Name: _____ Date: _____

# Structure of Matter

**Coherent Reading Protocol**

These prompts are designed to help you make sense of the main ideas from any reading.
The text is divided into four chunks. Stop and summarize the main idea after each chunk using words or images.

**Navigate into the reading: What information do you want to figure out as you read?**

**Early Ideas of Atoms**

People have always wondered what makes up the matter that surrounds us. People observe phenomena, like the shocks that occur when we build up static or the changes that happen when a material is heated, and we ask why it is happening. For example, the Maya in Central America noticed that some plants had unique properties when heated together. They purified these substances and figured out how to make vulcanized rubber – 3,000 years before this process was patented in the United States! During the 8th century in the Middle East, Muslim scholars learned how to purify metals and combine substances. They called this *al-kimia*, which eventually spread to Medieval Europe as *alchemy*. Even ancient Greek philosophers wondered about what makes up matter. A philosopher named Democritus (460-370 BCE) thought that matter was made up of tiny particles, but Democritus did not do experiments to test this. The philosophers gave us the English word for a particle of matter that we still use today: the **atom**. This idea about atoms being the smallest particles of matter was used for thousands of years to help explain many outcomes of chemical reactions.

**Is static electricity made of atoms?**

However, there were some phenomena that atoms alone could not explain. Like you, scientists in the 18th century were confused by what makes up static electricity. They identified three ways that matter could behave when static was produced:

1. Matter could be attracted to other matter.
2. Matter could be repelled by other matter.
3. Matter could just "hang out" without being attracted or repelled.

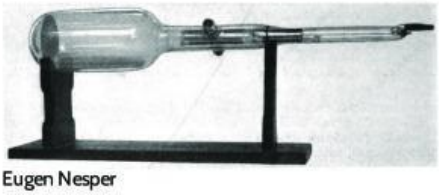
To help categorize these patterns, scientists started referring to matter as having either a positive or negative charge, and they called matter with no charge *neutral*. But what was changing about the matter to produce positive or negative charge? This was a mystery until the 20th century.

**Text Chunk 1: Write the main idea in your own words or images. (If you are not sure, reread and annotate.)**

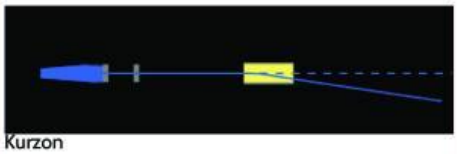

LIVEWORKSHEETS

**J.J. Thomson and Cathode Rays**

In the late 1800s, a scientist named J.J. Thomson was especially interested in a phenomenon he observed in cathode ray tubes. *Cathode ray tubes* are glass tubes filled with gas connected to a power source. The cathode ray tube creates a bright beam that moves from one end of the tube to the other. In fact, cathode rays look a lot like lightning! Since the gas was very hard to energize, Thomson suspected that something smaller than atoms might be causing the lightning-like beam. He designed several experiments to determine what was in these beams. Some of those experiments are summarized in the table below.

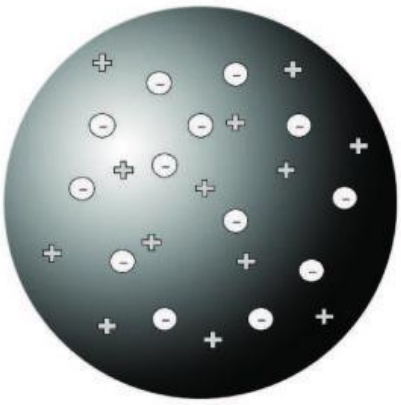


Eugen Nesper

| Experiment | Observations | Conclusions |
|---|---|---|
| Thomson held plates charged with static electricity next to the tube as the ray moved through the tube. | The beam bent toward positively charged plates and away from negatively charged plates. This happened no matter what gas was filling the tube.  Kurzon | The beam has a negative charge. Whatever makes it up can be found in all different kinds of matter. |
| Thomson placed a device that measures charge next to the tube. | The device detected charge only when the beam was deflected toward the device. | The negative charge is only in the beam, and the gas surrounding it is neutral. |
| Thomson measured the mass of the charge and the mass of the beams. | He noticed that the ratio of the mass of the charge to the mass of the beam was the same every time. It was also much smaller than the mass of any known atom. | The beam is made of tiny negative particles that always have the same mass and charge. |

From these experiments, Thomson deduced that the beams were made up of tiny, negatively charged particles much smaller than atoms. We call these particles **electrons**. They are **subatomic particles**, which means they are even smaller than an atom! In Latin, *sub* means "under" or "beneath."

After his experiments, Thomson thought that the atom was a solid, positively charged sphere with tiny, negatively charged particles embedded throughout it. Not all scientists agreed with Thomson's model of the atom.



Thomson's Atomic Model

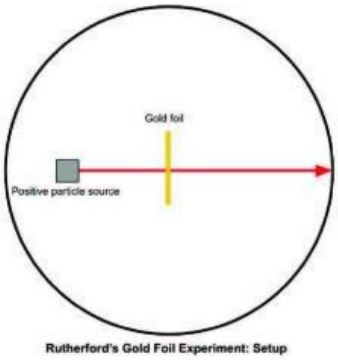
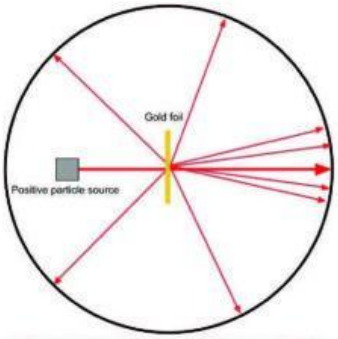
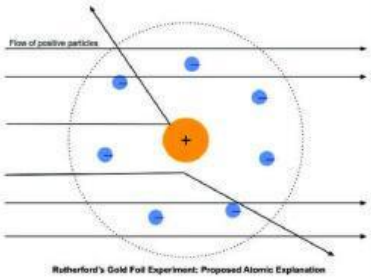
**Text Chunk 2: Write the main idea in your own words or images. (If you are not sure, reread and annotate.)**



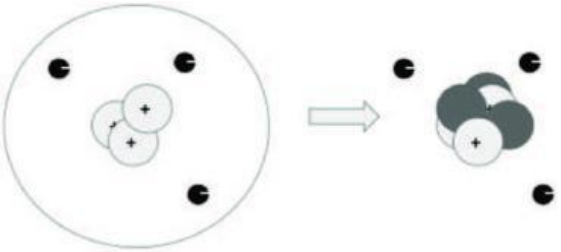
LIVEWORKSHEETS

**Rutherford and Gold Foil**

J.J. Thomson made an important discovery about the electron, but there were still many things about the atom left to figure out. Like all scientists, he worked with many people who helped him learn more about what interested him. One of those people was his student, Ernest Rutherford. Ernest Rutherford and two other scientists, Hans Geiger and Ernest Marsden, designed an experiment to determine where electrons were located in the atom. They used gold foil, or a very thin sheet of pure gold, and a beam of positive particles. By this time, they could precisely aim the positive particle beam at the areas inside an atom. The scientists recorded what happened when positive particle beams were aimed at different areas of each atom to learn more about the structure inside the atom. Some of the results of their experiment are summarized in the table below.

| Experiment | Observations | Conclusions |
|---|---|---|
| Tiny positive particles were directed at a thin sheet of gold foil. The foil was surrounded by a detector to measure where the particles ended up.<br>  <br>Rutherford's Gold Foil Experiment: Setup | Most of the positive particles went through the foil.<br><br>Some particles were deflected. The more closely those particles passed to the center of an atom, the more sharply they were deflected away from the atom's center.<br>  <br>Rutherford's Gold Foil Experiment: Observed Results | Most of the atom must be empty if the particles mostly pass through it unchanged.<br><br>A dense positive charge in the center of the atom repels the positive particles. This center is called the **nucleus**. It has a positive charge.<br>  <br>Rutherford's Gold Foil Experiment: Proposed Atomic Explanation |

Using the information from this experiment, scientists determined that Thomson's model was not very accurate, so they revised it. The data identified a second atomic particle that is positively charged and located in the center, or **nucleus**, of an atom. Scientists called the particles inside the nucleus **protons**. They also learned that most of the atom is empty space, and electrons move around in that space. Later, scientists learned that there is a neutral particle in the nucleus as well. That particle is called the **neutron**, and it is similar in size to the proton. The diagram to the right shows Rutherford's model and the later revised model that added neutrons.



Revised Atomic Models


LIVEWORKSHEETS

**Text Chunk 3: Write the main idea in your own words or images. (If you are not sure, reread and annotate.)**

**Subatomic Particles**

From these experiments, scientists agree that all atoms are made up of electrons, protons, and neutrons. Each subatomic particle has a specific charge: electrons are negative, protons are positive, and neutrons are neutral. Every type of atom contains a different combination of these three subatomic particles.

Not only are the charges different among the three subatomic particles, but their masses are as well. Electrons are much smaller than protons and neutrons. Their relative mass is just 1/2,000 of the mass of a proton or a neutron. This means that it takes 2,000 electrons to equal the mass of one proton or one neutron! Protons and neutrons have a similar mass to each other.

Our understanding of the structure of the atom and how we model that structure has changed over time. We have a better understanding of atomic structure today, but with new technology, we are still learning and revising our model of the atom. Scientists are constantly experimenting to learn more about subatomic particles. This research helps us understand how what happens inside atoms can cause the changes we observe in the world around us.

**Text Chunk 4: Write the main idea in your own words or images. (If you are not sure, reread and annotate.)**

**Choose one of these questions to write about as you navigate back to your lesson question.**

- Evaluate the usefulness of this reading. What did the reading help you figure out about our lesson question?
- What questions did the reading raise for you?
- What does this reading make you wonder?

Star (✱) 1 or 2 ideas you wrote that you are confident sharing with your peers.


LIVEWORKSHEETS

## References

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