A Waldorf High School Chemistry Program

RC Oelhaf

oelhaf@hotmail.com

Introduction

Since main subjects are taught in blocks, it is possible to design a program to meet the developing students' interests and needs. There are several ways to view the four high school years, ways which supplement and support each other and form the basis of the traditional approach to organizing chemistry and other subjects. We have in addition several general objectives for a chemistry program, namely, to provide a foundation for understanding fundamental chemical concepts and procedures and to do this in a Goethean or phenomenological style. Time limitations place restrictions on the total material and/or depth of the coverage.

The Question of Breadth

The original Waldorf School in Stuttgart, Germany, ran six days a week and had a six week summer vacation in contrast to our five days per week (Today German schools also have only five.) and a summer holiday of some 12 weeks. Altogether American schools have perhaps 36 weeks, not all of them are full due to various holidays. Main lessons also may only run two 45-minute periods for one and a half hours total. In general we have each year one three-week main lesson block giving us 2x15=30 classroom hours per year in contrast to perhaps 36 in the original school. Some schools have tried using extra main lesson time, mathematics skills classes or art blocks in the afternoon to bolster the schedule. At least one school has extended the school day to produce two main lessons a day. However most of us must make due with 30 hours a year or 120 over the high school program. In contrast, public schools or prep schools generally have one period a day for a whole year, or a total time of 5x37weeks = 185 classroom hours (somewhat less for prep schools). I taught in a prep school which allocated 7 hours per week to chemistry, allowing two full laboratory periods per week for a total of some 259 class hours. Today public schools also may similarly expand weekly classroom hours allocated to their science offerings.

How can we overcome this gap in technical education? Naturally we strive for depth, to present material so that it sticks, more likely in a block system than in daily lessons. Rudolf Steiner expected the teachers to be efficient, so that more could be learned and digested in a shorter time, allowing us to reach state expectations with fewer classroom hours. Still, it is difficult to match a conventional course, and we really do not want to do this. We are teaching, after all, all students, not only those with an interest in science or college. The solution which I have used is to offer extra chemistry lessons to interested students. We have done this on Saturday mornings (the most effective), in electives and in after school club settings. These courses generally emphasize theory and calculations, the main things we cannot push too far with general students in a Goethean context. These courses have been offered in the 11th and 12th grade, which seemed to be more appropriate than in earlier grades, especially considering the content of the 11th grade. A recent graduate, now completing university and applying to medical school, related that he decided to major in chemistry because of his delight in learning details of atomic structure. He was totally enthralled by orbitals and energy levels. I believe that we have a duty to open up these highly technical areas to students whose interests and abilities also need nurturing.

Goethean Chemistry

In a Goethean approach to chemistry, we begin with observations and a clear review of these observations. Students are allowed to reflect on these things during the night. The following morning on Day 2 the observations are revisited and implications are drawn out, implications which generally lead to further experimentation, and so the process continues. On the third day ideally students will participate in their own investigations verifying or exploring the area being studied. This three-fold

main lesson is an extremely efficient and powerful method of penetrating a subject. It is also quite difficult to put into practice, given limitations in time to carry out real laboratory investigations and often also limitations of student equipment and laboratory space. To the extent it can be approximated, however, considerable efficiency in learning can be accomplished.

Clearly, for students to undertake their own laboratory investigations they need space and a science laboratory designed for this purpose. The Waldorf school with the best designed laboratory that I am familiar with is Kimberton Waldorf School. Each student pair has a complete set of equipment in their desk for experimentation, with adjoining sink and gas. There are two labs, one for physics and chemistry, one for biology and geology. They share a generously sized preparation and storage room.
When the time comes for a school to remodel or build, it is certainly worthwhile to include generously proportioned and equipped science rooms.

In chemistry we are seeking to probe into the innermost hidden dimensions of the material world. Thus the introduction to chemistry is postponed in the Lower School until 7th Grade (in contrast to physics, which begins in Grade 6).   When students enter the high school, we should be able to presume that they have had an introduction to combustion, the limestone cycle and to acids and bases in 7th Grade and to photosynthesis, food types and digestion in the 8th. Nevertheless all must be (briefly) reviewed and confirmed before proceeding with new material. In any case there is no guarantee that all class teachers will have carried the subjects to sufficient depth. In fact the program in the Lower School should be more the experience of chemistry, the transformation of materials, without concern about why or how these things take place. Also students from other schools may not have the experiential foundation we would hope for. So it is always best to begin with a thorough review, but a review done efficiently, in a new way, a more advanced way, a more sophisticated way.

<u>Reaching the General Student</u>
Some students are naturally attracted to science and will be pleased to learn as much information as possible. However there are always several students, often a majority, who do not have a positive view of technical subjects. In general we have three ways of reaching and activating such students. First of all we can introduce subjects historically, showing science as evolving over time, not a fixed body of knowledge to be memorized. Secondly the introduction of historical personalities and their struggles to reach new insights can appeal to anyone. Thirdly, we provide ample opportunity for the students themselves to enter into the process through striking demonstrations and their own experimentation.

Further, using the teachers' meditation, calling to view each student in turn during the evening meditation, often gives rise to a special thought or story or relation to current events, with which the lesson may begin or be made directly relevant to life today.

9th Grade Chemistry

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A tradition has developed in Waldorf schools of teaching organic chemistry in 9th Grade. This does make sense from a number of points of view. Organic chemistry continues the developments in 8th Grade chemistry of nutrition and the oxygen cycle. But more important, 9th grade students feel arrived in the modern world, full of energy. Physics in the 9th grade concerns the internal combustion engine, energy and power. The origin of this power today is primarily fossil fuels; petroleum and coal. These are end products of organic processes, originating in plants. And organic chemistry is the area where the exciting and relevant research is taking place today. Finally 9th Grade may be viewed as in some ways corresponding to the earth element, coal and petroleum being as down to earth as it gets. Students should be ready to discus drugs objectively. So the experimentation with substances which change consciousness is particularly appropriate.

References

CHEM, Chemistry, an Experimental Science
____, Laboratory Manual
Julius, Fritz H, Fundamentals for a Phenomenological Study of Chemistry
McBride, J Michael, Freshman Organic Chemistry I, Open Yale Courses
McGee, Harold, On Food and Cooking
Mitchell, David S, The Wonder of Waldorf Chemistry, AWSNA

Course Outline

Observations of a Candle
Experiments with a Candle
Conclusions from the Candle Experiments
Tests for Carbon Dioxide and for Water
Demonstration: Magnesium and Carbon Dioxide
Human Breath Products
Photosynthesis and Respiration: Equations
Oxygen Cycle: Picture (would make a good frontispiece)
Demonstration: Glucose and Concentrated Sulfuric Acid
Analysis of Glucose
Sugar and Starch Tests and Properties
Carbohydrates
Chromatography Experiments
Fermentation
Distillation
Transformations of Sugar
- Chemical Equations
- Organic families: Alcohols,Ethers,Aldehydes, Ketones, Acids, Esters, Soap

Petroleum. Origin
- Stages of the Industry
- The Alkane Series
- Refining: Fractional Distillation
  - Octane Rating,Catalytic Cracking, etc.
- Saturated and Unsaturated Hydrocarbons

Coal: Origin and Types
Destructive Distillation

Some Block Notes

Opening Demonstration. Fill a two-foot rubber tube with starch, blow through a Bunsen burner

Combustion

My favorite way to begin is with the opening exercise in the Chemistry, An Experimental Science program, namely, observations of a candle, a simple, yet challenging exercise, and ultimately lots of fun. However it must be introduced properly, else students protest that they already know about candles (which they of course do not). I point out that at a new stage, one must first review everything learned up until that point, but at a deeper level, and very rapidly. My daughter was told by her college chemistry professor on the first day, that, prior to beginning new material, they would review all of high school chemistry, and in three weeks! Likewise, in graduate school, courses will often first briefly summarize what all should know from undergraduate work. And so we begin high school chemistry by looking at combustion, through the candle. One can also show Faraday's lectures on the candle, still in print after 150 years, and point out that actually what goes on in there is highly complex, and no one actually understands all the nuances even today. The first exercise is a contest: to take a simple candle (Shabbos paraffin are generally available in supermarkets.) and make as many observations as possible, first unlit, then lit. This exercise also involves a measurement review of using a scale, timing device, rule.

Next comes a set of small experiments with a lit candle, described in the associated exercise book. They involve testing various materials as wick, exploring the structure of the flame and bowl; relative temperatures in the flame; contents of the parts of the flame. For some students, this is the most fun they had ever had in a science class.

Tests, Chemical Changes, Main Substances

Next, tests for the products are introduced (limewater and cobalt chloride paper), and of course our own breath with straws and test tubes. It is always good to show the oxygen generated by plants. Elodea weed under an inverted funnel and collected in a test tube in a fish tank is convenient, but it takes several weeks for a testable quantity. For the fraction of oxygen in air, iron filings or steel wool in a wet inverted test tube over water can be used, but only if untreated filings or wool are available. (Make your own.)

A simple, yet visually striking demonstration of magnesium burning in carbon dioxide clearly shows the carbon, as well as a simple, yet vivid, chemical change. The equation (word and symbol) is obvious, building confidence in the student's ability to relate phenomena to formulas.

Burning wood shavings or excelsior demonstrates very well the various stages of combustion of organic material. Can the student imagine this process in reverse? Ask for results the next day, then point out, if they have not already thought of it, where this is going on all the time, namely, in the plant world, in photosynthesis. The oxygen cycle is now ready to be described in more detail. The remainder of the block is essentially drawing out the products of the original glucose molecules the plants produce.

Sugar and Starch

Sugar and starch are the focus of the next few days. Students have no doubt met these before. Now they should see how the experiments with starch demonstrate that their particles are much larger than those of the simple sugars. Chewing bread breaks the starch down into simple sugars, sweet to the

tongue. Also glucose and fructose respond differently to Benedict's Solution, indicating different structures. How can that be?

Analysis and a Chemical Formula

I do not believe that it is possible to proceed with organic chemistry without addressing chemical structure and molecules. Nevertheless we still seek to build everything up from experience, phenomenologically. So with filtering, with the action of acids and enzymes, we demonstrate the difference between a monomer and a polymer. We demonstrate the difference in chemistry, and hence structure, between simple sugars. Can we go further and determine the composition of sugar itself? We know that the plant makes it from carbon dioxide and water. And combustion produces carbon dioxide and water. If we suck out the water with concentrated sulfuric acid, pouring some into a small beaker partially filled with sugar, we get a carbon tower, hinting at the role of carbon as the backbone of organic substances.

Done more carefully, we can determine the relative masses of carbon and water in glucose. Heating a measured quantity of glucose in a small beaker or test tube, we can carefully drive off water vapor until only carbon is left. This is a longish demonstration, generally not completed in the classroom period, finished after class, with the residue available for the next class. If done carefully, the weight (mass) ratio of water to carbon is quite close to the accepted value of 18 to 12 or about 1.5. To go further, students must be supplied with the relative weights of these substances in compounds. With this in hand, an empirical formula of CH2O appears. Unfortunately this is the formula for formaldehyde, a poison. We must add a result from 10th grade chemistry, where molecular weights can be obtained, that the relative weight of the whole formula is 180. Thus we have a formula for fructose/glucose of C6H12O6. This analysis is exactly the kind of work which organic chemists carry out, so students obtain a taste of real chemical research.

Transformations of Sugar

From the plant's production of glucose we can go in two directions. One way is downward into coal and petroleum. And the other way is "upward," as sugar gradually loses the perfect balance between the fire of hydrogen, life of oxygen and structure of carbon. For sugar gives us a burst of energy, heightens our ego (even if for a short time, leading to a drop in energy afterwards). However sugar transformed into alcohol loses structure with the carbon, and so we lose control and give over to a "spirit."

The students can bring in various sugars or the teacher can supply them: molasses, honey, guava, malted barley, etc. The sugar is mixed with water and some live yeast added. The fermentation takes place conveniently in a 250ml Erlenmeyer flask, fitted with a one-hole stopper and glass right angle bend attached to a short rubber tube and a longer glass tube reaching into a 250 ml beaker with limewater, forming an air lock and the characteristic test for carbon dioxide. Following the complete fermentation, students should taste the results, which will not entice anyone to drink. The mash should be distilled, best mixing some together to obtain sufficient distillate. The result can also be tasted. A second distillation will generally be needed to obtain a concentration which may be burned.
(Prohibition, stills and related songs are possible here.)

Formaldehyde and Acetaldehyde are easily prepared by heating a copper wire coil in a burner and inserting it into a testtube containing a few ml of the corresponding alcohol. The copper oxide on the wire oxidizes the alcohol to the corresponding aldehyde, which can be wafted toward the nose. The removal of the water (of life) has produced a substance poisonous to life

Now the fun begins with concentrated sulfuric acid. First ether is produced as a result of the dehydration of ethanol, diethyl ether. Removal of the water causes further loss of control, to a loss of consciousness. The ether can be (carefully) wafted toward the nose after the removal of the burner and a little cooling off of the tube.

A variety of esters can be demonstrated, depending on the availability of organic acids and alcohols. With time and a good lab, students can make some themselves, though with much caution, as they are working with concentrated sulfuric acid. A ml or two of an organic acid and an alcohol in a test tube, followed by a small amount of concentrated sulfuric acid, one ml or less, is all that is needed. The reaction can be encouraged by gentle heating, with the mouth of the testtube pointed away from everyone.

If time permits, making soap is always lots of fun. Students can add some food color or fragrance if they like. Soap can be made in a petri dish (fitted with plastic liner) or in a small carton supplied by the student. The crucial step is stirring until the soap cools enough to thicken. If this does not happen, the result is three layers: lye, soap and fat.

An introduction to the important analysis method of chromatography is worthwhile. Liquid phase using a rectangle of filter paper in a stoppered Erlenmeyer flask is a convenient setup. Food colors or inks can be separated using water as the medium.

Petroleum and Coal

The petroleum industry should be discussed, from exploration to drilling and refining. Fractional distillation can be described, based on the students' own experience of distillation of a mash. Cracking, reforming, octane rating are worth explaining. The various products and their uses and the need for refining should be described.

How far the coal industry is addressed depends on time and interest. Destructive distillation of coal and wood and the resulting products can be easily demonstrated.

Industrial Tours:

Possible tours include a plastic molding operation, local brewery, petroleum refinery, bakery.

Appendix:

Student Laboratory Notebook (2)
Student Laboratory Desk Equipment (2)
Candle Experiments (4)
Percent Carbon in Glucose, Sample Results
Picture of Oxygen Cycle
Fermentation
Distillation
Picture of transformations of glucose
Chromatography: Food Colors
Chromatography: Plant Substances
Soap
Destructive distillation

10th Grade Chemistry

RC Oelhaf

After the explosive 9th grade and its extremes, it is time to seek balance and equilibrium. Water forms the natural medium for this exploration, and is the element associated with the 10th Grade. Water is a very special substance, with properties which are essential for our life on earth. Water plays a balancing or mediating role in major chemical processes: dissolving and crystallizing or precipitating, acids and bases, positive and negative ions. Water is the mediator in these dynamic equilibria. In the context of exploring these processes, it is convenient to introduce several important chemical concepts: Le Chatelier's Principle, the Second Law of Thermodynamics, positive and negative charges, moles and molarity.

References
W.A. Bentley and W.J. Humphreys, Snow Crystals
Kenneth S Davis and John Arthur Day, Water: the Mirror of Science
Alfred B Garrett, Chemistry
Alan Holden and Phylis Morrison, Crystals and Crystal Growing
Theodor Schwenk, Sensitive Chaos
Water. Our Thirsty World National Geographic Special Issue, April 2010
Wilkins, Andreas, Michael Jacobs and Wolfram Schwenk, Understanding Water

Course Outline
Water. Properties and Importance
Experiment: Solubility and Temperature with Potassium Nitrate
- LeChatelier's Principle

NaAc experiment: unsaturated, saturated, supersaturated solutions.
- Static and dynamic equilibrium
- Exothermic and endothermic reactions
- Spontaneous changes. enthalpy, energy, entropy, the Second Law of Thermodynamics

The electrolysis of water
- Laws of electrostatics

Relative Weights/Masses in Chemistry. Atomic weights/masses
- Gram formula weight/mass, mole, molarity, molality

Conductivity of Solutions: water, sugar water, salt water
Electrolytes and Non-electrolytes
Boiling point and freezing point changes of solutions
Arrhenius and the ionization theory
Acids and bases. Indicators
Ionization of water, Kw, pH
Cells and Batteries, Electroplating

Poetry: Shelley, Ozymandias or The Cloud
Poem of the Swampy Creek Indians
Song: Cool Water

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Opening Demonstration: Prepare equally concentrated Muriatic Acid (HCl) and lie (NaOH) solutions, mix measured equal amounts and sip. Offer to class members. Show danger signs on bottles.

Teaching the Block
Water
Gesture of water, necessity for life, contributions to life on earth, special or unique properties.
Oxygen, essential for life; hydrogen,element closest to fire
Ice, contribution to geology, aquatic life. Crystals, snowflakes
Homeostasis, global warming, pollution
Demonstrations and experiments: many suggestions in Wilkins, et al

Dissolving and Crystalizing
Crystals in nature, crystal growing. Students may have grown crystals in the lower school. If not, they could grow them. A demonstration may be sufficient. Introduce dynamic equilibrium.
Solubility curve of KNO3 as group experiment. Could be omitted if time is short, but produces a very nice curve, is a satisfying group experiment, and serves as background to the next experiment.

Solutions and mixtures, unsaturated, saturated and supersaturated solutions.
NaAc experiment: individual student experiment

The results are dramatic. The cooling on dissolving and warming on crystallizing are clear.

Can you sense the pain of the sharp crystals growing?

The stress of the supersaturated solution is relieved by crystallizing a portion of the solute.

The mixture of salt and water is more orderly, yields to disorder of a solution at higher temperature. Cooling shifts the equilibrium back to the orderly condition.

Exothermic and endothermic reactions, enthalpy, entropy, LeChatlier's principle

Measurements in Chemistry
relative masses ("atomic weights"), molecular, formula weights
Measuring Concentration of solutions: percent, mole, molarity, molality
These concepts are necessary prior to proceeding further with solutions, acids and bases...

Electrolytes and Non-electrolytes: Electricity and Solutions
Review of laws of electrostatics
Electrolysis of water. Properties of oxygen and hydrogen
Conductivity of solutions. distilled water, tap water, salt, sugar
Boiling and freezing point changes. Class experiment using various salts and concentrations
Arrhenius' life and his theory of ionization.
Measurement of molecular mass could be done as extra experiment by interested students

Acids and Bases, Indicators
Properties of common acids and bases. Character, examples
Student experiment: compare various common acids and bases for feel, smell, taste (very dilute, touch tongue, rinse mouth thoroughly)
Demonstration: Universal indicator from pH 14 to 0 using NaOH and HCl, diluting 1M solutions stepwise (l, 2, ...14, 13...)

Student experiment: Titration (if time and equipment permit)
Strong and weak acids and bases, ionization of water, pH, indicators. If time permits, buffers

Cells and Batteries : Examples. lemon, dry cell, car battery, electroplating demonstration

10, 3 (9)

Industrial Tours: electroplating plant, water purification plant, paper manufacturing

Appendix:
Crystal Growing

11th Grade Chemistry

RC Oelhaf

Students at this stage in life are seeking to be clear about their place in the universe. The curriculum responds with Astronomy, locating us in the cosmos, and with Chemistry raising the question of the structure of the universe on the most minute level. A small book illustrated this human place several years ago through a series of photos and drawings, taking us from a human being to the largest structures of the universe in one direction and to the smallest particles then known in the other (Philip Morrison et al, Powers of Ten). Two main questions weave their way through chemical history: Is the world continuous or particulate? Are there fundamental elements forming the foundation of the material world and if so, what are their relationships? How these questions have been resolved weaves through the history of chemistry from ancient times to modern. We are therefore faced with a huge task. We are not teaching a university course on the history of chemistry. Still, we must deal with Aristotle, the alchemists, Dalton, Mendeleev, and the Rutherford-Bohr model. After discussing the deficiencies of this model, the next step would be to DeBroilie, Heisenberg, and Schroedinger. As a practical matter, it is better to leave further steps in atomic theory and the question of particulate or continuous until 12th Grade Chemistry. There is already too much for one main lesson. And it will be easier to handle the wave-particle duality of matter after the 12th Physics block, in which the wave-particle duality of light will be discussed. The characteristics of major elements and classes and chemical calculations, and the gas laws are necessary for understanding the historical developments. (It would be very helpful if the gas laws had already been studied in 9th Grade Physics.) We do not want to short-change the artistic or spiritual nature of substances, in particular the seven metals. Student reports on a particular substance can provide a window into the human connections and make the material more personal. I generally gave a sample report on one of the metals, usually iron, where many aspects can be readily characterized. Other ways to show the relationships of the major elements include a 7-pointed star with the planets and Julius' 12 modern elements with the associated 4 classical elements.

If a four-week block is possible, this would be a great blessing. Perhaps some extra periods can be absorbed from a track class. In any event it is clear that the block must move rapidly and efficiently.

Recitation Suggestions: John Donne, "No Man is an Island..."
John Masefield, "Sea-Fever"

Student Report: One of the major elements. The 7 metals for the 7 planets should be included, also carbon, oxygen, hydrogen, sulfur, calcium, sodium, magnesium would be important Reports must be short due to time limitations. A written version should give more details. Some artistic representation to show the element's character would be especially helpful to indicate human or spiritual aspects..

Course Outline
Greek philosophy
Alchemists
Pflogiston
Lavoisier, Priestly and oxygen
Laws of Definite Proportion, Multiple Proportions
Gas laws. Boyle, Charles, Kelvin
Dalton. Life and work
Dalton's atomic theory

Gay Lussac and Avagadro
Kinetic theory of gases
Electrolysis and the Faraday (optional demonstration)
The size of molecules and Avagadro's number.
Chemical calculations
Ordering the elements. Mendeleev and others
The Rutherford-Bohr model, atomic spectra
Nuclear structure, subatomic particles, isotopes

Matter: What of "atoms" now?

References

Chemical Bond Approach Project, Chemical Systems
Frances, Keith, Rudolf Steiner and the Atom
Garrett, Chemistry
Julius, Frits, Fundamentals for a Phenomenological Study of Chemistry
Lavoisier, Elements of Chemistry
Lehrer, Tom, "The Elements" in Too Many Songs by Tom Lehrer, Pantheon Books
Lucretius, De Rerum Natura
Mason, History of the Sciences
McBride, J Michael, Freshman Organic Chemistry I, Open Yale Courses
LFC Mees, Living Metals
Morrison, Philip and Phylis, Powers of Ten, Scientific American Library, 1982
Pelikan, The Secrets of Metals
Steiner, Rudolf, The Boundaries of Natural Science CW 322
PSSC, Project Physics
Walker, Jearl, The Amateur Scientist, Scientific American December 1983, 164-170

Homework Assignment Topics

Boyle's Law
Temperature scales
Charles' Law
Molecular and formula weights/masses
Chemical Equations: writing formulas, balancing
Weight relations
Volume relations. STP

Through the Block:

Ancient Greek Thought. Aristotle sees continuous matter, intuitively clear.
Lucretius argues from experience: dust dancing in the sunlight. Brownian motion.
The Four Elements, character, as explanatory factors (will be gradually transformed into physical states of solid, liquid, gas, plasma)

Alchemists: goal, methods, contribution to evolution of chemistry. Three elements combine original idea with two modern (sulfur and mercury) with key role of salt recognized.

Oxygen: the phlogiston sidetrack, van Helmont and air, Priestly, Lavoisier.("The Revolution does not need scientists. Off with his head." Lavoisier's experiment after death.)

Demonstration: combustion of wood shavings, iron filings, magnesium
Plunge burning magnesium into CO2, note products of C and MgO, demonstrates O-R
Preparation and properties of oxygen.

Boyle and the Revival of Atomism. Gas laws. Boyle, Charles, Kelvin.

A simple review. Experiments done in 9th Physics, laws should have been discussed then.

Laws of Definite Proportions and Multiple Proportions:

Experiment: Copper and Sulfur. a simple, clear and satisfying student class experiment

Demonstration: Copper dust in large evaporating dish, heated gently, gradually stronger. Gradual heating brings out a series of colorful compounds of Cu and O. With luck a change in weight between CuO and CuO_2 can be seen.

John Dalton . Strange personality, wore black, founded meteorology observing weather daily in his home town, where it rains every day. Color-blind. Develops atomic theory with flaw, hinders chemistry for years (until Avogadro's Hypothesis recognized).

Kinetic Theory of Gases. Kinetic theory explains gas laws. Avogadro, Gay Lussac, Molar Volume

Chemical calculations. Balancing equations, weight relations, volume relations

Demonstration: The Size of Molecules. Measurement of an oleic acid film on water allows an estimation of molecular size and also of Avogadro's Number

Ordering the Elements. Various proposals. 7 metals. Julius: a human ordering of the major elements.

Triads, Newlands and Mendeleev, modern periodic table

Chemical Combinations. Valance, ion formation, reactivity of the elements. Chemical families. Demonstrations:

Reaction of sodium, potassium and calcium with water. Combustion of calcium and magnesium. Activity of halogens

Ionic and covalent compounds

Exceptions and Questions. -Many masses integral multiples of Hydrogen, but several not.

- -Tellurium and Iodine out of order
- -Many holes
- -Radioactive elements
- -Regularity in valence, but no zero valance
- -Why lengths of 2, 8, 8, 18...?

JJ Thomson and Electrons; Rutherford-Bohr Model, Neutrons

Experiment: Spectroscopy. Flame tests and/or hand spectroscopes.

Problems with the model, open questions: to be continued in 12th Grade.

Subatomic Particles. Is there an end?

Mass-energy: The 4 elements of Aristotle become the 4 states of matter: solid, liquid, gaseous, energy

Appendix

Block Report

Masefield, Sea Fever

Copper and Sulfur experiment (5)

Copper oxides experiment (3)

Boyle's Law experiment

Charles' Law experiment (2)

The Size of Molecules: oleic acid experiment (4)

Julius' ordering of the elements

The Seven Metals Star
Experiment Notes (2)

BLOCK REPORT

The purpose of this research report is to learn as much as possible about one particular substance (element), so that you will become to some extent an expert on it, and be able to understand its significance for chemistry and civilization in general. We will focus first of all on the common metals.

The report should include:

1. An oral report of 5 to 10 minutes in length.
2. A written report with proper references. Suggested length: minimum of 3 to 5 pages.
3. You may also be able to make a small artistic presentation of the nature or significance of the element chosen, which may be a picture, poem, music, dance, sculpture...

Sources. You are encouraged to consult at least one book and also articles or encyclopedias and chemistry books, as well as an internet search.

Topics which may be included in your report:

1. Ancient myths or associations with your element
2. History of discovery and use
3. Geography of production, reserves, extraction, processing
4. Importance in human civilization, technology
5. Physical properties
6. Chemistry
7. Role in human organism, in plants or animals
8. Uses in medicine or poisonous aspects

Any common themes or patterns of behavior appearing in the above survey (1 to 8)

12th Chemistry

RC Oelhaf

The 12th Grade is the time to take a wider view of the human enterprise, to explore human individual responsibility and possibilities. Thus the Geography block becomes Economics, the History through Art block addresses Architecture. The Biology block surveys Zoology, with the human the central character as the summing up of the other species. Rudolf Steiner's suggestion for 12th Grade chemistry may be seen in the context of these other subjects. For the 12th Grade chemistry block, Rudolf Steiner recommended presenting the chemistries of the four levels of being. These levels are the mineral, plant, animal and human. How shall we handle this challenge? Here is how I came out.

The difference between the chemistry of minerals and that of living organisms is clear enough. I began the block with an introduction to minerals and crystals. Growth is through the setting down of layers on the crystal lattice. The crystal types, the symmetries, the resulting actual forms in nature can be introduced. Growth is entirely from the surrounding solution. Form results from the internal character of the substance and from the external situation.

Both plants and animals govern growth in conjunction with the genetic endowment, the living or etheric forces and the external environment. The central role of enzymes is characteristic. Still there are clear differences which can be emphasized, for example, the chlorophyll with Magnesium as the central atom in contrast to hemoglobin with Iron. In general, plants grow until external circumstances limit further expansion. Animals have characteristic sizes and lifespans, to a large extent independent of the environment, in other words, determined internally rather than externally. Plants concern themselves with photosynthesis and the transformation of its products. Animals, by contrast, are constantly carrying out a vast array of complex and highly varied biochemical processes. The positions in the oxygen cycle are clearly complementary. The major portion of the block would be taken up with biochemistry. Discussion of steriochemistry and factors affecting rates of reaction would be appropriate.

If students have studied series in geometry or projective geometry, the contrast between arithmetic, geometric and hypergeometric series can be referred to. The arithmetic series grows stepwise as a crystal; the geometric ever expanding, as a plant. The third expands, then closes in on itself, as an animal.

What about humans? Much as the higher animals, humans carry out a great variety of chemical reactions in transforming, breaking down, and producing new substances. Since the beginning of the 20th Century, humans have also carried out nuclear transformations on a large scale through nuclear reactors. It would be well to explain how we obtain energy from this source and the biochemical effects of the resulting pollution and potential environmental disasters. The discussion of alternative energy sources and methods of limiting use would not be out of place, especially if these issues have not been addressed in other classes or in high school forums.

With the inclusion of crystallography, biochemistry and nuclear chemistry, I believe that the block is addressing major l2th grade issues and carrying out as best we can Rudolf Steiner's mandate. The actual content and weighting depends on what is contained in other 11th and 12th grade blocks.

12-2(15)

The Rutherford-Bohr Model Failures and Modern Atomic Theory These questions remains from 11th Grade Chemistry and must be addressed now. De Broglie, Heisenberg, Schroedinger are introduced and the modern view of atomic and molecular structure. The students have experienced the
wave-particle duality of light, so that meeting it again with matter is no great surprise. In my experience, students today accept these paradoxes better than their elders of the previous generation. And the wave-particle duality and the associated wave equation point to the structure of the atoms, molecules and periodic table. Students have studied calculus, so that an introduction to the wave equation may be possible, especially in response to student questions.

Continuous or Particulate? And what of matter? Is it in the end continuous or particulate? The answer as of 2012 is continuous. Matter's wavelike character means that discrete independent particles are unrealistic abstractions.

References

Lawrence Edwards, Projective Geometry
Seyhan Ege, Organic Chemistry
Linus Pauling, General Chemistry

Appendix

The Shadow
Four Levels of Being Notes
Chromatography of Natural and Refined or Artificial Substances
Crystal Types
Catalysis (2)
Reaction Rate and Concentration (3)
Reaction Rate and Temperature (3)

Some Block Notes

Wave-particle nature of matter. De Broglie, Heisenberg, Schroedinger.
Rudolf Steiner cautions against associating the electronic charge with all matter, thus slipping an evil (Luciferic) element into everything. While we cannot avoid describing the modern view, we can also indicate the potential for evil with help from an old radio show, "The Shadow." The reference to evil and the gruesome laughter come together with the total uncertainty of The Shadow's position, since he is invisible. To make things even more bewildering, these wave/particles also have a spin or magnetic moment, so once again electricity and magnetism are intimately connected.

Shells, subshells, orbitals. Convenient models are made from balloons: round for s orbitals, oblong for p orbitals. Balloons which blow up to about 3" x 9" are convenient. Two twisted and combined in the center produce a picture of hybrid orbitals found in Carbon (well to be discussed prior to biochemistry). Three treated the same way (in three different colors) show relations of the three p orbitals. Modern Periodic Table.

Mineralogy. Crystal, symmetry, classifications, origins, jewelry

Biochemistry. Photosynthesis. Catalysts. Steriochemistry. Some important systems in animal and human.

Nuclear Chemistry. Stable and unstable nuclei. Natural radioactivity. Disintegration series. Nuclear power, nuclear weapons, fallout