and Newton before him, Lavoisier sought to more deeply understand the relationship between particles of bodies, the void between them, and their properties.

Recall that Anaximenes explained all matter and changes in matter as the result of one element, air, subject to two opposites, Rarity and Density. Similarly, Empedocles explained all matter and changes in matter as the result of four elements that are subject to two opposite forces, Love and Strife. Lavoisier continues from this tradition by stating that all matter and changes in matter result from two opposite forces: **Attraction** and **Repulsion**. Through careful observation, he learned that by applying heat to many different materials, he could begin to see that Repulsion, or separation of particles, is caused directly by applying precise amounts of heat to an object.

If every particle is suffering one of these two opposite forces, then how does a solid object even stay together at all? Lavoisier explains that most particles suffer *both*: when the amount of Attraction and Repulsion on a particle is the same, that particle is in a state of balance called **equilibrium**. If enough heat is applied to a body, the Repulsive force becomes stronger than the Attractive one, and the particles will move far enough apart from each other that an object will no longer remain solid.

Lavoisier takes an experimental approach to demonstrating this idea by observing a very common substance: water. He observes that there is a precise, measurable connection between the solid, liquid, and gas (or "elastic aeriform") states of water and the amount of heat present in them: at precisely 0℃ (or, 32℉), water remains solid and is called ice. Above that temperature, Lavoisier says that there is a lack of **reciprocal attraction**, meaning some particles are more attracted than others due to an uneven amount of heat; this causes the liquid state we call water. On the other hand, he noticed that if you *raise* the temperature of water to above 212℉, water boils and becomes vapor, or gas. In either direction, at a precise point, a specific amount of change in the temperature of the substance always results in the same chemical change. Lavoisier then suggests that every kind of substance must have its own specific temperatures at which the substance enters a solid, liquid, or gas state of matter; for example, it just so happens that air's natural state is for the particles to be distant enough that it is a gas. But why is this the case?

Lavoisier attempts to prove this conclusion by inferring that there may be a hypothetical substance that serves as the *cause* of heat itself. (It's important to emphasize that word **hypothetical**: Lavoisier is doing what any good scientist does, which is propose a possible explanation to a difficult question, while remaining open to the idea that his suggestion could be incomplete or incorrect.) He says that this substance would have to be an extremely, microscopically thin fluid that fills in the void between particles and pushes them apart from each other, causing the effect of Repulsion through heat. He gives this fluid three different names: *igneous fluid, matter of heat,* and *caloric*, a word that can generally just mean "something that pertains to heat". This *caloric* would fill up all of the void between particles in order to push them apart: Lavoisier compares this idea to an image of a bowl of lead spheres being filled with sand: the sand would fill up between the lead spheres and begin to push them further away from each other within the bowl.

Lavoisier's hypothesis of the *caloric* fluid has since been disproven, but he himself stated that "we are not obliged to suppose this to be a real substance"; the important thing was that he was able to discover the relationship between a measured amount of heat and the change in a substance's state of matter, which *does* hold up. Just like all of the scientists before him, Lavoisier sought to explain changes in matter as the result of an ultimate material in order to have a concrete explanation of the laws that govern its behavior.

Name:____
Section & Course: ____
Teacher: ____
Date:____

Week 6, Monday: Lavoisier, *Elements of Chemistry* Reading Questions Worksheet

1. What two Pre-Socratics do Lavoisier's theories most seem to resemble?
   a. Lucretius and Newton
   b. Anaximander and Thales
   c. Heraclitus and Thales
   d. Anaximenes and Empedocles

2. By examining water in different states of matter, Lavoisier infers that the state of matter a substance is in is directly related to the amount of ____.
   a. strife
   b. heat
   c. electricity
   d. water

3. List the three names that Lavoisier gives to the "very subtle fluid" that makes bodies expand:

____

4. In your own words, try to describe how Lavoisier's *caloric*, or "very subtle fluid", could help explain how particles expand away, or are Repulsed, from each other.

____

____

____

____

5. Based off of both the lecture and the reading, does **heat** seem to be more of a quality, or a substance? Explain as best as you can in a few sentences.

____

____

____

____

Tuesday, May 5

Name: ____
Section & Course: ____
Teacher: ____
Date: ____

Charles and Boyle — "The Gas Laws"

Today, we will be learning about two more scientists, Charles and Boyle, and how they built upon the ideas of Lavoisier. Lavoisier, as you will recall, said that there were three states of matter: solid, liquid, and gas. The two scientists we will study today took a special interest in the last of these—the gas state—and we will soon see what they discovered.

Thinking Like Lavoisier

Let's do a little thought-experiment here. Imagine a clear, see-through balloon, tied up tightly at the top. It is *not* empty—it is full of *gases* (matter in air-like form). Now, I want you to imagine the gas in this balloon exactly how Lavoisier would have imagined it. Can you see it? Zoom in *really* close up—there they are, the tiniest little particles of matter, with plenty of empty space, or void, between them. They are attracted to each other like magnets, but remain at a distance from each other due to the repulsive force of "*caloric"* (that is, the substance of heat).

Alright, are you seeing it? Lots of particles, at a distance from each other in the void, kept at a distance by the caloric that is filling up the void. Okay now, here's the question: *What would happen if you added some caloric?* That is*, what happens if you heat up the balloon?*

Charles' Discovery

This is precisely the question that our next scientist, a Frenchman named Jacques Charles, was keenly interested in. If caloric, thought Mr. Charles, is what is separating the little particles, wouldn't adding more caloric cause them to separate *even more*? And wouldn't that then increase the *volume* (the space it takes up)? If a gas is heated up, the volume should increase.

Mr. Charles had a good hypothesis. But, like a good student of Lavoisier, he did not stop there, but set to work using Lavoisier's methods of experimentation, measurement, and inference. We can imagine Mr. Charles there, with a container full of gas, heating it up little by little, measuring the temperature and the volume each time, and recording all of his measurements on paper. And by the end of it—lo and behold—the volume changed as he added heat to it! Every time he raised the temperature, the volume of the gas increased. It was just as he predicted…

…And then it did *more* than he had predicted. Charles' opened wide in amazement. He double-checked his measurements—he couldn't believe his eyes! When the gas was heated, its volume expanded *in direct proportion to the heat introduced*.

Charles' "Law"

Mr. Charles must have been so surprised when he realized what was happening. The volume and temperature of gases are *directly proportional*. But what does this mean? Yes, it means that as temperature increases or decreases, volume increases or decreases with it. But even more than this, it *increases and decreases in the same ratio*! That is, if you double the temperature, you double the volume; if you triple the temperature, you triple the volume; if you cut the temperature in half, the volume will be cut in half also. This relationship is perfectly *mathematical,* and can be written as a mathematical statement called a *proportion*:

T varies directly as V

$$\frac{T_1}{T_2} = \frac{V_1}{V_2} \qquad T_1 : T_2 :: V_1 : V_2$$

This proportion has come to be known as "Charles' Law." That's right—it is called a *Law*. I assume you know what a human law is. Well, laws of nature are similar, except that they are not invented by human beings (they are *discovered* by human beings!), and furthermore, nature cannot choose to disobey them—they *always, always, always obey them*. If right now you were to put an air-filled balloon in the freezer, the gases inside would obey Charles' law *exactly*.[1]

Does it surprise you that the law of nature that gases follow is a mathematical statement? Just think about it! It's incredible! *Why do natural things sometimes obey mathematical laws?* Not all laws of nature are mathematical, but some clearly are. What does this mean about the universe we live in? Pythagoras would be jumping up and down with joy if he were here.

Another Question about Gas

Around this same time, there was another natural scientist who was also interested in the behaviors of gases and the ideas of Lavoisier. His name was Mr. Robert Boyle. He saw the importance of Charles' results, and what they meant about the forces of Attraction and Repulsion that Lavoisier had described. By increasing heat, you increase the Repulsive force, causing the gas to expand; by decreasing heat, you decrease the Repulsive force, allowing the force of Attraction to bring the particles closer together.

Robert Boyle wondered if there was another way to affect these forces of Attraction and Repulsion in order to change the distance between these particles (thereby changing the volume of the gas). What if you could *force* the particles closer together? After all, isn't something like that happening when you force more and more air into a bike tire—aren't you packing the air in, tighter and tighter, into a small space?

Volume and Pressure

Boyle hypothesized that you *could* change the volume by forcing it. And then, like a good follower of Lavoisier, he began experimenting and collecting precise and careful measurements.

Boyle found that you could indeed change the volume of a gas simply by forcing it. Imagine a piston, like the one pictured to the right. By pushing down on the piston, you could force the same amount of gas into a smaller space. If you pull the piston up, the gas expands to fill the space.

As you might imagine, the harder you push down, the harder the air is going to "push back." If you have ever pumped up a bike tire or a sports ball, you know that it keeps getting harder and harder to push more air in. This forceful "push-back" of the air is called *pressure*.

[1] If you can, you should try it! Take a balloon full of air and put it in the freezer. Wait some time for the air to get cold, and then look at it. Notice any change? Take it out and warm it up in your hands. What happens?

Boyle's Law

Boyle soon discovered that if he decreased the volume, the pressure increased. And as he increased the volume, the pressure decreased. And, what was more, his careful measurements showed him that these two quantities were *inversely proportional*. Yep, you guessed it—*another mathematical law!*

P varies inversely as T

$$\frac{P_1}{P_2} = \frac{\frac{1}{V_1}}{\frac{1}{V_2}} \qquad\qquad P_1 : P_2 :: \frac{1}{V_1} : \frac{1}{V_2}$$

These are the mathematical ways of expressing that if you double the pressure, you cut the volume in half; if you cut the pressure in half, you double the volume; and so on.[2]

Conclusion

Let's take a moment now to consider what Charles and Boyle had discovered. Well, for one, it means that gases—and perhaps even all matter—obey certain mathematical laws. (Loud cheers from Pythagoras and his followers!).

Secondly, these laws may also confirm Lavoisier's ideas (One loud cheer from Lavoisier!). If Lavoisier is right about matter—if there really are a bunch of little particles in the void, held in a kind of balance between the forces of Attraction and Repulsion—then it would make sense that increasing the force of Repulsion (caloric) would cause the volume to expand. It also makes sense of the fact that you can force the particles closer together, but that the pressure (or "pushback") of the gas would increase as you did so. (If you have ever tried to push two repelling magnets closer together, you know that the closer they get, the stronger the force pushing back. It seems reasonable to say that a similar thing is happening here.)

But still there are many questions left to answer. Most of all, *why the direct and inverse proportionality*? What is causing the changes to be so perfectly balanced and constant? What does this mean about the forces of Attraction and Repulsion? What does this mean about those tiny little particles? What does it mean about the void? Yes, there is certainly much mystery here still, but the discovery of these mathematical laws is an encouragement to keep searching, a promise that there *is* some hidden cause that we might be able to discover if only we persevere.

[2] Notice that in Charles' Law, volume and temperature either both increased or both decreased; here, with Pressure and Volume, **if one goes up, the other goes down**.

Charles and Boyle, “The Gas Laws” - Questions (Tuesday May 5)

1. Charles and Boyle are two scientists who focused their attention on the behavior of __.
    a. Solids
    b. Liquids
    c. Gases

2. To answer the questions they had about gases, they followed Lavoisier's methods of __.
    a. isolate, balance, and check
    b. experimentation, measurement, and inference
    c. stop, drop, and roll

3. Charles' hypothesized that, if heat (caloric) were added to a gas, the gas would __.
    a. remain constant
    b. increase in volume
    c. decrease in volume
    d. explode

4. Charles found that Volume and Temperature were ____________________ proportional.

5. This meant that, if the temperature of the gas doubled, the volume would _____________

6. Charles' Law, written as a mathematical statement, is ____________________________

7. Boyle attempted to change the volume of a gas by changing its __.
    a. weight
    b. mass
    c. equilibrium
    d. pressure

8. Boyle found that, as pressure increased the volume _______________. As pressure decreased, the volume _______________. The pressure and volume of a gas are ____________________ proportional.

9. Why were the discoveries of Charles and Boyle important for our understanding of the material world? Explain in 2-3 sentences.
    ____
    ____
    ____
    ____

10. (Optional) Put a balloon in the freezer and observe it to see if it seems to be following the Law! (An empty sealed water bottle will also work.) Which Law would be relevant here?

Wednesday, May 6

Name: ____
Section & Course: ____
Teacher: ____
Date: ____

John Dalton, *A New System of Chemical Philosophy*

Instructions for Today:

1. Read the document below. Then, read Chapter II: "On the Constitution of Bodies" by John Dalton on pp. 125-126 (Stop when you get to Chapter III!). Finally, complete the questions.

When we began our study of chemistry (sadly not in person but via these packets!), we introduced the Pre-Socratics and said they were interested in four big questions:

1. What are the first or ultimate principles of the cosmos? Are they material or of some other kind?

2. How many principles are necessary to explain everything in the cosmos?

3. From what material does everything come?

4. How are generation (coming into being) and destruction (passing out of being) possible? How do we explain the appearance of change in the universe?

Hopefully something you are realizing by now is that **these questions have not gone away as time has progressed**! Newer and modern chemists have – by and large – picked up these same questions in their own time.

The Pre-Socratics continue to impress with their enduring insights about the most important questions into the Material Causes of things.

Over the next two days, we will study the thoughts of a very important modern chemist, **John Dalton**, who was born in Eaglesfield, England in 1766. Pay attention to those English (Newton and Boyle were also English); like the Greeks of ancient times, there have been many important and prominent English chemists in the modern era. There must be something in the water – or tea – over there!

As you read here and in the textbook (pp. 125-126 today and 127-129 tomorrow), pay close attention to how Dalton sounds like some of the Pre-Socratics (specifically, Democritus, Empedocles, and Parmenides), as well as his fellow modern chemists such as Lavoisier, Charles, and Boyle. The great scientific conversation continues!

Let's look again at the first Pre-Socratic question:

1. What are the first or ultimate principles of the cosmos? Are they material or of some other kind?

Here's Dalton's answer:

Dalton says the ultimate principles of the cosmos are material. Bodies are composed (made up) of very small particles called "atoms", the things that are a+tomos (uncuttable). Yes, atoms! John Dalton was the first to use that word again since Democritus. We're very used to hearing that word casually used today, but as people participating in the larger scientific conversation, we need to pay close attention to key words such as **atom**.

Dalton then further describes these atoms by saying **heat** will spread them out and cooling will allow them to draw closer together. He pointed out water as an example. When it gets hot, the atoms separate and eventually you have steam or water vapor, which is a gas. As the gas cools, the atoms come closer together and you have liquid water again.

Now, do you also remember from Monday Lavoisier discussing Attraction and Repulsion? Sounds similar! But wait, there is an even deeper connection. Do you remember from Friday April 17 (Week 3 packet) when you read about a Pre-Socratic who discussed Love and Strife as the forces uniting and separating things? Do you remember who that was? It was Empedocles! Love and Strife – Attraction and Repulsion – it all sounds so similar. Dalton agrees.

So, what is new about what Dalton is saying then? Plenty. Let's take just one new idea for today and save the rest for tomorrow.

Dalton sought to answer a big question – but more fully and in a different way – that Newton also addressed:

Say you have atoms that make up water in Dallas and atoms that make up water in London. Will these atoms be the same thing (water in this case) no matter where we find water?

Dalton answered with a resounding yes. Different scientists talked about how particles may have varied in shape and size; Dalton agrees (as we will see), but he says the same *type* of particle (say hydrogen) will always be the same no matter where you find it. How does he know this? He had some fascinating methods, but let's take a simpler one involving the weight of water. Say you weighed a gallon of water every day for 10 days in Dallas and London. Would it always weigh the same? Yes![3] The reason, Dalton says, is because the atoms making up water are the same throughout the created universe. If you have hydrogen atoms in Greece they will be the same as hydrogen atoms in Hyderabad. If you have gold atoms in a bank in Switzerland, they will be the same as gold atoms in your hand in Irving (lucky you!).

[3] Unless, as we studied in Mass v. Gravity, something else, such as changes in altitude or planet, is affecting the weight

Ultimately, Dalton concludes:

All atoms of the same kind of substance are perfectly uniform (the same) in size, shape, and weight.

This may seem like an unremarkable development to us, but if it does it is only because we are standing on the shoulders of giants like Dalton

We will hear more of his genius tomorrow, but hopefully a few things are standing out:

- Dalton is carrying on the ancient conversation begun by the Pre-Socratics and pondering similar questions, though from a new angle. Indeed, he brought back the term “atom” that had largely been out of use for over 2000 years!
- He is definitely modern like his predecessors: Mr. Lavoisier, Mr. Charles, and Mr. Boyle. We can tell because he is interested in defending his arguments by conducting experiments and taking measurements and generally having experimental results and data to support his claims. As you will see modern natural scientists (right up to the present day) have a strong, strong bias for having “data” and measuring things. This has obvious benefits but also consider: What blind spots that might emerge from this hyper-focus on measurement?
- The final question to continue thinking about is, “How on earth were so many Brits (with some Frenchmen, too) so good at chemistry for so many centuries? ‘Blimey, beats me!

John Dalton, *A New System of Chemical Philosophy* - Chapter II Worksheet (Wednesday May 6)

1. Dalton brought back, over 2000 years later, which key word that was used by Democritus?
    a. Indefinite
    b. Ultimate
    c. Atom
    d. Element
    e. None of the Above

2. Dalton's experiments led him to agree with Lavoisier that **heat** is a key factor in causing atoms to draw farther apart from each other. This explains why when we heat water, we get water vapor, which is a gas. Lavoisier referred to his theory as one of "Attraction" and "Repulsion" Both Lavoisier and Dalton sound similar to a natural scientist who came many centuries before them. Which one?

    a. Thales
    b. Anaximenes
    c. Anaximander
    d. Pythagoras
    e. Empedocles
    f. Democritus

3. Which new idea did Dalton introduce - with measurement data to support it?

    a. "New" substances are formed when atoms are rearranged and form new combinations
    b. Atoms of elements such as hydrogen vary depending on the substance they are part of
    c. Heat is what causes atoms to separate and repel from one another
    d. Oxygen atoms (or any atom of the same element) will be the same in weight, size, and shape throughout the entire universe

4. Like Lavoisier and Charles and Boyle, Dalton defended his ideas with… Choose TWO answers

    a. Measurement data
    b. Models of atoms
    c. Experiments
    d. The Pythagorean Theorem
    e. Photographs of moving atoms

5. (a) Explain how Dalton is similar to the Pre-Socratics. (b) Then, explain how he is very much a modern chemist.

    (a)____

    ____

    ____

    (b) ____

    ____

Thursday, May 7

Name: ____
Section & Course: ____
Teacher: ____
Date: ____

John Dalton, *A New System of Chemical Philosophy*

Instructions for Today:

1. Read the document below. Then, read Chapter III: "On Chemical Synthesis" by John Dalton on pp. 126-127 of the *Nature of Science* textbook. Review the tables on pp. 128-129. Finally, complete the questions.

Yesterday, we learned how Dalton brought back an important word from ancient times: **atom**. We also learned he asked many of the same questions about the reality of the universe as the Pre-Socratics, but that he had a different scientific approach than the ancients. Like his fellow modern counterparts, he also strongly emphasized the use of **experimentation** and **measurement**, as well as **inference/induction** (although induction is not something new to modern science).

But what was new in Dalton's thinking? Yesterday, we noted that he used experimentation to demonstrate that all atoms of the same type (for example, hydrogen) will be the same in weight, size, and shape throughout the entire universe. An atom of hydrogen in Texas will be the same as an atom of hydrogen on the sun.

Today, we are going to take a closer look at his other new insights.

To introduce his next insight, let's recall again an enduring question of natural science: *How do we account for change? Can new things come into being?*

Remember an important point about Dalton: he is interested in **quantity** and measuring things (Can't you see Pythagoras smiling?). From his experiments, he inferred that there are an exact number of atoms in a given object. Say you have some water vapor trapped in a glass. Dalton did not claim to know exactly how many small parts of water there were, but there was a specific number. Also, remember he agreed with Empedocles and Lavoiser that there were forces of Attraction and Repulsion at work that allowed atoms to separate and recombine. What this leads to is that **new atoms are not created; they are simply recombined through processes of what he called chemical "analysis" (the separation of particles) and chemical "synthesis" (the chemical joining of particles).** Dalton said it was the amount of **heat**, which he thought was a kind of fluid (interesting), that was responsible for separation or the lack of it.

Parmenides (and Lucretius and Democritus) would be proud! No new atoms come into being or pass out of being; all change is explained through a recombination of existing matter.

This may not strike us as amazing, but pause and ponder this for a moment. Presumably you have interacted with water today. Think about the water you drank or washed with. Mr. Dalton is claiming that the *specific atoms of* hydrogen and oxygen making up that precise water (and he knew it was hydrogen and oxygen!) have *always existed* since the dawn of creation and will continue to exist until the end of time. Seasons come and go, empires rise and fall, but the amount of hydrogen we have in the universe will always stay the same; it will only recombine in new ways on and on until the lights on the cosmos go out. Here are Mr. Dalton's actual words on the subject:

"No new creation or destruction of matter is within the reach of chemical agency. We might as well attempt to introduce a new planet into the solar system, or to annihilate one already in existence, as to create or destroy a particle of hydrogen" (Dalton, "On Chemical Synthesis").

Now as we have seen, Mr. Dalton is emphatically *not* the first scientist to make this claim, but he develops the claim by trying to demonstrate it with **experiment, careful measurement, and inference**[4] and by developing our understanding and knowledge of these never-dying, never-being-born atoms. That's our next point.

Before revealing his next insight, it's helpful again to review a big question that has been on our natural scientists' minds across the centuries: *How many ultimate substances are there?*

If you recall, Thales and others said only 1 (Thales said water). Then, there were others like Empedocles who said four (Earth, Air, Fire, Water). Dalton said…

TWENTY![5]

There were names for these different "Elements" as they were called by then and he drew up a "Table of Elements". I bet you've heard of the Periodic Table of Elements (the most recent one is on p. 168 in your textbook; compare with Dalton's on p. 129). Dalton developed an early version of the current one! The elements had names such as Carbon, Soda, Lead, Gold, Mercury, Iron, and Lime. We do need to make one thing clear: Mr. Dalton did *not* discover all these elements nor did he claim to. Then, what did he contribute? Mr. Dalton contributed **measurements** about their properties and a greater understanding of how elements combined with one another (like hydrogen and oxygen → water).

What did Mr. Dalton learn about the elements? He learned their **weights** relative to Hydrogen (which has a weight of "1"; everything is compared to hydrogen). Remember that Dalton came to the conclusion that any element of the same kind (think of each individual atom of silver in the universe), would have the same weight. So, if you found something with a different weight, you found a new element!

Dalton relied on the knowledge gained by other scientists in the area of chemical analysis (separation of particles) and synthesis (recombining of particles) to gain insight on the **weights** of elements *and* the **ratios** that were apparent in how they combined. Hmm… "ratio". That word should remind us of an important Pre-Socratic. It's Pythagoras, who saw unity and harmony in **ratios** over 2000 years before Mr. Dalton and his fancy measuring tools came along. The more things change, the more they stay the same... (wait, can things change? Parmenides! Ah!)

Mr. Dalton saw that atoms of elements come together in fairly predictable ways and follow "general rules" in their different combinations. These rules are listed as bullet points on p. 127 of your textbook.

In order to understand the rest of what Dalton did, it's important to know the term **compound**.

---

[4] When you hear "Inference", think: "Induction"

[5] At least… he thought there could be more he didn't know about.

Compound: A substance formed by two or more elements chemically combined. For example, "water" is a compound of 2 hydrogen atoms and 1 oxygen atom.

Remember, Dalton's big contribution was figuring out the weights of the various elements. Here's how he did it:

Because (1) Dalton had tools that could weigh the compounds and (2) because he figured out the rules on how elements often combined and (3) because he knew which atoms made certain compounds, he realized how much each element weighed compared to hydrogen. Look at his Table of Elements on p. 127. You can see a number next to each element name. Hydrogen has a "1" and Carbon a "5", for example. This means Carbon is five times heavier than Hydrogen.

What is the significance of these discoveries?

This is a reasonable question. The significance of his work is pretty serious. Remember that a fundamental question on scientists' minds is how many ultimate substances there are. Not only was Dalton giving a number and names but he was also giving **quantifiable** details *about* each of those elements. Then, taking things a step further, he figured out **quantifiable** ways in which the various elements interacted. These experiment-based results added to the understanding of the elements *and* **how these elements come together to form new substances**.

Now Dalton did not get everything correct (for example, he thought water was 1 hydrogen atom and 1 oxygen atom), but he made significant advances in our understanding of chemical synthesis. He not only could name elements but talk about the process of their combination and separation.

Remember the phrase: **experimentation** and **measurement**, and **inference/induction**. The first two of these methods are what distinguish these recent scientists, including Dalton, from ancient scientists. But never forget how the ideas of new scientists like Dalton echo so much of what their predecessors from over 2000 years ago said. Democritus introduced the term "atom". Pythagoras recognized the centrality of number and ratio. Aristotle (and others) addressed concerns about change and "new" substances. The modern scientists certainly contribute important new understandings to the fundamental questions about the natural world, but they are also certainly, as Newton readily acknowledged, "standing on the shoulders of giants".

John Dalton, *A New System of Chemical Philosophy* - Chapter III Worksheet (Thursday May 7)

1. John Dalton brought back the word "atom" after over 2000 years. He also used:
   a. ____
   b. ____
   c. ____
2. Chemical **analysis** refers to the _____________________ of atoms and chemical **synthesis** refers to the ________________________ of atoms.
   a. creation; destruction b. destruction; creation
   c. separation; joining d. joining; separation
3. Dalton thought new things did not come from nothing; he thought new things were the result of the recombination of already existing atoms.
   a. True b. False
4. Mr. Dalton came to the realization that elements come together in certain ___________ to form compounds.
   a. Weights
   b. Heights
   c. Ratios
   d. Sizes
5. Mr. Dalton primarily contributed to our understanding of which aspect of elements?
   a. Quantity b. Shape c. Form d. Final Cause

6. Look at Mr. Dalton's Table of Elements on p. 129. Then, look at the recent Period Table of Elements on p. 168. Write one thing that is the same and one thing that is different about them.

Same	Different

7. A significant contribution of Dalton's was his measurement of the weights of different elements. What does it mean that carbon, according to Dalton, has a weight of 5?
   a. Carbon atoms weigh 5 ounces
   b. Carbon atoms are 5x the length of hydrogen atoms
   c. Carbon atoms are 5x as heavy as hydrogen atoms
   d. Carbon atoms are 5x as heavy as oxygen atoms

Friday, May 8

Stop by Office Hours at 11:30 if you can.

Review your work and/or catch up on anything you have not yet completed.