Teaching High School Chemistry

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INTRODUCTION

The high school chemistry student is just beginning to discover how things are put together. He has many naïve ideas to explain what things are made of and what laws govern their transformations. At the same time, he is prepared to discover chemistry because he has learned math skills and has been exposed to information about science. The chemistry teacher can gently guide the student to discover for himself the laws that govern chemical reactions and transformations.

This unit will teach eleventh grade students about the periodic table, the structure of the atom and the conventions for naming compounds and writing formulas. I want to teach this early in the course because the structure of the atom is the key to chemical reactions; the periodic table is probably the greatest graphic organizer of all time and writing chemical equations is where chemistry starts. The skills learned in this unit will be used through the entire course. The students will use guided discovery, guided practice, laboratory exercises and student presentations as strategies for learning. The students will do research in the textbook, in the library or on the Internet. Some content has to be provided in notes or lecture because it is difficult for the student to find.

UNIT OBJECTIVES

The course is divided into eight units. This particular unit deals with the structure of the atom, the periodic table, naming chemical compounds and writing formulas. The student will become familiar with the structure of the periodic table. The student will learn how the arrangement of electrons determines how the elements will combine to make compounds. The student will learn strategies for making sense of what he or she reads. The student will learn to make graphic organizers and PowerPoint presentations to help him or her organize new information. The student will learn how to name compounds knowing the formula and how to write the formula knowing the name. The student will learn to elaborate his or her own ideas and how to present them. The student will write formulas and name compounds. The unit lasts three weeks or seven 90 minute classes.

OVERVIEW OF THE UNIT

The Periodic Table (a graphic organizer)

The first lesson deals with atoms and the periodic table. The development of the periodic table happened before subatomic particles had been discovered. More than two thousand compounds were known but there was disagreement about their formulas. The 63 elements known at the time the periodic was developed will be used to illustrate its parts and features. These 63 elements will be placed where they are in the modern periodic table leaving out the other elements discovered since. Only the symbol and atomic mass will be shown in this table. This makes the point that there was not a lot of information to organize when it was invented, but its usefulness has kept it in use many years. It is a great teaching tool. It helps students make sense of information about the elements and to discover relationships between compounds and

different elements. Notes on the scientists and discoveries that were essential for the development of the periodic table will be provided to the class. These notes will be used to develop a flow chart showing how the periodic table came about. The lesson includes an explanation of relative mass and its determination. A guided discovery exercise will be used to justify the idea of the atom as an indivisible unit. The teacher will try to guide the discussion to reach the conclusion that if matter could be divided infinitely then all matter would be composed of nothing. Students will work in pairs to create a flow chart that traces the steps leading to the creation of the periodic table of the elements.

For extra credit, any two or three students will be allowed to prepare a PowerPoint presentation that shows how different elements have similar reactions that show that they belong in the same family in the periodic table. PowerPoint presentations require the student to create a response that is visual and acts as a graphic organizer of the information. In addition sound can be added to a PowerPoint presentation to make it even more interesting.

Mendeleyev only gave us the relative atomic mass, the name of the element and how the properties of the elements fell into groups. Later the electron and the proton were discovered and the ordinal position of an element told us how many electrons surrounded the nucleus. It was not until X-ray diffraction allowed the counting of protons and neutrons in the 20^{th} century, that the modern periodic table was possible. The periodic table now contains the average atomic mass, the atomic number, the arrangement of electrons, and information on other periodic trends.

The Structure of the Atom

The second lesson will deal with the arrangement of electrons around the nucleus and the implication of quantized orbitals. Discovery activities, in the lab, will allow the student to experience the way that the products of a reaction are determined.

Just as a series of events was necessary for the development of the periodic table, a discovery led to the idea that compounds could be separated into elements that were attracted to a positive electrode and elements that were attracted to a negative electrode. Ionic and molecular compounds were identified. The discovery of electrons proved that atoms were divisible. The elements on the left of the periodic table are metals, and the non-metals are on the right. Metals are attracted to the positive and the non-metals to the negative. This unit will stress the contribution of Lavoisier, Dalton, Berzelius, Mendeleyev, Rutherford and Bohr.

Chemical Names and Formulas

The third lesson deals with naming compounds and writing formulas. This lesson will start with the discovery of ionic and covalent bonding. The chemical families will be identified and their common properties will be listed.

The characteristics of molecular compounds will be learned and the student will prepare concept maps and notes to organize the information he is learning. The guided practice exercises will involve the use of flow charts that list the rules and steps involved. The positive charge of the cation will be balanced by the negative charge of the anion. The criss-cross rule will be used to determine the subscripts that produce balance.

The use of prefixes for naming molecular compounds will be practiced in cooperative group activities.

The naming rules for binary and ternary compounds will be put on flash cards.

In the first half of the 20^{th} century the discovery of the neutron and isotopes allowed us to include subatomic particles in the periodic table.

For extra credit, a pair of students may prepare a PowerPoint presentation that shows examples. A PowerPoint presentation requires the student to create a response that is visual and acts as a graphic organizer of the information. In addition sound can be added to a PowerPoint presentation to make it even more interesting.

THE WHOLE UNIT

The three lessons in this unit set the foundation for the whole course. The periodic table organizes a huge amount of information about the elements that make up all matter. When it was invented, atoms were considered indivisible because there was no knowledge of subatomic particles. The discovery of electrons, protons and neutrons validated it and fit the framework like a glove. Naming compounds and writing their formulas is easier once their relationship, in the periodic table, is understood.

Learner-centered strategies

Chemistry is a large content area that is rapidly growing. Regular chemistry classes are large with students of varying learning style and ability. I will employ instructional strategies that will support students at both ends. Some students can master a lot, while other students struggle to master the minimum. I will teach representative pieces and hope that some generalization will occur. All of the units will attempt to make instruction student-centered and to meet the needs of different learning styles. Math skills and vocabulary will be stressed in every unit. Discovery activities are intended to help internalize new information. Discovery activities will be included in the lesson plan to decrease the cookbook and memorization activities. The use of attribution and bibliographies will be explained. The periodic table is always displayed in the classroom because we constantly refer to it. This curriculum unit establishes the foundation for the ones that follow. The class will return to the periodic table when working on the other units.

Instruction Strategies

Instruction will be guided by the five principles of active learning. Students will be taught to use previous knowledge, summarize and organize information, think critically about text and create their own elaborations of the information. They will learn to monitor their understanding and use a variety of strategies to make sense of what they read. The reading assignments will be reinforced by pop quizzes which allow the use of notes on an index card. Every unit will include extra credit work. This work appeals to students who can do work at a higher level than the average student. The extra credit work is shown to the class on a TV and is discussed by the class.

A higher level of understanding can be achieved when the student is required to prepare his or her own product that can be used to teach others the skills involved. When understanding is put ahead of memorizing many questions will have to be asked to discover and change the learner's naïve ideas. The lessons will be made up of pieces that include lecture, guided practice, concept mapping, preparing of reports, laboratory exercises and presentations in front of the class. All lessons will include lab activities that will allow the student to demonstrate writing competence and his or her ability to do careful work and to analyze results. Each lesson will have an assessment instrument. Every effort will be made to insure that students do their homework. Every minute in the classroom will be devoted to academic activities only.

Every student will learn how to prepare a PowerPoint presentation that will be a group activity. The preparation of a PowerPoint presentation is a higher order activity. The presentation will include all of the elements (graphs, calculations and tables) necessary to teach the skills learned to someone else. Individual instruction will be provided for students with no PowerPoint experience. Every student will learn how to use a spreadsheet to graph data and to do calculations using the formula function.

The students will use their hands and see the result of their work. Self-assessment is reinforced by the teacher and by their peers. The laboratory is a wonderful environment for discovery teaching. The students will participate in forming the questions that are important in the exercise. Together with their bench mates, they will answer the questions and write the laboratory report. The students will also write the procedures, and make careful observations. In order to increase learning, the students will be required to do a lab for each lesson and to report results in a form suitable to demonstrate support for the objective of the unit.

Assessment

There is a core of required activities, and there is one extra credit activity for each lesson. The student may do the minimum and get a good grade; or he or she may improve his or her grade by doing the extra work. Each lesson will produce a grade for the concept map, for the quiz, the lab, class work and homework. The required minimum skills must be evaluated and strengthened to make the journey of discovery enjoyable. Every student will participate in the creation of a PowerPoint presentation that can be used to teach others what he or she has learned. In order to produce a usable presentation the student has to be able to collect the information he or she will use in the presentation. Some information can be read from books or on-line. Some information must be gained "hands-on" by performing experiments. Handouts will include library and on-line references where students can get additional information on the subject.

To make the instruction learning focused rather than performance focused the student must monitor his or her progress with feedback from the teacher and by setting his or her own goals. An experiment is associated with each lesson to help develop critical thinking skills and process skills and the actual execution of the experiments will provide the essential involvement, first hand, which is an element of learning which is often scarce in school. Turning the laboratory exercises into discovery sessions will provide an opportunity for students to go through the mental steps that humans have actually gone through to arrive at the level of scientific understanding we currently enjoy.

The student will maintain a notebook containing notes, lab reports, practice work sheets and concept maps. The student notebook will be checked every week to find the concept map and guided practice work sheets. The notebook grade makes up 15% of the grade for every marking period.

Individual Instruction

Individual instruction is required whenever a student misses instruction due to absence or when a student has not mastered a required skill, even after re-teaching. Individual instruction can be given in class while other students are engaged or as tutoring outside of class. This activity makes possible assessment of the individual student and additional remediation. When a student is absent, a way must be found to get the student caught up. The student may not be able to do it by himself and a tutoring session may be necessary. This is the classic stitch-in-time situation.

Quiz

The student will read the assigned sections and prepare notes on an index card to use on the quiz. Every lesson will have a quiz. Some of the quizzes will be of the fill in the blank type. They will create their own flash cards for remembering the rules and will be able to use the flash cards in the quiz.

Test

The student will demonstrate mastery of the content of the unit by completing a test once every two weeks, at the end of a unit or unit lesson. A practice test may precede the regular test in order to practice the skills and determine if the class is ready for the test.

Laboratory Activities

All lab activities involving open flames, chemicals, electric devices or stored energy devices will be preceded by safety instructions and discussions. The discussions will include student suggestions about the possible hazards and personal protective equipment. Instructions for cleanup, sanitation and disposal of waste will be in writing and will be modeled by the instructor. Allowing students to develop the questions and suggest the best way to find the answers is more satisfying to the student. The resulting product is owned by him/her.

Parent Contact

The parent should be contacted by the time the first progress report gets home. The parent should know that the teacher wants his/her child to succeed. The parent should be encouraged to help. The teacher can make it easy for the parent to contact him.

Notes for Lesson One

The first lesson will align with the curriculum in Atomic structures and the periodic table. The student will be provided with notes detailing the contributions of the scientists being studied with library and on-line references. The student will create a flow chart showing the relationship of the scientist to the discovery and the discoveries to each other. The law of definite proportions suggested that the relative weight of the elements could be determined from the formula. Some used oxygen as the reference element and some used hydrogen. Unfortunately not much distinction was made between molecules and atoms, some of the formulas were incorrect and no one knew that hydrogen and oxygen were diatomic molecules. As a result many of the relative weights were not correct. Avogadro had suggested a solution but very few scientists were aware of his work.

Within a short span of time three chemists created a periodic table of the elements. This invention was the most significant developments in the science. The body of knowledge had reached the point where somebody was going to invent the periodic table. That someone was likely to come from among the best chemists of the day. The ability to think "outside the box" allowed them to organize what had recently been learned about elements in a way that explained why these differences existed. De Chancourtois had found a repetitive pattern, every seven elements, when arranging the elements by atomic weight in a spiral table. Lothar Meyer also invented the periodic table but did not publish because he could not explain the gaps in his table or some elements whose atomic mass did not fit in the table. Dimitri Mendeleyev simply explained that the gaps were elements not yet discovered and the elements that did not fit had their masses calculated incorrectly. He was saved when two new elements were found that fit his gaps and he was able to suggest an error in one of those that had the wrong mass. *His periodic table was created with no knowledge of subatomic particles.*

Robert Boyle put chemistry on the path to becoming a science. This included the phlogiston theory to explain how matter was transformed. By 1774 this new science needed revision. A new language had to be invented. This language was finally provided by Lavoisier. In 1789 he published *Elements of Chemistry* a book comparable to Newton's *Principia*. This book was the result of 15 years of research in his laboratory and the current literature, organizing what was then known to produce the definitive text on the science of chemistry. He named 33 elements. He replaced the phlogiston theory with the theory of combustion, a chemical reaction in which oxygen combines with the combustible. He renamed many compounds to comply with a system in which the names were self-explanatory. If an element were compounded with nitrogen, phosphorus or sulfur the result was named a nitride, sulfide or phosphide. The oxygen containing acids were nitric acid, phosphoric and sulfuric acid.

John Dalton brought back the atom but he added the idea that atoms of different elements were different from each other and that atoms could be assigned a relative mass that was a multiple of the mass of hydrogen, which was the lightest element. Louis-Joseph Proust proposed the law of definite proportions that stated that compounds consisted of elements in simple ratios by weight. To Dalton this implied that atoms of different weight would combine one to one into compounds with the same ratio. He suggested that the relative weight of other elements could be determined relative to the weight of hydrogen and assigned the atomic weight of oxygen as eight because it was known that water contained oxygen and hydrogen in an eight to one ratio by weight. An international conference was called at Karlsruhe to determine the best way to calculate relative atomic mass.

Dimitri Mendeleyev attended the Karlsruhe conference and when he returned to Russia he set about gathering reliable information on the relative atomic mass of all of the elements. He repeated the determinations in his lab to verify the data. Between 1750 and 1800, the second half of the 18th century, the periodic table provided the way to organize what was known about elements and the way they reacted.

Notes for Lesson Two

Between 1850 and 1897 the electron was discovered, and its charge and mass were determined as well. Rontgen discovered X-rays in 1895. In 1900 Planck suggested his quantum theory.

Radioactive elements and the three types of radiation; alpha, beta and gamma were discovered between 1896 and1910. Along with the photoelectric effect, these discoveries led to the conclusion that all matter contained electrons. In 1914 Mosley's work on X-ray spectra determine that the number of protons increases with the ordinal position of elements in the periodic table.

Between 1909 and 1911 Rutherford clarified the nature of the nucleus as being a heavy positively charged central mass around which revolved sufficient electrons to neutralize the positive charge. The electrons revolved around the nucleus like planets revolve around the sun. In 1913 Bohr uses Plank's quantum theory to suggest a better model for the location of electrons around the nucleus.

The isolation of isotopes for most elements increased the possible numbers of atoms and is useful in explaining radioactivity. The invention of the spectroscope allowed the identification of many elements by recognizing their unique spectra. The explanation for the spectrum had to wait on the invention of quantum theory. Finally quantum mechanics suggested that electrons had spin and as a consequence two electrons of opposite spin could occupy the same sub-orbit.

Notes for Lesson Three

In 1800 the development of the voltaic pile made it possible to split many molecules, using electrolysis, into their component elements. Upon ionization elements became positive or negative and were attracted to electrodes of the opposite charge. In 1812 Berzelius proposed the Dualistic theory. *Atoms in molecules are held together by electrical attraction.* Ions of metals had a positive charge and those of the non-metals a negative charge. That put hydrogen on the metal side.

In 1839 Dumas proposed a theory of types. Berzelius' theory dealt with electrolytes and Dumas with non-electrolytes. At the time, the electron and the proton were not known. Frankland proposed that atoms had a certain combining power that determined the number of atoms, of another element, with which it would combine. Using hydrogen as the unit of combining power, the valency of an element is the number of hydrogen atoms with which it would combine. Once

the arrangement of electrons in the atom was understood, a better explanation was available. The types of valency bonds include ionic (electrovalent), covalent (shared electrons) and coordinate covalent. There are double covalent bonds and hybrid bonds.

Summary

The periodic table of the elements and the electronic configuration of atoms represent the starting point for teaching high school chemistry. Students enjoy most the courses in which they have the highest competence. "Everyone likes to do what they are good at." The high school student who can solve problems in chemistry using his own logic instead of trying to memorize will feel confident about pursuing a science career.

We can import nurses, science teachers and engineers from countries with very poor educational systems because the few exceptional students in those countries are attracted by our high standard of living. By increasing the number of students who opt for science courses, and become competent, we increase the number of American students who become doctors, engineers and nurses. Students enjoy science when they have achieved competence. When science teachers help students become competent, the number of students choosing science for a career will increase.

LESSON PLANS

Lesson Plan 1: Unit 2: Atoms and the Periodic Table

Atoms and the Periodic Table

Objectives: The student will form his own explanation of the development of the periodic table. He will identify the periods, groups and organization of the periodic table. The student will create his own elaboration to connect the law of definite proportions and the relative mass of the elements.

Goal: To discover the learner's previous knowledge and elaborate any naïve ideas concerning how metals differ from non-metals, and which elements belong in groups. Discover how the periodic table links the relationship between different elements. What are periods and groups? What do they tell us about the elements? How are non-metals alike?

Activities: The student will construct a periodic table containing the elements known to Mendeleyev to investigate the usefulness of this invention. A guided discovery activity will involve the entire class seeking to understand how the idea of the atom, the elements in different combinations, and the law of definite proportions came together to explain the different equivalent weights of different elements. They will identify groups, periods, non-metals and transition metals. The student will arrange the known elements according to their relative mass.

Materials: Handout on historical background, the text, a blank periodic table, a list of elements known to Mendeleyev with their symbol and atomic mass

Assignments: Create a study guide for a quiz on this lesson. Write the names of the elements on the list and turn it in as homework. Turn in the flow chart for a grade.

Assignments: Students will collect /research information about an assigned group in the periodic table. They will receive a PowerPoint file that they will modify with their own information. If they are already competent they can make their own PowerPoint "from-scratch".

Prepare Flow Chart Showing Creation of the Periodic table

Objectives: The student will be able to make a flow chart showing the development of the periodic table. The student will describe the location of groups in the periodic table and what their similarities are.

Goal: The student will use the periodic table as a graphic organizer for the information known about the existing elements.

Activities: The student will construct a flow chart which illustrates how this table was created. The student will identify sections of the periodic table giving the type of elements found there and the properties that make them similar to each other. The student will prepare an outline of the information in the text. The outline will be graded.

Materials: Notes, text, periodic tables

Lab Activity: The Atomic Mass of "Candium"

Objectives: The student will use different beans to represent isotopes of the atom "bean."

Goal: Clarify the difference between isotopes of the same element and why the atomic mass is not a whole number. The student will know the difference between an arithmetic average and a weighted average mass.

Activities: This lab activity will become a discovery session to clarify the composition of the atom. The student will be expected to explain why the atomic mass of some elements is not a whole number. If an atom has the same number of electrons and protons and the protons and neutrons have the same mass, then the atomic mass has to be a whole number of amu's (atomic mass units). The student will write a procedure for determining the average mass and weighted average mass of a sample of representative units. Determine the mass of Avogadro's number of representative units.

Materials: Sample of different beans, scale, calculator and lab work sheets

Assignments: Complete test, read Ch 8 of *Chemistry* & make notes.

Test: Atoms & the Elements

Objectives: The student will demonstrate mastery of the objective in this unit of study on a test by identifying the position of groups, periods and transition metals in the periodic table.

Goal: To get feedback on student competence and to re-teach if necessary.

Activities: Multiple choice test on atoms and the elements

Materials: Test, answer sheets

PowerPoint Presentation

Objectives: To organize the properties and uses of elements in the periodic table.

Goal: To make a PowerPoint presentation about a group in the periodic table.

Activities: Two students will collect information about a group in the periodic table. The information will be presented to the class and a copy will be stored in the cabinet for use by anyone.

Materials: Periodic table handout, list of web sites, list of books

Lesson Plan 2: Unit 2: The Structure of the Atom

Topic: The Structure of the Atom

Objectives: The student will explain the significance of quantized energies of electrons as they relate to the quantum mechanical model of the atom. The student will explain the difference between the planetary model and the quantum model of the atom. The student will write electronic configurations for non-metals and for alkali metals.

Goal: To use the periodic table to write the electronic configuration of elements. The student will show the relationship of metals to cations and of non-metals to anions. Review changes in the structure of the atom.

Activities: Guided practice in groups of three with teacher assistance. A guided discovery exercise using Pauli's exclusion principle and the aufbau organization of electrons to determine the location of electrons around the nucleus of metals and non-metals. Use prepared work sheets. Use the periodic table.

Materials: Notes, worksheets, periodic tables, transparencies and the text

Assignments: Prepare notes on an index cards for use in the quiz that will follow.

Topic: Concept Map of the Structure of the Atom

Objectives: The student will relate electronic configuration to quantum mechanics.

Goal: To organize the ideas found in this lesson, the student will draw the electronic configuration of elements with teacher assistance.

Activities: The student will draw a concept map linking Aufbau principle, Pauli's exclusion principle, energy level, electron configuration, quantum, Hund's rule and the quantum mechanical model.

Materials: Periodic table and worksheet.

Topic: Write a Study Guide for the Test

Objectives: The student will organize material read in the text into a useful review packet.

Goal: To practice active reading and note taking strategies.

Activities: Work in small groups to complete review packet over this lesson.

Materials: Notebooks, textbooks and review packet

Assignments: Complete review packet and study for test.

Topic: Lab Activity physical properties of transition metals

Objectives: The student will recognize physical and chemical properties of solutions containing transition metal salts. The student will relate physical properties to the electronic configuration.

Goal: To determine who learned to use the solubility tables.

Activities: Teams of three students will choose the reagents, set up the experiment, make the observations, and write the lab report.

Materials: Set of labeled reagent solutions, Pipettes, Watch glass

Assignments: Use the procedure in the textbook as a guide and submit the proposal to the teacher for approval. Collect data and write lab report.

Extra credit project

Prepare a PowerPoint presentation that will explain the relationship between quantum mechanics, photons and the photoelectric effect. Explain threshold frequency and wavelength. The presentation will have five panels.

Test: Electron Arrangement in Atoms

Objectives: The student will demonstrate mastery of the objective in this lesson on a test.

Goal: Assess student competence. Give feed back to student.

Activities: Take the test on structure of the atom.

Materials: Multiple choice test, Scantron cards, number 2 pencils, and the Periodic table

Lesson Plan 3: Unit 2: Naming Compounds & Writing Formulas

Topic: Chemical Bonding and Valence

Objectives: The student will distinguish between ionic and molecular compounds. The student will define cation and anion and relate them to metals and non-metals. The student will define chemical formula, molecular formula and formula unit.

Goal: Relate valence to metals and non-metals. State the laws of definite and multiple proportions, monatomic and polyatomic ions, rules for writing formulas and naming binary compounds, and use of prefixes when naming molecular compounds.

Activities: Guided practice using flow charts to name compounds and to write the formulas. Complete worksheets with teacher assistance. Prepare a study guide for taking the quiz.

Materials: Notes, worksheets, periodic table, text

Topic: Lab to Identify Type of Reaction & Write Formula

Objectives: The student will demonstrate the ability to make careful observations and write a lab report. The student will follow the instructions in the lab manual. Evaluate each others projects for required information and creativity.

Goal: The student will list the signs that a chemical reaction has occurred. The student will determine the valence of the elements in an ionic compound.

Activities: Oral definition of the terms: anion, binary compound, cation, ionic compound, law of definite proportions.

Materials: Reagents, plastic bag, test tube, water

Assignments: The student will write a lab report including the formulas for the reactions and identify the type of reaction.

Test: Naming Compounds and Writing Formulas

Objectives: The student will demonstrate mastery of the objective of this lesson on a multiple choice test. The student knows the symbols used in writing an equation.

Goal: Apply the rules for naming and writing formulas for binary and ternary ionic compounds.To get feedback on competence and to re-teach if necessary.

Materials: Notes, test, periodic tables

Assignments: Complete test.

ANNOTATED BIBLIOGRAPHY

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