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The Origin of the Elements

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Overview

This curriculum unit, entitled "The Origin of the Elements", is intended for eleventh grade students enrolled in my chemistry classes who attend an inner city Philadelphia public high school. It will be used in conjunction with unit three of the School District of Philadelphia's standardized curriculum for chemistry. As outlined in the school district's *Planning and Scheduling Timeline for Chemistry*, the entire unit "Periodic Table and Periodic Trends" is meant to be completed within a three week period. During that time, the students will examine the role electrons play in chemical behavior, electron configuration, in addition to becoming familiar with the organization and uses of the periodic table. Although most high school textbooks briefly mention the occurrence and/or abundance of individual elements of interest on Earth, they rarely give any insight into the origin of the elements. Therefore, the aim of this unit is to present the students with a basic understanding of how the elements were formed. This will include current information on Big Bang also referred to as primordial, stellar and supernova nucleosynthesis. In doing so, the students will also be introduced to the history of the Big Bang and stellar evolution as a means of stimulating interest in astronomy and cosmology. To accomplish these goals, approximately six to eight days will be allocated for its completion. In addition, this unit will be in alignment with several of the Pennsylvania Academic Standards for Science and Technology, including standards: 3.1.12 "Unifying Themes", 3.2.12 "Inquiry and Design", 3.4.12 "Physical Science, Chemistry, and Physics", and 3.7.12 "Technological Devices".

Rationale

The History of the Big Bang Theory

In order to answer the question "From where did the elements originate?" one must consider two major areas of cosmology. The first being the formation of the Universe and the second being stellar structure, formation, and evolution. Advances in cosmology during the twentieth century have led to the prevailing theory that the Universe was formed from a cataclysmal event commonly called the Big Bang. In examining the spectral analysis of a number of spiral nebulae, Vesto Slipher concluded in 1912, on the basis of measurable Doppler redshifts, that these nebulae were moving away from the Earth. Then in 1915, Albert Einstein published his general theory of relativity which in part predicted that the Universe was expanding. Contrary to his theory, Einstein believed in a static rather than an expanding Universe. It was not until 1922 when a Russian cosmologist and mathematician, Alexander Friedmann, derived a series of equations from Einstein's general relativity equations, predicting that the Universe was expanding. Georges Lemaître, after having verified Friedmann's equations, suggested in 1927 that the Universe began as a "primeval atom", the forerunner of the Big Bang. Additional evidence of an expanding Universe came from an equation derived by Edwin Hubble in 1929 on the basis of observations of galaxies made by him and associates. That equation, now referred to as Hubble's Law, showed a direct relationship between the distance to a galaxy and its recessional velocity. Simply put, Hubble's Law states that as the distance between galaxies increases so does the velocity of their separation. Credit is therefore given to Hubble for elucidating the concept of an expanding Universe.

Two prominent theories of an expanding Universe were debated following World War II. Among those who supported the steady-state model was Fred Hoyle. In this model, new matter would be created as the Universe expands. The second theory, proposed by Georges Lemaître, was the primeval atom model. This theory was based on the premise that an explosion of a "primeval atom" occurred. The term Big Bang originally came from a 1949 radio broadcast on the BBC in which Fred Hoyle was referring to Lemaître's model. The debate between these two theories would last for years. The deciding factor involved the observation of cosmic microwave background radiation (CMB). Lemaître and George Gamow predicted in 1930 that the explosive event would have produced a

radiation fireball that should be detectable as blackbody radiation filling the entire Universe, and currently having a temperature in the area of 5K. Therefore, detection of this cosmic radiation would lend credence to the Big Bang theory. The discovery of CMB by Arno Penzias and Robert Wilson occurred accidentally in 1964 when the pair, in an effort to detect microwaves in space for Bell Laboratories was able to detect low level background radiation coming from all directions. This was the evidence needed to resolve the debate between the steady-state and Big Bang theories. Since then, additional evidence from a number of space probes, including the COBE (Cosmic Background Explorer) satellite, have supported the Big Bang theory as the prevailing theory of the origin of the Universe (1, 2, 3, 4, 5).

Stellar Evolution

The reasons for reviewing stellar structure, formation, and evolution will become obvious when discussing the specifics of elemental origins. At this point, it is important to understand what characteristics determine a star from other astronomical objects. In general, stars are composed primarily of hydrogen and helium gases. The outer surface of a star, called the photosphere, is an area where light in the form of photons is able to leave the star's surface. For the Sun, beneath the photosphere, and making up approximately thirty percent of the solar radius, is the zone of convection. In this region the gases, heat, and energy circulate by means of convection currents. It is within the core of the Sun, or zone of radiation, that gases, heat, and energy radiate to the outer layers of the star. For stars of different masses, the location and extent of the radiative and convection zones are different from the Sun. The surface temperature of stars can range from 3.0×10^{3} K to in excess of 2.0×10^{4} K. The temperature within the core, however, can range anywhere from 10^{7} K to 10^{9} K.

When referring to the mass of stars, cosmologists use the unit solar mass. The mass of our Sun which is approximately 2×10^{30} kg has been designated as one solar mass. With this in mind, the mass of the different types of stars usually range from one-tenth to one hundred solar masses. Generally, it is the mass of the star which will determine its fate. The more massive the star, the more energy it expends and the shorter its lifespan. Other means of classifying stars include their brightness, or magnitude, their luminosity and their age. Independently, in 1913, Ejnar Hertzsprung and Henry Russell discovered a relationship between the brightness of a star and its surface temperature. By plotting the surface temperature versus the luminosity, an extremely important astronomical tool was created, the Hertzsprung-Russell diagram. With this diagram, one can determine the luminosity, surface temperature, and spectral class of stars. Based on this diagram, stars have been classified as white dwarfs, main sequence, red giants, and super giants.

An understanding of stellar classification and evolution is an essential component of understanding the origin of the naturally occurring elements. The first process in the formation of a star involves the clumping and condensing of gases and dust particles within a nebula. This condensing of matter is due to the gravitational forces between the gas particles. As the condensing process increases, the gas particles move closer together. The result of which is an increase in both the random collisions between the particles and the heat generated. A star with sufficient energy to release microwaves and infrared radiation is called a protostar. The energy within the protostar, however, is insufficient for nuclear fusion. As the protostar undergoes additional condensing, it becomes increasingly denser generating exceedingly more heat. When the core reaches a temperature of about 10^7 K, nuclear fusion reactions can take place. The pressure generated from these fusion reactions eventually causes a cessation of the condensing process. This is a stabilizing factor with the end result being a main sequence star. The point at which the star uses up its fuel and the conversion of hydrogen to helium as well as the nuclear fusion reactions stop, the core of main sequence star begins to condense again with an increase in the amount of heat generated. While the core shrinks, the outer regions of the star expand, and the star becomes a red giant. Nuclear fusion reactions will begin to occur this time outside the core of the star, and eventually the core will begin the fusion of helium to carbon and oxygen. Characteristics of red giant stars include a larger surface area, a reddish color, and a lower surface temperature. The fate of a red giant is dependent upon its mass. Red stars with a mass of up to a few times the mass of the Sun will shed their outer envelopes and eventually shrink and become a white dwarf. If the white dwarf is a single star, it will slowly cool down until it becomes a dark, dense cinder in the sky. If it is part of a close binary system and it gains additional mass from its companion it may end up undergoing a type Ia supernova explosion. In contrast, red stars with higher masses will develop regions that are undergoing nuclear processes with increasingly massive elements. At the end of this stage of their lifetime the star consists of an iron core with surrounding shells of lighter nuclei until we reach, near the surface, a shell where hydrogen "burning" is taking place, and above it, a layer without nuclear processes. When the Fe core cools, it will begin a collapse that upon bouncing back will cause an explosion called a type II supernova. The remaining core will form, depending on its mass, a neutron star or a black hole (6, 7, 8).

Big Bang Nucleosynthesis

At this point, sufficient background information has been given whereby an explanation of the origin of the elements can begin. During the early 1920's, Arthur Eddington was among the first astrophysicists to propose that the energy in the stars was obtained by a fusion reaction between hydrogen atoms to produce helium. Evidence provided by Hans Bethe, among others, in the 1930's formulated the nuclear mechanisms by which stars produce energy. However, in 1938 Carl Weizsächer suggested that elements heavier than helium-4 could not be produced in stars and therefore were probably produced prior to the formation of stars. It was not until after World War II that most of the work on nucleosynthesis, that is the formation of elements by means of nuclear reactions from pre-existing elements, occurred (9,10).

The idea that the chemical elements were produced by nuclear reactions involving neutron capture shortly after the Big Bang was proposed by George Gamow, Ralph Alpher, and Hans Bethe in 1948. This paper was instrumental in stimulating interest in Big Bang nucleosynthesis (BBN) which has also been referred to as primordial nucleosynthesis. In a follow up paper by Alpher and his coworkers Robert Herman and James Follin, they reported that during BBN helium-4 was the predominant product. Enrico Fermi and Anthony Turkevich later showed that BBN beyond helium-4 was not possible due to the Coulomb barrier. In principle, the greater the atomic number the greater the Coulomb barrier, as shown in the following equation:

$U = (kZ_1Z_2*e^2)/r^2$

U = the Coulomb barrier force

k = Coulomb's constant which is $8.987\ 6 \times 10^9\ Nm^2/C^2$

Z = atomic number

e = elementary particle charge which is $1.602\ 176\ 53 \times 10^{-19}$ C

r = distance between interacting particles

As just a reminder, the atomic number of an element refers to the total number of protons within its nucleus. The mass number of an element, such as helium-4 or ^4He, refers to the sum of the protons and neutrons within its nucleus. Therefore, in order to resolve the Coulomb barrier problem, the nuclei would need to be at a sufficiently high temperature whereby they would have enough energy and velocity to undergo nuclear fusion. During the first second following the Big Bang, a wide range of events were occurring. These phases included a period of cosmic inflation, elemental particle formation, the formation of baryonic matter, collisions between elementary particles, decreases in particle energies and temperatures. Between one second and three minutes after the Big Bang when temperatures had cooled to approximately 10^9 K, BBN began to take place. During this time period elements such as deuterium (^2H), tritium (^3H), helium-3 (^3He), and helium-4 (^4He) were being formed by nuclear fusion and neutron capture. To a lesser degree lithium-7 (^7Li) was formed by a chemical not nuclear reaction between ^4He and ^3H. However, this process did not produce any heavier elements (11,12,13).

Stellar Nucleosynthesis

Hans Bethe in 1939 considered two methods by which energy was produced in stars. These two methods were the proton-proton (PP) chain and the carbon-nitrogen-oxygen (CNO) cycle. The proton-proton chain actually involves three different sets of nuclear reactions and requires temperatures in excess of 10 MK. The PPI process takes place at temperatures between 10 MK to 14 MK. The temperature requirements for PPII are between 14 MK and 23 MK. For temperatures above 23 MK, PPIII reactions occur. The elements produced by way of the PP chain include ^3He, ^4He, ^7Be, ^7Li, and ^8B. Fred Hoyle later proposed a mechanism by which nuclear fusion reactions would be able to synthesize the elements from carbon to iron in stars. It was the 1957 review article by Burbridge, Burbridge, Fowler, and Hoyle that laid the framework for stellar nucleosynthesis. In that paper they outlined eight processes by which stellar nucleosynthesis could take place from hydrogen. Without going into the details, they included: converting hydrogen to helium, burning helium to carbon, oxygen, and neon, the capture of alpha particles, the equilibrium e-process, the slow s-process of neutron capture, the rapid r-process of neutron capture, the proton capture p-process, and an unknown x-process. Since then, the most important stellar nucleosynthetic processes appear to be: 1. hydrogen burning which involves the proton-proton chain and the CNO cycle, 2. helium burning involving both the alpha and triple alpha processes, and 3. the burning of heavier elements including carbon, neon, oxygen, and silicon.

Stellar nucleosynthesis occurs in layers or shells depending on the temperature within the star. At the surface, the temperature is never high enough to undergo any nuclear processing. Since the temperature increases with depth, a region will be reached where it is about 10^7 K, where hydrogen undergoes fusion to form helium. At this point, there is a fundamental difference between low mass stars (stars with masses lower than about 2-3 times the mass of the Sun), and higher mass stars. All stars begin evolving towards the Giant branch when hydrogen is exhausted in the stellar core. As the star evolves in this stage, there is some mass loss from the surface that is expanding, as the core is shrinking.

When the core temperature exceeds 100MK, helium nuclei begin to fuse to form carbon and oxygen. At this point non-relativistic degeneracy sets in, and the active life of the star has reached an end. The outer envelope has been shed out, and what remains is a hot, inert stellar core, called a white dwarf. It is very small and dense (the mass must be lower than 1.4 times the solar mass), and the size is very similar to the size of the Earth. All the results of stellar evolution become forever trapped within the white dwarf that begins to cool down to eventually become a dark cinder in the sky. For higher mass stars, however, the evolution does not end up there, but it continues to subsequent stages. There, at yet deeper levels, heavier elements are synthesized by the fusion of helium nuclei up to iron-56. Elements having mass numbers less than 56 and that are not multiples of 4 are produced in side reactions with neutrons. Moving in toward the core of the star helium is converted into carbon by the triple alpha process at 10^8 K. At a larger depth, the temperature increases to the point where carbon atoms will undergo fusion to produce neon at temperatures in the range of 10^9 K. As the depth (and temperature) of the star continues to increases neon will go on to form oxygen. Oxygen will fuse to form silicon, and silicon in turn will go on to form nickel. At this point the star is classified as a red giant and has been undergoing stellar evolution. Silicon will begin to burn at 4×10^9 K forming iron which cannot undergo any further stellar nucleosynthesis because of its high binding energies. A few elements having masses larger than ^{56}Fe are formed through the equilibrium process. Eventually the fuel will be exhausted at which point energy production ceases, gravity causes the core to collapse, and the star undergoes a massive explosion, or type II supernova. The elements synthesized just prior to a supernova explosion would include: hydrogen, helium, carbon, oxygen, neon, magnesium, silicon, sulfur, chlorine, argon, potassium, calcium, titanium, vanadium, chromium, manganese, iron, cobalt, and nickel. (14, 15, 16, 17, 18, 19).

Supernova Nucleosynthesis

Stellar nucleosynthesis of the elements up to iron has involved exothermic nuclear fusion reactions. During supernova nucleosynthesis, the heavier elements are created through endothermic reactions involving primarily neutron capture and to a lesser degree proton capture. When a star undergoes a supernova explosion, a high concentration of neutrons, called the neutron flux, will be emitted. The entire process of neutron capture during supernova nucleosynthesis is called the r-process and occurs at extremely high temperatures in a matter of seconds. The elements synthesized during this process are formed by a rapid absorption of neutrons producing the neutron rich isotopes of the heavier elements up to mass number 254. Highly unstable isotopes are produced during this process since the rate of neutron capture is greater than that of b-decay. These unstable radioactive nuclides will eventually decay into stable isotopes. The proton capture p-process, is believed to be responsible for the synthesis of approximately thirty to thirty-six proton rich elements which are heavier than iron. These elements cannot be synthesized by either the s-process or r-process. Because of the problems associated with overcoming very high Coulomb barrier forces, the p-process is believed to be a relatively minor process that requires extremely high temperatures (20, 21, 22, 23).

Objectives

This unit has been designed in such a way that the students should be able to: (1) explain the three different processes by which the elements are synthesized, (2) list the elements synthesized during Big Bang nucleosynthesis, (3) explain why elements with mass numbers greater than iron-56 do not undergo nuclear fusion in stars, (4) explain the differences between the s-process and r-process, and (5) explain how spectroscopy is used to identify elements. These behavioral objectives are in alignment with the Pennsylvania Academic Standards for Science and Technology as well as the School District of Philadelphia's core curriculum for chemistry.

The following is a list of the Pennsylvania Academic Standards for Science and Technology that this curriculum unit satisfies, and a brief explanation of each. A more detailed explanation is given in the appendix. The first academic standard 3.1.12 "Unifying Themes", involves providing the main ideas that integrate major concepts in science. Academic standard 3.2.12 "Inquiry and Design" allows students the opportunities to become independent learners through activities that improve their skills in manipulating variables, interpreting data, raising questions, and observing. Academic standard 3.4.12 "Physical Science, Chemistry, and Physics" involves chemistry students being able to study the relationship between matter, atomic structure and its activity. The last academic standard to be addressed is 3.7.12 "Technological Devices" allows the students to perform investigations using laboratory apparatus and the opportunity to observe and measure changes that take place over time (24).

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. The initiative involves the use of six teaching strategies that would address school-wide success. The first strategy involves the students previewing content specific vocabulary on a daily basis. In the second strategy, the students would preview, analyze, and connect material presented in their textbooks. Reciprocal teaching, summarizing material, the use of comprehension connectors, and note taking are the other teaching strategies that are expected to lead to school-wide success among our students.

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 factors: team organization, cooperative management, the will to cooperate, the skill to cooperate, basic practices, and structuring the cooperative lesson. In the next few paragraphs, a brief summary of each factor will be presented (25).

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, average, and below average 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. From a classroom management viewpoint, teacher determined learning groups tend to eliminate behavioral problems associated with

those groups which were determined by the students.

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 classroom must be established early and used consistently. 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 variety of different assessments. Students can be given individual grades for a project, or they can be made 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 team building, information sharing, thinking skills, communication skills, and content mastery. A brief list of classroom structures and lesson designs include: brainstorming, jigsaw, numbered heads together, rally table, round robin, roundtable, student teams achievement division (STAD), team projects and think pair share. A detailed review of each activity is given in *Cooperative Learning* (26).

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 sheet of paper, relevant material about the 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 (27).

In order to address and improve reading comprehension, my students will participate in reciprocal teaching techniques. This is another cooperative learning activity which 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 or assigned reading material, summarizing that material, and reporting out to the rest of his or her group (28).

Students will also be able to utilize a variety of interactive tutorial software and online websites including, but not limited to, SciLinks, go.hrw.com. Holt Online Learning, and http://imagine.gsfc.nasa.gov. SciLinks is an online website developed by the National Science Teachers Association which contains links and activities related to concept specific topics. The Holt Publishing Company has developed several online resources such as: go.hrw.com for worksheets, activities, and projects directly related the textbook used by the students. The Holt Online Learning is an online website where students can access help in solving problems.

Classroom Activities

Utilizing the Cornell Method of note taking and cooperative learning strategies, such as brainstorming, numbered heads together, reciprocal teaching, and team teaching, the first few days of the curriculum unit will focus on the students researching the Big Bang theory, stellar evolution, Big Bang, stellar, and supernova nucleosynthesis. As an assessment project, each group of students will be given a different list of astrophysicists and mathematicians from whom they could choose to write a report. Additionally, students will be able to create timelines involving the Big Bang and the expansion of the Universe, as well as creating posters illustrating different concepts of Big Bang, stellar, or supernova nucleosynthesis.

Activity 1: Power Point Presentation

The main activity for this unit will be for each cooperative learning group to prepare and present a fifteen minute power point presentation on a different aspect of the origin of the elements. After briefly presenting the basic foundations of the Big Bang theory and nucleosynthesis, each group will be assigned one of the following topics for their presentation: history of the Big Bang theory, stellar evolution, Big Bang nucleosynthesis, stellar nucleosynthesis, supernova nucleosynthesis, nuclear fusion reactions, and neutron capture reactions. The students will be escorted to the high school library where they will research their topics for two days using both written and electronic resources. The following two days each group will prepare their power point presentation. Presentation and discussion of their work will take place over the last few days of this unit.

Additional activities for this unit have been taken from *Imagine The Universe! What is Your Cosmic Connection to the Elements?* The following is a list of activities from which I will choose in supplementing this unit throughout the year. A detailed description of each activity including procedures, materials, and worksheets can be found at the website under teacher resources. (29)

Activity 2: "How Do the Properties of Light Help Us to Study Supernovae and Their Remnants"?

The behavioral objectives for this activity include: (1) students will learn how white light can be separated into its various colors, (2) students will learn the mathematical relationships between wavelength, frequency, and energy of light, (3) students will learn how to solve for a variable by rearranging an algebraic equation, and (4) students will learn about the nature of light and the electromagnetic spectrum. After reading the article entitled "What is Electromagnetic Radiation?" the students will be able to use the following equations: $c = \Lambda f$ and $E = hf$ to complete the worksheet entitled "Calculation Investigation". Using the aforementioned equations, the students will be able to solve for different variables with the proper units by rearranging the algebraic equations. The time allocated for this activity is one class period.

Activity 3: "Atoms and Light Energy"

The behavioral objectives for this activity include: (1) students will learn the basic structure of the atom, (2) students will be able to calculate the energy differences in the different states of a hydrogen atom, and (3) students will be able to compare their calculations with the known bright line spectrum for hydrogen. After reading the article entitled "Inside the Atom" the students will complete the worksheet entitled "Calculate the Energy". Using the following equation:

$$E = (-13.6 / n^{2}) \text{ eV}$$

where n is the principal quantum number and eV is equal to 1.6×10^{19} Joules, the students will be able to: (1) calculate the energy of the first excited state, (2) calculate the energy released by a photon of light falling from fourth energy level down to the second energy level, (3) use the relationship between the energy and wavelength to calculate the wavelength of the photon in question (2), and (4) compare the calculated wavelength with the given bright line spectrum for hydrogen. The time allocated for this activity is one class period.

Activity 4: "Supernova Chemistry"

The behavioral objectives for this activity include the students being able to: (1) learn about nuclear fusion, (2) learn about gravitational collapse, (3) learn the classification of supernova remnants, (4) learn why supernovae are important, and (5) compare and contrast the observed visible spectra from a variety sources including known elements. After reading the articles entitled "Supernovae" and "Supernova Remnants", the students will perform a laboratory activity using various glass emission tubes filled with known gases, fluorescent tubes, and regular light bulbs. With the aid of colored pencils, the students will draw diagrams of the spectra they observe. They will also answer such questions as: (1) How do scientists know that the helium discovered on Earth is the same as what was discovered on the Sun?, (2) After comparing the visible spectra of the known elements, what gas is in fluorescent tubes?, (3) Are there any differences between incandescent and fluorescent bulbs?, (4) Why are fluorescent bulbs considered energy efficient?, and (5) Based on the spectra produced from the "plant grow" bulb, why is the light better for plants? The time allocated for this activity is two days.

Activity 5: Cosmic Shuffle

For this activity, the behavioral objectives are: (1) the students will be able to understand the primary type of nucleosynthetic process that takes place in stars, and (2) the students will be able to write balanced equations for nuclear fusion reactions up to oxygen. This is a card game in which students are dealt seven cards from a deck containing the symbols, in relative proportions, of various isotopes, electrons, neutrons, positrons, and energy. The object is for the student to use the cards in their hand and/or chosen from the deck to form a nuclear fusion reaction. Scores are based on the mass number of each element that is formed. One class period will be allotted for completion and discussion of this activity.

Activity 6: Cosmic Ray Collision

The behavioral objectives of this activity are: (1) the students will be able to determine the probability of a collision occurring between objects at different distances, and (2) the students will be able to compare their results with the probability of a collision occurring between cosmic rays and atoms in space. The activity reports this to be a one in thirty chance. This activity should take one class period to complete and discuss.

Activity 7: What's Out There?

In this activity, the behavioral objectives are: (1) the students will be able to estimate the composition of elements within a given population, and (2) the students should be able to determine what object the population represents based on the composition of the given population. This activity is allotted one class period for completion and discussion.

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This resource is intended to help teachers establish an effective cooperative learning environment.

Cox, P. A. (1990). *The Elements: Their Origin, Abundance, and Distribution*. Oxford:

Oxford University Press.

This is a good resource, in particular, for the origin of the elements.

Freedman, R. & Kaufmann III., W. (2005). *Universe seventh edition*. New York:

W. H. Freeman and Company.

This textbook covers astronomy and cosmology at an advanced level.

Kagan, S. (1992). *Cooperative Learning*. San Juan Capistrano, CA: Kagan Cooperative

Learning.

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

Mason, S. (1991). *Chemical Evolution: Origins of the Elements, Molecules and Living*

Systems. Oxford: Clarendon Press.

This is an excellent resource for stellar nucleosynthesis at an advanced level.

Myers, T., Oldham, K., and Tocci, S. (2004). *Chemistry*. Austin: Holt,

Rinehart, and Winston.

This is the recommended textbook for chemistry as assigned by the School District of

Philadelphia.

Pennsylvania Department of Education. (2006). *Pennsylvania Teacher's Desk Reference*

and Critical Thinking Guide. Jacksonville, FL: Educational Tools, Inc.

This reference guide details the academic standards for science and technology for grades 9-12 and address the assessment anchors and teaching strategies.

Phillips, C. & Priwer, S. (2006). *Essential Astronomy: Everything You Need to*

Understand the Mysteries of Our Universe. Avon, MA: Adams Media.

This book gives a thorough introduction into astronomy and cosmology at the basic level.

Rhoades, J. & McCabe, M. (1992). *The Cooperative Classroom: Social and*

Academic Activities. Bloomington, IN: National Educational Service.

The activities in this book are designed to improve the social skills of the students within cooperative learning groups.

The School District of Philadelphia. (2006). *Planning and Scheduling Timeline for*

Science: Grade 11 Chemistry.

This booklet outlines the sequence of units to be covered, the time allocated for each unit,

and the resources to be used in teaching each unit.

Electronic Resources

A Brief History of Astronomy. Retrieved June, 2007, from

http://www.krysstal.com/astrhist.html

This article gives a synopsis of astronomical events between 4000 BC up to 20 01.

Big Bang. In *Wikipedia* [Web]. Retrieved June, 2007, from

http://en.wikipedia.org/wiki/Big_Bang

This article gives a thorough history of the history of the Big Bang theory.

Big Bang Nucleosynthesis. Retrieved June, 2007, from

http://astro.berkeley.edu/~mwhite/darkmatter/bbn.html

This is a short, not too technical, article on big bang nucleosynthesis.

Big Bang Nucleosynthesis. In *Wikipedia* [Web]. Retrieved June, 2007, from

http://en.wikipedia.org/wiki/Big_Bang_nucleosynthesis

This is a thorough overview of Big Bang nucleosynthesis with a good deal of references.

Burles, S., Nollett, K.M., & Turner, M.S. Big Bang Nucleosynthesis: Linking Inner

Space to outer Space. Retrieved June, 2007, from

http://www.arxiv.org/abs/astro-ph/9903300

The article gives a concise, but technical, history of Big Bang nucleosynthesis.

Cooperative Learning. Retrieved April, 2007, from

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.

Cooperative Learning. Retrieved April, 2007, from

http://edtech keenesaw.edu/intech/cooperativelearning.htm

This article briefly reviews the components of cooperative learning and cooperative learning activities.

Cosmology and Stellar Evolution. Retrieved June, 2007, from http://helios.nasa.gov/ed-acecosmo.html

The article which briefly describes the Big Bang, nucleosynthesis, fusion, and stellar evolution.

Coulomb Barrier. In *Wikipedia* [Web]. Retrieved June, 2007, from

http://en.wikipedia.org/wiki/Coulomb_barrier

In this short article the equation and explanation for Coulomb's law is given.

History of the Big Bang theory. In *Wikipedia* [Web]. Retrieved June, 2007, from

http://en.wikipedia.org/wiki/History_of_the_Big_Bang

This is a brief non-technical article on the history and future of the Big Bang theory.

Big Bang nucleosynthesis. In *Wikipedia* [Web]. Retrieved June, 2007, from

http://en.wikipedia.org/wiki/Big_Bang_nucleosynthesis

The article covers the characteristics, sequence, and history of Big Bang nucleosynthesis.

Formation of the High Mass Elements (What Happens Inside a Star). Retrieved June,

2007, from http://aether.lbl.gov/www/tour/elements/stellar/stellar_a.html

This is a good, but not highly technical, article for explaining stellar and supernova nucleosynthesis.

Hubble's Law. In *Wikipedia* [Web]. Retrieved June, 2007, from

http://en.wikipedia.org/wiki/Hubble%27s_law

This is a nice article for explaining the history and explanation of Hubble's law.

Lochner, J. Retrieved, June, 2007 from Imagine The Universe! Web site:

http://imagine.gsfc.nasa.gov/

This is a marvelous website for both teachers and students. It is a tremendous source of information on astronomy and cosmology in addition to classroom activities and resources.

LaRocco, C. & Rothstein, B. The Big Bang: It sure was Big!! Retrieved June, 2007, from

www.umich.edu/~gs265/bigbang.htm

This is a very nicely done article on the Big Bang theory.

Nucleosynthesis. Retrieved June, 2007, from

http://www.bartleby.com/65/nu/nucleosy.html

This is a brief article that reviews the proton-proton cycle, the carbon-nitrogen-oxygen cycle and nucleosynthesis of heavier elements.

Nucleosynthesis. In *Wikipedia* [Web]. Retrieved June, 2007, from

http://en.wikipedia.org/wiki/Nucleosynthesis

This is an excellent article on the history and types of nucleosynthesis including Big Bang, stellar, and supernova processes.

Nucleosynthesis of The Elements. Retrieved June, 2007, from

http://www.meta-synthesis.com/webbook/32_n_synth/nucleosynthesis.html

This is a rather nice, but brief, overview of Big Bang, stellar, and supernova nucleosynthesis.

Origin and Chemical Evolution of the Elements. Retrieved June, 2007, from

http://origins.colorado.edu/uvconf/white_final/node5.html

This is a highly technical article on Big Bang, stellar, and supernova nucleosynthesis.

Origin of the Chemical Elements. Retrieved June, 2007, from

http://www.chem1.com/acad/webtext/geochem/02txt.html

This is a nice article, without being overly technical, on primordial, stellar and supernova nucleosynthesis.

Reciprocal Teaching. Retrieved July, 2007, from

http://www.ncrel.org/sdrs/areas/issues/students/atrisk/at6lk38.htm

This article gives an overview of reciprocal teaching methods.

Schramm, D. N. (1998). Primordial Nucleosynthesis. *Proceedings of the National*

Academy of Science, 95, Retrieved June, 2007, from

http://www.pnas.org/cgi/content/full/95/1/42

This was a highly technical paper presented at a colloquium entitled "The Age of the Universe, Dark Matter, and Structure Formation" held in 1997 at the Beckman Center in Irvine, CA.

Stellar Evolution. Retrieved June, 2007, from http://www.bartleby.com/65/st/stellare.html

This is a brief, but thorough, overview of stellar evolution.

Stellar nucleosynthesis. In *Wikipedia* [Web]. Retrieved June, 2007, from

http://en.wikipedia.org/wiki/Stellar_nucleosynthesis

This is a very brief article on stellar nucleosynthesis.

Supernova nucleosynthesis. In *Wikipedia* [Web]. Retrieved June, 2007, from http://en.wikipedia.org/wiki/Supernova_nucleosynthesis

This is a very good, but short, article on supernova nucleosynthesis and the r-process of neutron capture.

The Elements: Forged in Stars. Retrieved June, 2007, from

http://www.teachersdomain.org/resources/ees05/sci/ees/eiu/fusion/index.html

This is a brief article on nuclear fusion in the stars.

The Origin of the Elements. Retrieved June, 2007, from

http://www.teachersdomain.org/resources/phy03/sci/phys/matter/origin/index.html

This is a very basic introduction into the topic of nucleosynthesis.

Student Resources

go.hrw.com

This website has activities worksheets, and resources directly related to the material presented in their textbook.

Holt Online Learning

Students will access this website for additional tutorial support in problem solving.

Lochner, J. Retrieved June, 2007, from Imagine The Universe! Web site:

http://imagine.gsfc.nasa.gov/

Students will access this website for content specific information on the Big Bang and nucleosynthesis in addition to curriculum specific activities and resources.

Myers, R., Thomas, Oldham, Keith, B., and Tocci, Salvatore *Chemistry,* Austin: Holt,

Rinehart, and Winston, 2004.

This is the recommended textbook for chemistry as approved by the School District of Philadelphia.

SciLinks

This is an online website developed by the National Science Teachers Association which contains links and activities related to chapter specific topics.

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

3.1.12 Unifying Themes: The unifying themes of science and technology provide big

ideas that integrate with significant concepts. There are only a few fundamental

concepts and processes that form the framework upon which science and

technology are based, which includes: the structure of matter.

E. Evaluate change in nature, physical systems and man made systems.

- Evaluate fundamental science and technology concepts and their

development over time (e.g. Universe theories).

- Analyze how models, systems and technologies have changed over time (e.g. theory of solar system).

3.2.12 Inquiry and Design: The nature of science and technology is characterized by

applying 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.

A. Evaluate the nature of scientific and technological knowledge.

- Critically evaluate the status of existing theories (e.g. classification of subatomic particles).

C. Apply the elements of scientific inquiry to solve multi-step problems.

- Organize experimental information using analytical and descriptive techniques.

3.4.12 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.

A. Apply concepts about the structure and properties of matter.

- Classify and describe, in equation form, types of chemical and nuclear reactions.
- Apply the conservation of energy concepts to fields as diverse as studies of the origin of the Universe.

D. Analyze the essential ideas about the composition and structure of the

Universe.

- Analyze the Big Bang Theory's use of gravitation and nuclear reaction to explain a possible origin of the Universe.
- Correlate the use of the special theory of relativity and the life of a

star.

3.7.12 Technological Devices: Students use tools to measure, move, and make things.

Technology enhances the student's abilities to identify problems and determine

solutions.

B. Evaluate appropriate instruments and apparatus to accurately measure

materials and processes.

- Apply and evaluate the use of appropriate instruments to accurately measure scientific and technologic phenomena within the error limits of the equipment.