# Atomic Structure

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## Overview:

The proposed curriculum unit is designed for an eleventh grade, college preparatory, chemistry class. The unit will present a sequential, developmental history of the structure of the atom from the ancient Greek philosophers up to, and including, current research on elementary particles. As designed, the unit will encompass a two-week period. In addition to the contributions of the early Greek philosophers, topics to be discussed will include the accomplishments of prominent nineteenth, and twentieth century chemists, physicists and mathematicians. In addition to cooperative learning strategies and traditional note taking, the students will use computer software, on-line websites, and conduct laboratory experiments that help demonstrate specific concepts.

## Rationale:

I have been a high school science teacher with the School District of Philadelphia for over twenty years. During that time, I have taught physical science, biology, chemistry, physics, and applications of science and technology. For the past twelve years, I have been teaching at Robert E. Lamberton High School, one of the smaller, neighborhood, public high schools in the city of Philadelphia where I have witnessed changes in: administration, faculty, pedagogical strategies, demographics, and scholastic achievement. The focus of the school, however, has remained the same: an academic, college preparatory high school. Currently, I am teaching four chemistry classes to mostly eleventh grade students. The entire eleventh grade population, at the school, consists of about one hundred and twenty predominantly African-American students whose scholastic ability varies widely with many students having below grade level reading and math skills.

This curriculum unit has been designed to complement unit two of the School District of Philadelphia's core curriculum for chemistry. As outlined in the *Planning and*

*Scheduling Timeline* (1), unit two is primarily devoted to the historical development of the atom (1). The purpose of this unit, therefore, is twofold in nature. First, and foremost, the students will be presented with a thorough background into the structure of the atom. Additionally, the unit was prepared to demonstrate to the students how scientific theories can change over time based on the accomplishments and contributions of individuals from a variety of disciplines.

The idea that matter can be broken down into a fundamental particle that is no longer divisible can be traced back approximately 2400 years ago to ancient Greece. It is believed that the Greek philosopher Leucippus and, to a greater extent, his student Democritus were the first to theorize the concept of the atom (2). Their ideas were, in large part, discounted by a number of other well known philosophers of that period, such as Aristotle and Plato. Aristotle believed that matter could be divided indefinitely and that substances were combinations of four elements: fire, air, earth, and water. As a result, the concept of the atom which was based on philosophical thought remained unchanged and obscure for centuries (3).

It was the English chemist, John Dalton who, for the first time, presented scientific evidence for the existence of atoms. In 1803, Dalton proposed his model of the atom based on the findings of the eighteenth century French chemists Antoine Lavoisier, and Joseph Proust. Using the law of conservation of mass, the law of definite proportions, and the law of multiple proportions, Dalton's atomic theory consisted of the following four points: 1. matter is composed of indivisible particles or atoms, 2. atoms of the same element are identical, 3. the atoms of different elements are different in chemical properties and mass, and 4. compounds are formed when the atoms of different elements combine in definite proportions. From this, Dalton envisioned the atom as being a solid sphere that was indivisible and thus the smallest particle of matter (4).

For nearly one hundred years, Dalton's model of the atom remained the foundation of nineteenth century chemistry. Expanding the work conducted by William Crookes on cathode rays, in 1897 John Joseph Thomson discovered the negatively charged electron. This important discovery demonstrated, for the first time, that the atom is not the smallest, or fundamental, particle of matter, but that to the contrary the atom must contain even smaller subatomic particles. Thomson theorized that if the electrons had a negative charge, there must be, as yet to be discovered, positively charged particles. With this in mind, Thomson's model of the atom, also referred to as the "plum pudding model" was envisioned as be composed of a soft, mushy, positively charged sphere with the negatively charged electrons embedded in it (5).

In describing the structure of the atom, one must also give attention to the nature of light. Controversy as to the true nature of light dates back to the seventeenth century. At that time, Christian Huygens believed that light behaved as waves, whereas Sir Isaac Newton believed that light acted as particles having linear motion. One important premise of Newton's corpuscular theory of light was that the speed of light in water would have to be greater than the speed of light in air. It was in 1802, that Thomas Young, an English physicist, demonstrated in a series of experiments that light did in fact behave as waves. The final evidence against Newton's corpuscular theory of light came in 1850 when the

French physicist, Jean Foucault, experimentally determined that the speed of light in air was greater than the speed of light in water. In 1865, the Scottish physicist and mathematician James Clerk Maxwell formulated a series of equations with which he was able to predict that light, heat, and electricity were all forms of electromagnetic waves. During the later part of the nineteenth century, however, the German physicist, Max Planck, proposed that light was made up of quanta, or photons, giving rise to the quantum theory of light. Planck's findings once again revived the particle theory of light controversy (6).

Ernest Rutherford, one of Thomson's students, performed his famous gold foil experiment in 1909. The results of this experiment led Rutherford to propose his planetary, or orbital, model of the atom. In this model, the negatively charged electrons were believed to occupy definite orbital paths around a small, dense, positively charged center called the nucleus. However, his model was inadequate in explaining why the orbiting electrons did not lose energy and collapse into the nucleus. Four years later, in 1913, the Danish physicist, Niels Bohr, expanding Max Planck's findings proposed that an orbiting electron, within a specific energy level, is able to absorb energy from light or heat and jump to a higher energy level, known as the excited state. After losing energy, the electron would return to the lower energy level, the ground state, giving off light of a particular frequency. Bohr's model thus explains the problem encountered in Rutherford's model (7).

Since Max Planck proposed that waves behaved as particles, the French physicist, Louis de Broglie, in 1923, theorized that particles should have wavelike characteristics. From their findings, light is currently believed to behave as both particles and as waves. Erwin Schrödinger, an Austrian physicist, formulated the wave function equation in 1926 that is used to calculate the probability of finding the location of a given electron. Then in1927, Werner Heisenberg, the German physicist, went on to propose his uncertainty principle, which is the inability to know both the exact location and velocity of an electron at any given time. Applying these findings to Bohr's model led to the creation of the wave-mechanical model of the atom. Briefly stated, instead of electrons orbiting the nucleus in circular paths, the wave-mechanical model suggests that the electrons, being particles, orbit the nucleus in wavelike motion (8).

In 1932, while working on the discrepancies between the atomic number and the actual atomic mass of elements, James Chadwick, an English physicist, discovered yet another subatomic particle, the neutron. Being electrically neutral and having about the same mass as a proton, the neutron was thought to be a proton-electron complex. This theory is no longer held to be valid, as will be addressed later (9).

Experiments with particle accelerators after World War II have led to the discovery of numerous new subatomic particles. These discoveries ushered in the era of elementary particle physics. The two main categories of elementary particles, based on their spin characteristics, are the fermions and the bosons. Since fermions are believed to be involved in the structure of all matter, they will be discussed in preference to the bosons. Fermions, having odd half-integer spins, obey the Pauli exclusion principle which states that the electrons in an orbital pair must have opposite spins. The fermions are classified into twelve different classes or flavors. Of particular interest, to this curriculum unit, are the leptons and the hadrons. There are six types of leptons that are believed to be true fundamental particles having no further internal structure. The leptons either have no electrical charge or a -1 electrical charge. Based on these characteristics, electrons are considered to be leptons. Hadrons are composite particles that are believed to be made up of quarks. There are six different types of quarks, all having fractional electrical charges. Both protons and neutrons are considered to be hadrons. The proton is composed of two up quarks and one down quark. The up quarks have a +2/3 electrical charge whereas a down quark has a -1/3 electrical charge. This composite makeup would give the proton its overall +1 charge. The neutron, no longer believed to be a proton-electron complex, is made up of two down quarks and one up quark. Based on the aforementioned electrical charge designation for each type of quark, the composite makeup for the neutron would explain its overall neutral charge (10).

**Objectives:**

This curriculum unit has been designed in such a way that each student should be able to: 1. explain the different types of atomic models, who proposed them and when, 2. explain the differences between electrons, protons, and neutrons based on their locations, and electrical charge, and 3. explain the significance of elementary particles to the structure of the atom. These objectives are in alignment with both the Pennsylvania Academic Standards for Science and Technology and the School District of Philadelphia's core curriculum for chemistry.

As designed, the curriculum unit is intended to address at least two Pennsylvania Academic Standards for Science and Technology. The first, academic standard 3.2, "inquiry and design", involves comparing different scientific theories, and performing experiments. The second, academic standard 3.4, "physical science, chemistry, and physics", includes understanding the nature, composition, and properties of matter. Unit two of the School District of Philadelphia's core curriculum for chemistry is entitled "Atomic Structure". It involves the sequential events leading up to the modern atomic theory thereby demonstrating the scientific method with an emphasis on theoretical changes based on new observations and discoveries.

**Strategies:**

The School District of Philadelphia's Office of Curriculum and Instruction has developed a plan for improving the scholastic performance of each student in every high school within the district. This initiative involves the use of six strategies that would address school-wide success, and includes the following: 1. previewing content specific vocabulary on a daily basis, 2. previewing, analyzing, and connecting material presented in textbooks, 3. reciprocal teaching, 4. summarizing material, 5. the use of comprehension connectors, and 6. structured note taking.

Implementation of this plan relies heavily on the use of student centered, cooperative learning techniques, peer tutoring, and the ability to take notes. Cooperative learning has been a viable pedagogical strategy for many years. The benefits of cooperative learning to the student include improvement in: scholastic achievement, social skills, and self-esteem. To maximize the benefits, to both the student and the teacher, deliberate care should be taken in establishing the learning groups. In order to create, manage and maintain a successful cooperative learning environment, one should consider the following six key concepts:

1. team organization
2. cooperative management
3. the will to cooperate
4. the skill to cooperate
5. basic practices
6. structuring of the cooperative lesson

In the next few paragraphs, a brief summary of each concept will be presented (11).

In the past, I have found that team organization should be based on academic heterogeneity rather than random selection or determined by the students. The former category, academic heterogeneity, allows for the establishment of groups with high, middle and low achieving students. Academic heterogeneity within the class can be determined within the first week of school by administering an entrance test. Personally, groups consisting of four students have worked out extremely well for a number of reasons. Besides allowing for academic heterogeneity, it also takes into consideration student attendance rates. Individual groups can still function even if half of the students within any group are absent on any given day. In addition, it permits peer tutoring opportunities within each group.

Classroom management is essential in order for a cooperative learning environment to be effective. This can be accomplished through: cooperative management, the will to cooperate, and the skill to cooperate. It is imperative that students understand the guidelines for acceptable classroom behavior. For example, teacher directed signals for addressing the noise level within the class must be established. The will to cooperate is developed over time and is based on positive social interactions and pride within the group. The skill to cooperate involves students being able to assume specific roles within the group, listen to, and work with each other.

The basic practices inherent to cooperative learning include: simultaneous interaction, positive interdependence, and individual accountability. Students, within the cooperative learning classroom, have the freedom to simultaneously interact with each other which is not afforded in the traditional classroom setting. Positive interdependence comes from the achievement of individual students within a group and of the entire group as a whole. Individual accountability can include a number of different forms. Students can be given individual grades for a project, or they can be aware of their part of a group grade.

Effective classroom management is due, in large part, to the structuring of the lesson. Structuring not only involves the arrangement of students within groups, but it also includes the manner in which individual lessons are designed and presented. These structures, designs, or activities are meant to improve such areas as: teambuilding, information sharing, thinking skills, communication skills, and content mastery. A brief list of classroom structures and lesson designs include:

- Brainstorming
- Jigsaw
- Numbered Heads Together
- Rallytable
- Roundrobin
- Roundtable
- Student Teams Achievement Divisions (STAD)
- Team Projects
- Think Pair Share

A more detailed review of each is given in *Cooperative Learning* (11)**.**

By improving their note taking skills, students should be able to utilize, practice, and/or engage in summarizing, comprehension connectors, and structured note taking. Therefore, I intend to teach my students the highly successful method of note-taking that was developed by Walter Pauk, an English professor at Cornell University, in the 1950's. The Cornell Method, as it is referred to, involves writing a key word, phrase, or concept on the left hand side of a sheet of paper. In a column, on the right hand side of the paper, relevant material about that concept is written in short sentences, or phrases. Finally, at the bottom of the page, the material listed is then summarized into a short paragraph. This widely used method enables students to improve their skills in summarizing material presented in both lecture and written form (12).

In order to address, and improve, reading comprehension, my students will participate in reciprocal teaching techniques. This is another cooperative learning activity that is designed to encompass four skills: summarizing, questioning, clarifying, and predicting. Each student within the group will be responsible for reading a specific section within their textbook, summarizing that material, and reporting out to the rest of his or her group (13).

Students will also be able to utilize a variety of interactive tutorial software and online websites including, but not limited to: Holt ChemFile Interactive Tutor, ChemASAP, Chemistry: Connections to Our Changing World Interactive Student Tutorial, SciLinks, go.hrw.com, and Holt Online Learning. SciLinks is an online website developed by the National Science Teachers Association which contains links and activities related to chapter specific topics . The Holt Publishing Company has developed several online resources such as: go.hrw.com for worksheets, activities, and projects directly related to the textbook used by the students. The Holt Online Teaching is an online website where students can access help in solving problems. Additional hands on activities that will be used include traditional laboratory experiments.

**Classroom Activities:**

Utilizing the Cornell Method of note taking and cooperative learning techniques, such as: brainstorming, numbered heads together, reciprocal teaching, and team projects, the first few days of the curriculum unit will focus on presenting the students with an historical background on the development of the atom. After completing the assigned work from their textbooks, the students will then complete a number of assignments using the following on-line SciLinks topics:

- Development of Atomic Theory (HW4148)
- Current Atomic Theory (HW4038)
- Subatomic Particles (HW4121)
- J. J. Thomson (HW4156)
- Atomic Nucleus (HW4014)
- Atomic Structures (HW4015)
- Atoms and Elements (HW4017)
- Energy Levels (HW4051)
- Electromagnetic Spectrum (HW4048)
- Light and Color (HW4075)
- Producing Light (HW4099)

As an alternative assessment project, each group of students will be given a different list of scientists and mathematicians from whom they could choose to write a report. Additionally, the students will be able to create posters of the different models of the atom. Prior to assessing the student's knowledge of the concepts presented in this unit, the students will use the following computer software programs:

1. Holt ChemFile Interactive Tutor Module 2 entitled "Models of the Atom" contains the following sections:
    - Atomic Structure Tutorial
    - Atomic Structure Practice
    - Electron Structure Tutorial
    - Electron Configuration Tutorial
    - Electron Configuration Practice
2. ChemASAP (Prentice Hall) Chapter 5: "Atomic Structure and the Periodic Table contains:
    - Animation 4: The Nuclear Atom
    - Assessment Section 5.1 entitled "Atoms" is made up of five fill in the blank and multiple choice questions dealing with Dalton's atomic theory.
    - Assessment Section 5.2 entitled "Structure of the Nuclear Atom" also has five fill in the blank and multiple choice questions focusing on subatomic particles.
    - Assessment Section 5.3 entitled "Distinguishing Between Atoms" has five fill in the blank, multiple choice and true or false questions.
3. Chemistry: Connections to Our Changing World Interactive Student Tutorial (Prentice Hall) Unit 2: "The Structure of Matter" includes the following:
    - Animation: "Rutherford's Experiment"
    - Animation: "Electron Orbital Shape"
    - Chapter 3 test contains twenty multiple choice questions which focus on the structure of the atom.

- Chapter 4 test is also made up of twenty multiple choice dealing with electron configurations.

This unit was designed, in part, to address standard 3.2, "inquiry and design", of the Pennsylvania Academic Standards for Science and Technology. As a result, at least three laboratory experiments relating to the structure of the atom will be assigned.

Experiment 1: Relating Electrons and Probability (14)

The purpose of this activity is to demonstrate the work of Erwin Schrödinger and Werner Heisenberg. In this experiment, students will be able to examine the probability of locating an electron within any of the first three energy levels. The activity involves tossing a single dice at least fifty times. Three sides of the dice have one dot written on it, two sides have two dots, and one side has three dots written on it. To determine the probability, students will use the following equation:

Probability = number of favorable outcomes/ total number of outcomes

The expected probabilities would be as follows: tossing a one 0.50, tossing a two 0.33 and tossing a three 0.17.

The students will be able to graph their results using the following procedure. One dot represents any square up to three centimeters from the center square, or nucleus, on the graph paper. This is intended to represent electrons located within the first energy level of an atom. The second energy level is determined by two dots. They are graphed by using the squares on the graph paper located between three and five centimeters from the center square. The third energy level is determined by the side of the dice having three dots. Those results are graphed in the squares between five and seven centimeters from the nucleus, or center square. From the probabilities calculated above, the results should indicate that the electrons have a higher probability of being located in the lowest energy levels, the one closest to the nucleus. Based on their results, the students will be expected to answer the following questions:

1. What is the definition of probability?
2. Which area contained the most darkened squares?
3. How do the results compare among different groups of students?
4. Which energy level shows the highest probability for finding an electron, and which energy level shows the least probability for finding an electron?
5. What is the probability of finding an electron in the first energy level, the second energy level, and the third energy level based on this experiment?

Experiment 2: Flame Tests (15)

In explaining the energy requirement for the movement of electrons around the nucleus of an atom, Niels Bohr proposed that by absorbing energy from light or heat, electrons within a specific energy level, are able to move from a region of lower energy, or the ground state, to one of higher energy, or the excited state. Electrons in the excited state are unstable and, therefore, readily lose energy in the form of light, as they return to their normal ground level state. The frequency of the emitted light, f, is directly proportional to the energy E which is released, as given by Planck's equation, $E = hf$, where h is Planck's constant which is equal to $6.63 \times 10^{-34}$ joule-seconds. This absorption and emission of energy by the electrons is the reasoning associated with their continuous movement around the nucleus.

By performing this experiment, students will be able to observe the characteristic flame color produced when individual 0.5 M chloride solutions of barium, calcium, lithium, potassium, sodium, and strontium are placed in a laboratory burner. When viewing the flame through a spectroscope, students will be able to determine the bright-line, or emission, spectrum for each metallic element. In the final part of the experiment, students will also be able to identify an unknown chloride salt based on its characteristic flame color and bright-line spectrum.

As part of their laboratory report, the students will be asked to answer the following questions:

1. What problems may be encountered when the flame tests are used for identification purposes?
2. Are there any ions that produce similar colors in the flame tests, and if so which ones?
3. How are the colors of light emitted by the flame test produced?
4. Define the terms: quanta, ground state, and excited state.
5. Explain how a spectroscope works. When observed through a spectroscope, what does the flame test produce?
6. Explain the relationship between spectral lines and the energy levels in an atom.
7. Explain, mathematically, how the wavelength of a spectral line and the quantity of energy that it represents are related.

Experiment 3: Finding the Charge of an Electron (16, 17)

In the later part of the nineteenth century, the British physicist John Joseph Thomson discovered the first subatomic particle, the electron. From his studies on the electron, Thomson was able to calculate its charge/mass ratio but not its electrical charge. Several years later, the American physicist Robert Millikan, using Thomson's charge/mass ratio values was, however, able to calculate the electrical charge for an electron in his infamous oil drop experiment. This value remains the fundamental unit of electrical charge.

This experiment is based on the electroplating of zinc electrodes. Electroplating is an electrolytic process involving the oxidation and reduction of metals in the presence of a suitable electrolyte and an electric current. To better understand the underlying chemistry associated with the process, it is important to examine the individual half-reactions that take place. Half-reactions allow one to examine individually the details of the chemical reactions occurring at both the anode and cathode electrodes. For the metal serving as the anode electrode, oxidation occurs whereby the metallic electrode loses electrons and subsequently releases metallic ions into the electrolyte solution. In this experiment, the oxidation reaction can be written as follows:

Anode (-) electrode $Zn \rightarrow Zn^{2+} + 2e^-$

At the cathode electrode, reduction of the metallic electrode is occurring. For this particular experiment, zinc ions, in the electrolyte solution, are being deposited onto the cathode electrode which is also accepting electrons. The half-reaction for the reduction reaction can be written as:

Cathode (+) electrode $Zn^{2+} + 2e^- \rightarrow Zn$

The initial electroplating setup consists of connecting two zinc electrodes to an external battery and an ammeter. The electrolyte into which the electrodes are immersed is a 1.0 M zinc sulfate solution. After a period of twenty minutes, the students will be able to use the data obtained to calculate the charge of an electron through a series of simple equations that are listed below:

1. Calculation of the change in mass of zinc:
   change in Zn mass = mass of Zn electrode (after) – mass of Zn electrode (before)

2. Calculation of the number of zinc atoms:
$$\text{number of Zn atoms} = \frac{\text{change in mass of Zn electrode (g)}}{\text{molar mass of Zn (g/mol)}} \times (6.023 \times 10^{23} \text{ atoms/mol})$$

3. Calculation of the average current:
$$\text{average current} = \frac{\text{total current over 20 min (Amp)}}{\text{20 (min)}}$$

4. Calculation of total charge:
$$\text{total charge} = \text{average current (Amp)} \times \text{ 20 (min)} \times 60\,(\text{sec/min})$$

5. Calculation of charge per atom: The SI unit for electric charge is the coulomb. One coulomb is equal to one ampere $\times$ second.
$$\text{charge per atom} = \frac{\text{total charge (coulombs)}}{\text{number of Zn atoms (atom)}}$$

6. Calculation of charge per electron:
$$\text{charge per electron} = \frac{\text{charge per atom (coulombs/atom)}}{\text{2 electrons per atom (e/atom)}}$$

At the conclusion of this experiment, the students will answer the following questions:

1. How do their results compare to the accepted value?
2. What was the percent error?
3. How do their results compare for the two electrodes used?

4. How does one explain the change in mass for each electrode?
5. How would using different metal electrodes affect the value of the electric charge?

**Endnotes**


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This is an excellent source for the historical development of the atomic theory and the nature of light.

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Spencer Kagan has presented an excellent, in-depth analysis of cooperative learning.

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Atomic Models from Aristotle to Schrödinger <http://improbable.org/era/physics/ atom.html>.
In this article, the atomic models of Aristotle, Dalton, Bohr, de Broglie, and Schrödinger are briefly presented.

Atomic Theory <http://en.wikipedia.org/wiki/Atomic_theory>.
This article gives a brief history of the atom from Leucippus and Democritus up to Heisenberg's uncertainty principle.

Atoms <http://nobeliefs.com/atom.htm>.
This article compiled by Jim Walker gives a thorough overview of the history of the atom from ancient Greece up to the present day.

Cooperative Learning <http://www.co-operation.org/pages/cl.html>.
A brief overview of cooperative learning is presented with ideas on establishing an effective cooperative learning environment.

Cornell Notes <http://en.wikipedia.org/wiki/Cornell_Notes>.
This article briefly reviews the Cornell Method of note taking.

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Rhinehart, and Winston, 2004.
This is the assigned textbook for the chemistry course as assigned by the School District of Philadelphia.

*Physical Science (Laboratory Manual)*, Englewood Cliffs, NJ: Prentice Hall, 1991.
This laboratory manual contains the experiment entitled “Relating Electrons and Probability”.

Wagner, Maxine *Chemistry: the Study of Matter Laboratory Manual* (second edition), Newton, MA: Allyn and Bacon, 1987.
This laboratory manual contains the experiment entitled “Flame Tests”.

**Appendix-Content Standards**

The Pennsylvania Academic Standards for Science and Technology, which will be addressed in this curriculum unit, were taken directly from the *Pennsylvania Teacher’s Desk Reference and Critical Thinking Guide,* and include the following:

3.1.10 Unifying Themes: The unifying themes focus on the fundamental concepts and processes that form the framework upon which science and technology are organized, such as: the structure of matter.

B. Describe concepts of models as a way to predict and understand science and technology.

- Distinguish between different types of models and modeling techniques and apply their appropriate use in scientific applications.

3.2.10 Inquiry and Design: The nature of science and technology is characterized by process knowledge that enables students to become independent learners. These skills include observing, classifying, inferring, predicting, measuring, computing, estimating, communicating, using space/time relationships, defining operationally, raising questions, formulating hypotheses, testing and experimenting, designing controlled experiments, recognizing variables, manipulating variables, interpreting data, formulating models, designing models, and producing solutions. These process skills are developed across the grade levels and differ in the degree of sophistication, quantitative nature and application to content.

A. Apply knowledge and understanding about the nature of scientific and technological knowledge.

- Compare and contrast scientific theories and beliefs.
- Integrate new information into existing theories and explain implied results.

C. Apply the elements of scientific inquiry to solve problems.

- Conduct a multiple step experiment.
- Organize experimental information using a variety of analytical methods

3.4.10 Physical Science, Chemistry and Physics: Physics and chemistry involve the study of objects and their properties. In chemistry, students study the relationship between matter, atomic structure and its activity. Laboratory investigations of the properties of substances and their changes through a range of chemical interactions provide a basis for students to understand atomic theory and a variety of reaction types and their applications in business, agriculture and medicine. Physics deepens the understanding of the structure and properties of materials and includes atoms, waves, light, electricity, magnetism and the role of energy, forces and motion.

A. Explain concepts about the structure and properties of matter.
    - Know that atoms are composed of even smaller subatomic structures whose properties are measurable.

3.7.10 Technological Devices: Students use tools to observe, measure, move and make things. Technology enhances the student's abilities to identify problems and determine solutions.

B. Apply appropriate instruments and apparatus to examine a variety of objects and processes.
    - Describe and use appropriate instruments to gather and analyze data.
    - Apply accurate measurement knowledge to solve everyday problems.