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The Rediscovery of Matter: A Historical Trek through Classical Chemistry

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Unit Overview

The technological development that launched the modern society into the space and computer age has relied heavily on a number of basic scientific principles. For example, our electron manipulation makes it possible for computers to functions properly or electricity to power our homes. Despite these types of contributions, the average citizen, regrettably, has little true appreciation for science; what one cannot see, feel, or touch becomes magical, beyond his/her ability to comprehend. This may explain why students often have difficult grasping scientific concepts. As teachers we must reincarnate science by explaining the tricks behind the magic. Through discussions, experimentation, and review and analysis of the classic experiments, we can rediscover those basic laws, theories and principles and thereby guide students toward a better understanding of science.

This unit explores that historical development of the modern atomic theory through the study of matter and the analysis of several classic experiments. It begins by asking the question “What is matter?”. Students will collectively develop a definition though discussions and debates of several ancient philosophical theories by individuals like Plato, Anaxinander, Aristotle, etc. By first developing an independent picture of matter students will be able to recognize any flaws in their definition as new facts, concepts, and/or laws regarding matter are presented. To monitor the progress at constructing a well-formulated definition students will keep a journal.

Once a working definition of matter is developed, the unit will proceed with of the study of classic experiments by scientist like Dalton, Faraday, Thomson, Millikan, and Rutherford. As major theme throughout the unit is rediscovering of matter students become the scientists and, presented with experimental data, must interpret and make conclusions. This method will allow students to seek a clear understanding of why and how the established conclusions were made.

With the review of classic experiments completed, students will establish connections between their findings through debate and discussion, and formulate a hypothetical atomic theory. Students can than review the actual atomic theory as it exist today and compare and contrast this theory with their hypothetical theory.

Ancient Knowledge of Matter

The Greeks were the first in recorded history to ponder extensively about the nature of matter. Their speculations on this issue were left mainly to philosophers who drew their conclusions from observation and reasoning. One of the earliest of these thinkers was Thales who, having observed that water turned to air and steam when heated and solid when frozen, reasoned that all matter was derived from water. Heraclitus, however, believed that the ever-changing nature of fire was compatible with that of matter and thus reasoned that fire was the origin of all matter. Parmednides provided a counter argument; he believed that change was inconceivable since change requires the creation of something new from nothing. This Parmednides argued is impossible, instead he believed that the universe is unchangeable and that change is only an illusion.

It was the atomists (i.e. Democritus and Leucippus) who provided the most accurate and concise depiction of matter at that time. According to the atomist, the basic component of matter (atom) was tiny particles that were qualitatively similar. Some atoms had hooks or eyes, and others had grooves, humps, or depressions that allowed them to unite in various ways and numbers. Until Dalton, this was the most accurate interpretation of matter in that atoms were described as the most basic form of all substances. The atomists' theory was an early version of the current atomic theory.

This section of the unit will focus on how philosophers of antiquity defined matter and the bases for such definition. It will involve reading from ancient Greek literature, class discussion of ideas from these readings, development of a class definition of matter based on deductive reasoning, and journal writing. The guiding question for this section is, "what is matter?".

This section of the unit will partially fulfill Content Standards on scientific inquiry of New Haven Public Schools' Academic Performance Standard by:

- Encouraging student to communicate and defend an argument
- Helping students recognize that the results of scientific inquiry emerge from different types of investigations and public communication among scientist

Instructional Technique

The time limit for this section is 5-7 45 minutes class periods. It will be primarily taught using a modified Socratic Seminar format designed for 30-45 minutes class period. In additions students will keep a journal of the daily discussions which will be later used to develop a class definition of matter.

Socratic Seminar

The Socratic Seminar is a discussion and debate forum originally used by Socrates about 2400 years ago. Through the seminar, students and teacher, functioning at an equal level, pulling from the experiences, ideas, and opinions of each other. Rather than becoming passive learners, students are actively engaged in conversations with their teachers and fellow "classmates". Essential to the success of a Socratic Seminar is the establishment of an environment that is non-threatening and which encourage students to freely express their opinions. The teacher must not dominate the discussion or establish an environment where he/she is seen as an authority on a specific issue.

In the classroom, Socratic Seminars is set up with two groups of students. Each group comprises roughly a half of the class. Students of Group 1 will become actively engaged in the discussion while Group 2 will act mainly as observers and will be responsible for recording the discussion. Chairs are arranged to form an inner (active participants) and outer (observers) circle. The teacher should participate mainly as an observer or a passive participant. The Socratic Seminar consists of four important components:

- a piece of text which introduces a specific idea
- questions presented by the students that relate to the text
- a seminar leader who functions more as a coach
- the participants

The Text

Students will be given a piece of text1 a day prior to the seminar and will be required to write a journal response to this reading as homework. This will encourage students to begin thinking about the idea presented. The texts to be used are as follows.

The Questions

Questions will be generated as the discussion proceeds. The teacher must assign one or two students to lead the discussion. Prior to the journal writing homework, the leader(s) may cue students in on possible direction for the discussion and ask students to address the reading from a given prospective. The leader must have a series of questions, viewpoints, concerns, etc. regarding the reading that will be used to keep the dialogue flowing. Each seminar will begin with the inner circle reading their journal entry. Students may pose questions or make comments to any individual regarding a specific idea presented in the journal. A dialogue will often following smoothly. Before the close of the seminar the inner circle must debate in favor of or against the concepts, ideas, or theories presented in the text.

The Leader

The leader must not be the center of attention but must instead serve to keep the momentum of the discussion moving. He/she must remember that they are more of a participant than a leader and must allow all participants equal opportunity to express their ideas.

The Participants

Students in the outer and inner circle will rotate with each seminar. It is important that the participants, both inner and outer circle carefully study and think about the text. Journal writing is designed specifically to encourage student to take this task seriously. The teacher must reinforce the importance of a carefully thought out and well written journal response. The teacher may choose to collect and grade the journals.

The role of the inner circle participant has been clearly outlined. Outer participants will be responsible for recording the important points from the discussion and than summarizing them after the seminar discussion. Outer circle participants may be assigned to look from arguments that either support or oppose the text. Ideally these students can display charts that outline the pros and cons of each seminar.

The Laws that cleared the Way

The ancient philosophers laid the foundation for a new way of looking at nature. Much of the ideas about matter provided by the Greeks were based on logic and reasoning rather than experimentation and observation. Consequently, little proof was provided to support the ancient claims. To answer the question "what is matter?" the latter two could not be ignored.

Two major discoveries on the principle of chemical behavior path the way to providing a working answer. First was the discovery of the law of conservation of matter by Antoine Lavoisier. In his experiment, Lavoisier measured the masses of substances before and after chemical reactions and found that the masses always remained constant. From this he concluded that matter couldn't be created or destroyed, but instead is conserved. The second discovery was the law of constant composition by Joseph Proust who observed that a given compound always maintained the same elements in the same proportion of mass regardless of quantity of the compound. This section will explore these two laws and afford student an opportunity to improve on the definition of matter.

This section of the unit will partially fulfill Content Standards on scientific inquiry of New Haven Public Schools Academic Performance Standard by:

1. Designing and conducting scientific investigations, while taking into account the proper safety precautions
2. Using mathematics in scientific inquiries

Instructional Technique

The time limit for this section is 5-7 45 minutes class periods. It centers on two laboratory exercises and class discussion.

Discussion and Laboratory Exercise – Matter is Conserved

Students will have a greater appreciation for the law of conservation of matter if they can deduce this law for themselves. A day prior to the lab investigation the class will engage in a discussion on an experiment performed by Lavoisier and the previously documented observations by others that compelled him to carryout his experiment. The discussion will center on the two experiments described below. A Socratic seminar will be ideal here:

Experiment 1 (alchemist) - when water is boiled for sometime in a glass or ceramic container solid residue tends to collect in the container at the end. The alchemist interpreted this as the transformation of water into earth under the influence of fire.

Student will be asked to argue for or against the credibility of the alchemist experiment and the validity of their conclusion. They will then consider methods of improving the experiment by using controls. Once a suitable experimental plan is outlined students will be presented with a description of Lavoisier's experiment for comparison to the alchemist's.

Experiment 2 (Lavoisier) – Lavoisier boiled a weighed quantity of water in a weighed pelican (a closed vessel having a long neck bent back upon itself, picture) for 100 days. At the end of the boiling the total weight of the pelican and its content had not changed. This clearly showed that the fire had not contributed any new mass to the system. Lavoisier, however, observed that the mass of the pelican had decreased, but the mass of the content (water and residue) had increased by an amount equivalent to what was loss from the pelican. He concluded that the solid material must have come from the glass.

Student must then write in their journals their interpretation of how Lavoisier's finding affects the alchemist's conclusion and how it affects the class' definition of matter.

The laboratory exercise will involve a study of mass changes in the two chemical reactions shown below. (For a complete lab handout and description of procedures please reference Wagner et al; page 47). Through this lab student will observe Lavoisier's law of conservation of matter:

(Reaction 1) $Na_2CO_3(aq) + CaCl_2(aq)$ ($2NaCl(aq) + CaCO_3(s)$

(Reaction 2) $CaCO_3(s) + H_2SO_4(aq)$ ($CaSO_4(s) + H_2O + CO_2(g)$

The idea is that the mass of components of Reaction 1 will remain constant throughout the reaction, while that of Equation 2 will decrease. The decrease is expected because the gaseous substance (CO_2) produced will leave the reaction system. Student will be expected to analyze and make assumption as to why that difference in mass occurred in Reaction 2 but not in Reaction 1. They will also be expected to draw conclusions in reference to Lavoisier's experiment. The exercise will close with the class collectively developing of a law (law of conservation of matter) that is supported by the experiments.

Discussion and Laboratory Exercise – Matter Maintains a Definite Composition

Students will explore the law of constant composition by observing the changes in mass of melons following overnight dehydration. The objective is to obtain a clear and accurate understanding of the concepts of the lawpercent composition for the components of a given substance remain constant regardless of the amount of substance present.

Prior to the laboratory exercise students must understand how to calculate percentage compositionthe teacher may chose to provide students will homework practice problems on percentage composition.

The exercise will involve weighing out various quantities of sodium carbonate hydrate ($Na_2CO_3(10H_2O)$ and determining the percent composition of water in the hydrate. Students will observe that regardless of the amount of sample analyzed, the percent composition remains relatively constant. (The complete lab handout with procedures can be found on page 21 of Heisig's Experiment in Chemistry for Engineering Students).

Dehydration is carried out in a clean dry crucible and takes about 30 minutes. Quantities should range from 1-5 grams and should be placed in the crucible. Students than weigh the crucible, hydrate, and cover together. The crucible is heated on a triangle with a small flame until the residue becomes powdery. This will take about thirty minutes or until total mass remains constant. While students wait for dehydration to complete they will respond in their journals to the following question: How will the amount of hydrate used affect the percent composition? The exercise is followed by a class discussion lead by the teacher. The purpose of this discussion is to clearly establish the law of conservation of matter by drawing on the conclusion generated from the laboratory exercise.

The Origins of Dalton's Atomic Theory

An answer to the matter question finally began to take shape with the work of John Dalton. By observing previous experiments and through his research, Dalton concluded that the properties of matter could be explained in terms of an atom. Dalton's atomic theory of matter was based on the following postulates:

1. Each element is composed of extremely small particles called atoms.
2. All atoms of a given element are uniquely identical.
3. Atoms cannot be created of destroyed.
4. A given compound always has the same relative number and kinds of atoms.

Dalton's theories were developed from a number of observations that either contradicted of shed light on previous work. In 'Theory of the Absorption of Gases by Water' Dalton considered that different types of substances (atoms and molecules) were physically unique in terms of quantity and mass. He wrote

> "The greatest difficulty attending the mechanical hypothesis arises from different gases observing different laws. Why does water not admit its bulk of every gas alike? …I am nearly persuaded that the circumstance depends upon the weight and number of ultimate particles of several gases: those particles that are lightest and single being least absorbable and the other more as they increase in weight and complexity."

Dalton is hypothesizing that physical properties (i.e. density, texture, etc) of matter may depend on properties (mass and quantity) of some basic component (atom).

This part of the unit will explore Dalton's Atomic Theory through the study of various works by Dalton and others who contributed to this theory.

This section of the unit will partially fulfill Content Standards on scientific inquiry of New Haven Public Schools Academic Performance Standard by:

1. Designing and conducting scientific investigations.
2. Incorporating technologies.
3. Communicating and defending a scientific argument.
4. Using mathematics to analyze and solve problems.
5. Recognizing that results of scientific inquiry emerge from different types of investigations and public communication among scientists.

Instructional Technique

Working in groups of three, student will make use of Internet and library resources to research Dalton's atomic theory. In this assignment students will be required to research and discuss the experiments and observations made by Dalton's and others of his time which ultimately lead to the development of the atomic theory. Accompanied by a 3-5-page paper, each group will present their research to the class. A question answer section will follow each presentation. This part of the unit will conclude with students designing and constructing a model impression of an atom that must be supported with cited experimental evidence.

Research Project

Students will be given 3 days of class time to research and organize their report. It is essential that each group have access to the Internet and that the prescribed time is set aside for groups to perform their research. The teacher must set daily objective that will keep students on task.

Explaining the Inner Atom

By combining Lavoisier's law of conservation of matter and Proust's law of definite proportions, Dalton was able to establish his atomic theory and to suggest a model for matter as tiny solid particles. Explaining the atomic theory was the stepping stone to developing the modern model for the atom. Dalton's work provided a general explanation for matter. But what exactly are these atoms that Dalton and, previously, the atomists had proposed? What were they made of? What give them shape and form? What distinguished on atom from another?

It was not until the discovery and further investigation of the electron in the late 1800s that the true nature of the atom could be explored. Once associated with the atom, electrons appeared to universal component of all matter. It was believed that the negatively charged electron floated in a sea of positive chargethis was the only conceivable organization to support a stable atom composed of negatively charged particles. This model of the atom was referred to as the plum pudding modelit was likened to the English plum pudding; negative electrons represented the plums floating in the pudding.

In 1909, Ernest Rutherford performed his famous gold foil experiment that discredited the plum pudding model. Instead, Rutherford's experiment established that the atom is mostly empty space with an extremely dense, positively charged nucleus.

This section will explore Rutherford's nuclear model of the atom through a class discussion, review, and analysis of his classic experiment and a laboratory exercise that assigns the students to develop a logical model of a hidden object.

This section of the unit will partially fulfill Content Standards on scientific inquiry of New Haven Public Schools Academic Performance Standard by:

1. Designing and conducting scientific investigation
2. Communicating and defending a scientific argument
3. Recognizing that the results of scientific inquirynew knowledge and methodsemerge from different type of investigations and public communication among scientist.

Instructional Technique

The time limit for this section of the unit is 2-3 45 minutes class periods. It will begin with the review and analysis of Rutherford's gold foil experiments and an interpretation of his results from this experiment. This review will be followed by a laboratory exercise that challenges students to determine the approximate shape, size, and location of an object hidden inside a black box. Students must develop their own procedures and draw conclusions based on their observation

The teacher may find Niel Jespersen's book Chemistry quite helpful at explaining the experiments performed by scientists like Sir William Crookes (cathode ray tube experiment), Robert Millikan (oil drop experiment) whose work contributed to Rutherford's experiments. The book can be purchased from Barns & Nobles or Amazon.com.

Review of Rutherford Gold Foil Experiment

Rutherford's experiment verified that an atom is mostly space and the bulk of the mass is concentrated in a very small volume of the atom called the nucleus. Prior to his experiment, it was generally accepted that the mass was evenly distributed through out the atom as is demonstrated by the plum pudding model. To test this model, Rutherford performed an alpha scattering experiment where he aimed very small alpha particles through a very thin piece of gold foil. If the previous plum pudding model accurately depicted the atom, Rutherford expected that most of the alpha particles would be deflected as is shown in the figure 1 (appendix). Instead, Rutherford observed that the vast majority of the particles passed through the foil without any deflection, as though the foil was not there, while a few particles were deflected at large angles (figure 2; appendix). From this, he concluded that most of the particles pass through empty space, while a few collided with the relatively dense nucleus.

Introduction to the Experiment

The teacher will provide a brief (15 minutes) introduction to the plum pudding model and explain this model to the students. The important idea to get across is that the mass of is evenly distributed throughout the atom. An overhead projection of the plum pudding model atom as shown in figure 1 is helpful at providing students a visual representation of this model. Allow students to ask questions for clarification.

Once students have been introduced to the model, the teacher must discuss the concept of deflection. Ask students the following questions

What would they expect to occur if light is shined at mirror? (Answer: it will be reflected). What happens then if the mirror reflective surface was not completely intact, but was instead transparent at certain areas? (answer: some of the light will pass through) To better introduce the idea of deflection, the teacher could perform a demonstration by shinning light through the two different types of mirrors and allowing the students to observe for him or herself.

Analysis of the Models

Once the plum pudding model is introduced, assign students to groups of 2 to complete worksheet 1 in the appendix. The worksheet is design to get student to think creatively and critically about the plum pudding model and Rutherford's gold foil experiment.

Developing a Model of a Hidden Object

The exercise was revised from Exercise and Experiments in Modern Chemistry. Like Rutherford's experiment students will perform an experiment to determine the approximate location, size, and shape of an object located in a box. The teacher will prepare boxes sealed with a stationary object and a marble that acts as a probe. Working in groups of 2 students will develop their own procedure, record their observations and construct a logical model. (For a complete lab handout please refer to page 141 of Exercise and Experiments in Modern Chemistry). The exercise is designed to model Rutherford's experiment in that the box represents the atom, the hidden object represents the nucleus, and the marble represents the alpha particle.

General Organization of Electrons, Protons, and Neutrons

The teacher should provide students with picture of a general and simplified structure of the atom, showing the nucleus composed of protons and neutrons, and electrons outside the nucleus. Protons are positively charged and are held together in the nucleus by the neutrons (proton glue) which has no charge. Electrons are negatively charged and exist outside the nucleus. Both protons and electrons have equal but opposite charge magnitude. Protons and neutrons have relative masses of ~1.00g and electron has a relative mass of 0.00 g thus the mass of atoms is roughly equivalent to the combined mass of the protons and neutrons. (See Table 1 for some general information on protons, neutrons, and electrons).

Exercise Determining the number Particles in an Atom

The periodic table can be used to determine the number of protons, electrons, and neutrons in a particular element. For any given element the number of protons (p) is equal to the atomic number (z) of the element ($p = z$) and the number of electrons (e) equals the atomic number minus the charge ($e = z – c$). The number of neutrons (n) is equal to the mass number (m) minus the atomic number ($n = m – z$).

In this exercise students must complete a table by calculating the number of protons, neutrons, and electrons (See worksheet 2).

Energy and the Atom

While the general structure of the atom was being discovered, physicists were performing experiment that would revolutionize how matter is viewed. They observed that each element, when heated, produced a characteristic color with discrete wavelengths of light (line spectrum) that was unlike the uniform rainbow spectrum of white light passing through a prism. With the exception of hydrogen, the line spectra of most elements are very complex. Consequently, Niels Bohr used the hydrogen atom to explain a model that considered line spectrum. The solar system model, as it is called, assumes that electron move around the nucleus in certain allowed orbits (which are also called energy levels or shells). Electrons thus retain definite energy characteristic of the orbit in which it is moving. The further a shell is from the nucleus, the more energy an electron will possess. Electron can move from the lowest possible Energy State (E1; ground state) when they absorb energy (i.e. when heated) to a higher energy state (E2; excited state). When the electron returns to the ground state, it emits a definite amount of energy (DðE) equal to the difference in energy between the ground and excited states (DðE = E2 - E1). The characteristic color or wavelength is explained using the equation, DðE = h × c (lð, where h and c are constants and lð is the wavelength. Since each element is capable of emitting a unique amount of energy, each will give a unique wavelength.

The actual model is more complex than the Bohr's solar system model. Teachers can find additional information on the wave-mechanical model most introductory chemistry textbooks, or see Mortimer's Chemistry listed in the reference section. It will suffice, however, to simply discuss the Bohr's model of the hydrogen atom so that student have a general idea of orbits, shells, atomic energy, etc.

This section of the unit will introduce students to the Bohr's model of the hydrogen atom and help students develop an appreciation for electron orbits and the related energy. It will focus mainly on a lecture and a laboratory experiment.

This section of the unit will partially fulfill Content Standards on scientific inquiry of New Haven Public Schools Academic Performance Standard by:

1. Designing and conducting scientific investigation while taking proper safety precaution into consideration
2. Using mathematics in scientific inquiry
3. Recognizing that the results of scientific inquirynew knowledge and methodsemerge from different type of investigations and public communication among scientist.

Instructional Technique

The time limit for this section is 3-4 45 minutes class periods. It centers on a lecture/class discussion and a laboratory exercise.

Lecture on the Bohr's Model for the Hydrogen Atom

The important concepts to get across are described in the section summary above. To begin discussing the solar system model it will be helpful to show a figure of the solar system to be used as an analogy for explaining the hydrogen atom. Student should be able to visualize the planets as electrons moving in specific orbits and the sun as the nucleus. They must also understand why each element will produce a unique line spectrum. This is accomplished by describing each element as a solar system with varying number of planets at unique distances from their sun. If each unit distance from the sun is a specific energy value, when students calculate DðE for various excitement/relaxation events they will observe unique series of wavelengths for each solar system.

Flame Test Lab Exercise

The laboratory exercise to be used can be obtained in Prentice Hall Chemistry: The Study of Matter, page 127. In this exercise students will observe unique color emission for different metallic ions (Na+, K+, Li+, Ca2+, Sr2+, Ba2+, Cu2+) when heated and, base on this observation, must determine the identity of an unknown substance.

Teacher General Background on Electron Structure of the Atom

The rotation of electrons around the nucleus is much more complex than the model proposed by Bohr. All electrons do not move in circular pattern, as do planets but instead move in spherical and dumb-bell shaped spatial regions around the nucleus that are called orbitals. There are 16 different orbitals (1 s orbital; 3 p orbitals -px, py, pz; 5 d orbitals -dyz, dxz, dxy, dx2-y2, d z2, and 7 different f orbitals). Orbitals exist in subshells that in turn exist in shells (these terms are explained later). Unlike the planetary orbits where the exact location of a planet can be pin-point at any given time, electron orbitals represent a region of space around the nucleus where there exists a high density of electron. It gives the probability of an electron be at a specific point in space at a given time. Each orbital has a distinct shape and orientation in space. s orbitals are spherical around the nucleus while the other three are dumb-bell shaped (for a pictorial representation of each see Jespersen Chemistry, page 15-16). As stated previously, the number of each type of orbital may vary. There is 1 s, 3 p, 5 d, and 7 f orbitals, each aligned with the x-, y-, and z-axis differently (see Jespersen page 15-16). Each orbital holds a maximum of two electron, thus s orbitals hold a total of 1 (2 = 2 , p holds 3 (2 = 6, d holds 5 (2 = 10, and f hold 7 (2 = 14 electrons.

The modern model of the atom has a nucleus of positively charged protons surrounded by orbitals of negatively charged electrons. The electrons, moving in their orbitals, are distributed at distinct Principal Energy Levels (or shells). These shells are distinguished by their Principal Quantum Numbers (n) 1 for the first shell (closest to the nucleus), 2 for the second, 3 for the third, and so on. Each shell can have a maximum of n2 orbitals (i.e. the second shells can have 22 or 4 orbitals) and 2n2 electrons.

Energy Sublevels or subshells exists within shells and are the direct vessels for orbitals (orbitals in subshells; subshells in shells) and are represented by their Azimuthal Quantum Number (l). l begins with 0 and can move up incrementally by 1 but can never be greater than n-1, thus there can be a maximum of n subshells. There are four different types of subshells that are of importance to high school chemistry; these are s, p, d, and f subshells with l = 0, 1, 2, and 3, respectively.

Magnetic Quantum Numbers (ml) are used to represent the orbitals. ml has a value from - l ...o...+ l . For example, for l =1 (p subshells) ml =-1,0,1 where these numbers represent px, pz, and py, respectively. Since each orbital can carry a maximum of 2 electrons there must be a way to distinguish the two electrons. Pair electrons must have opposite spins that are given a Spin Quantum Number2 (ms) of +½ or –½.

Concluding Assignment

The teacher may chose the complete this unit with an in-class test and a 3 page typed paper where each student is expected to provide a written interpretation of matter and to express how their concept of matter has changed over the course of the unit. The class as a whole must develop a final definition for matter.@$:

Work Sheet 1 – Looking Inside the Atom Student #1 _________________

Student #2 _________________

Dalton's atomic theory explained in general terms that matter was composed of tiny particles and that each element (e.g. Gold, silver, carbon) consists of uniquely identical particles. In a sense, Dalton's theory showed only what atoms look like if viewed from the outside. Scientist wanted to understand what "stuff" gives atoms their substance and how this "stuff" was organized.

The Plum Pudding Model

Once scientists discovered electrons (the "stuff") and associated them with atoms a model was developed to explain what atoms looked like on the inside. This model, called the plum pudding model, said that the "stuff" was evenly distributed throughout the atom to create a solid mass.

(FIGURE HERE)

Ernest Rutherford performed an experiment to test this model. In his experiment he took a thin sheet of gold foil and aimed tiny particles called alpha particles at it. Alpha particles are much like light in that they will easily pass through open space. Rutherford wanted to see if the gold sheet would stop the alpha particles from going through by reflecting the alpha particles like a mirror would reflect light.

Question 1: Why did Rutherford use a thin sheet of foil rather than a square block?

(HINT: it was not to save cost)

What did Rutherford observe in his Experiment?

Rutherford found that instead of reflecting the alpha particles like a mirror would reflect light, almost all of the alpha particles went directly through the foil and only a very small amount was reflected. See the figure below.

(FIGURE HERE)

Question 2: How does the reflective property of atoms differ from that of mirror?

Question 3: The stuff is the only part of the atom that can reflect alpha particles. If this is the case, what does the observation from Rutherford's experiment tell you about the arrangement of the "stuff" in the atom?

Draw a model of an atom that fits the observation Rutherford made.

Question 4: If you were Rutherford what conclusion would you make about the atom?

Work Sheet 2 – Determining the number Particles in an Atom Name ____________

Using the Periodic Table and the equations provided complete the following table

Equations

1. The number of protons (p) is equal to the atomic number (z) of the element

p = z

2. The number of electrons (e) equals the atomic number minus the charge (c)

e = z - c

3. The number of neutrons (n) is equal to the mass number (m) minus the atomic number.

n = m – z

Symbol	Atomic Number	Mass Number	p	e	n
Co			59		
	48		112		
			14	7	7
			84		48
A1			27		
	60		144		

Figure 1 The Plum Pudding Model of the Atom

Atoms were believed to have there mass evenly distributed with negatively charged ele-ctrons floating in a sea of positive charge. With such a model, Rutherford reasoned that most of the high speed alpha particles will be deflected so that very few actually pass th-rough the atom.

(figure available in print form)

Figure 2 Rutherford's Nuclear Model

When aim through a thin piece of gold foil, a majority of the particles passed freely through and there was very little deflection. Rutherford concluded that most of the atom is open space and that the deflection was due to the massive nucleus.

(figure available in print form)

Notes

1 You can find the thoughts on matter by philosophers of antiquity at www.web-lines.com/philosophy/xeno.htm (5/16/99) or by simply searching the Internet for sites that offer this information. 2 The practical significance of quantum number-- n represents the average distance of the electrons from the nucleus, or the size of the shell. l represent the shape of the orbital within the subshell. ml represent the orientation of the orbital in space and ms represents the spin of the electron.

Bibliography

Teacher Reading List

Greenaway, Frank. John Dalton and the Atom. London, England: HeinemannEducational Books Ltd, 1966 Ihde, Aaron. The Development of modern Chemistry. New York, NY: Harper & Row Mierzecki, Roman. The Historical Development of Chemical Concepts. Warszawa, Poland: Klumer Academic Publishers Mooe, F. J. A History of chemistry. New York, NY: McGraw-Hill Book Company, Inc, 1918 I found these four books extremely helpful at providing information on the history of chemical development and reviews of the classic experiment. I used Greenaway's book extensively to research Dalton's contribution to the atomic theory. Mierzecki's book provided a wonderful overall review of important concepts and developments while also interconnecting the work of various scientist Heisig, G. B. Experiments in Chemistry for Engineering Students. Minneapolis, MN: Burgess Publishing Co, 1941 Metcalfe, W. Exercises and Experiments in Modern chemistry. New York, NY: Holt, Wagner, Maxine. Prentice Hall: Chemistry, the Study of Matter: Laboratory Manual 3rd Edition. Needham, MA: Prentice Hall, Inc. These three book help me develop various laboratory exercises, class activities and worksheets. Ihde, Aaron. The Development of modern Chemistry. New York, NY: Harper & Row Jespersen, Niel. Chemistry. New York: Barrons Educational Series, Inc. Mortimer, Charles. Chemistry 5th Edition. Belmont, CA: Wadsworth Publishing Company These three books provided more up-to-date scientific concepts that I used in the later part of the unit. Jespersen's book was my favorite because he has presented very complex chemical concepts in a clear and concise manner that is easy to read and follow. I definitely recomend that you check Barns & Nobles bookstore for this book. It is basically a will written handbook of common referenced chemical concepts.

Student Reading List

Jespersen, Niel. Chemistry. New York: Barrons Educational Series, Inc.

Mortimer, Charles. Chemistry 5th Edition. Belmont, CA: Wadsworth Publishing Company

I have already commented on these two books. The student reading list is really left to the teacher. Most important for the unit is that the students have an up-to-date chemistry textbook. Most high school text will include information on the concepts presented in this unit. Teacher can supplement the reading with information they find useful. List of Materials

Journal Notebook for each student

Overhead projector

Transparencies

500 g each of the following

Na2CO3

CaCl2

CaCO3

H2SO4

Na2CO3(10H2O

Internet Access Computers

Mirror

Aqueous Solutions of each of the following ions

Na^+, K^+, Li^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Cu^{2+}