Alchemy Notes

Alchemy is the medieval chemical science and speculative philosophy whose aims were the transmutation of base metals into gold, the discovery of a universal cure for disease, and the discovery of a means of indefinitely prolonging life.

The alchemist believed all matter had a common origin and had the ability or potential to change shape, color, or make-up. The alchemist sought a complete scheme of things; in which God, the angels, man, animals, and the lifeless world all fitted into place. Also the origin of the world, its purpose, and end were to be clearly visible.

Greek philosophy (600 BC to 500 AD), along with Egyptian and Babylonian science (3500 BC to 200 AD), Chinese alchemy (300 BC to today) all lead to Arabic Alchemy (850 BC to about 1500 AD)

Gold was important to the alchemist for a number of reasons:

1. it was the same color as the Sun and very rare
2. it was very heavy (dense), often found in the pure state, malleable, and did not tarnish or decay (as did every other metal)
3. no single acid or base of early times could dissolve it
4. it was used in a variety of ways: money, jewelry, paintings, medicines, building, etc.

The alchemist sought to change base metals into gold for their benefactors. They professed to have found a tool that would allow them to transmute cheap substances into gold. This tool was called the **Philosopher's Stone**. This substance was defined as "a stone that is no stone, but contains within it the seeds by which cheap metals may be transmuted into gold and silver."

Had these alchemist been able to do this, gold would have, of course, lost all monetary value to their benefactors.

The idea of prolonging life and making gold out of cheap metals is basically the same idea: doing something magical and special, to uplift the life of people who did not always have the best in life (there has to be some reason for calling it the Dark Ages).

The alchemist were a varied lot. Some were charlatans, some professed to be wizards, some were just con men. But most were early researchers. They worked with making glass, brick, pottery, and fermenting fruit juices (acid research).

Alchemist are given credit for three major contributions to science:

1. **lab techniques**
2. **medicines**
3. **lab tools and supplies**

Lab techniques: the alchemist attempted and developed the following procedures, still used today.

1. **distillation** – heating 2 or more liquids (mixed together) so that the liquid with the lowest boiling point (the most volatile or mot easily evaporated) is turned to vapor which is then condensed (returned to liquid state) and collected in another container
2. **filtration** – using some material which strains out solid particles from solution
3. **crystallization** – causing some solution to form crystals, usually by drying it
4. **coagulation** – causing a liquid to become a soft, semi-solid mass
5. **evaporation** – using heat to cause a liquid (or some part of liquid) to be changed into a vapor
6. **extraction** – removing one liquid or solid from another mixture by using solvents (substances that will dissolve another substance) that dissolves only one of the original substances, thus forming a separate layer or area where separation takes place.

Medicines – The alchemist had always sought a way of transforming people into more perfect human begins and becoming a doctor and learning the use of medicines helped. This helped the alchemist gain the confidence of the people as well as making a living.

Lab Tools and Supplies – A number of the tools we use in lab today were devised by the alchemist. Of great importance, mineral acids and alcohols were developed. The use of minerals in the lab was new. Before only plant and animal matter had been used. The significance of this is that **minerals are usually present in large quantities, they are easily transported, and the properties do not change as rapidly as organic materials (long shelf life).**

H_2SO_4 = Sulfuric Acid

HCl = Hydrochloric Acid

HNO_3 = Nitric Acid

So, what were the three goals of these alchemist:

1. **turn base metals into gold and silver with the Philosopher's Stone (they thought they could use their early chemistry – mix materials to turn the metals into gold – they saw tin and copper mix to form bronze – but they couldn't do it – we can transmute metals today (certain combinations only) but it cost more money than its worth)**
2. **cure sickness by using the Elixor of Life (aren't we still looking for the cure-all)**
3. **prolong life using the Fountain of Youth (if you could live for a longer span, you would also need the cure-all for disease and plenty of gold)**

"There were many types of alchemist who made use of the art for different purposes. There were a few of the **mystical or religious** character whose true object was the guidance of mankind to salvation. There were the **philosophical** alchemists steeped in the doctrines of Aristotle and who sought, by the transmutation of base metals into gold, to prove their thesis – the unity of all things. We find also the **mercenary** alchemist whose only hope was to find in the Philosopher's Stone the key to a store of unlimited riches. But there was a large number of these early investigators possessing **scientific** character, and whose desire was to discover the properties and combinations of metals as well as the best method for their manipulation. In a measure, alchemy ended its days in failure and fraud, largely because charlatans and fools ere attracted to it by mercenary objects. In another sense, the heritage of the alchemist is a vastly rich one, and in their blind groping for a new way to make gold they paved the way for the modern science of chemistry." from Harold P. Gaw, Alpha Alpha '25 GMA – 1942-46.

The greatest influence on science by a single man prior to the alchemist was probably **Aristotle**. Born in 384 BC (died in 322 BC), the Greek teacher, politician, philosopher said that Nature strives toward perfection, with the circle and gold as natures examples of this perfection. He along with the Greeks believed the Universe to be made up of the **4 Primal Elements (earth, air, fire, and water**). A fifth, ether, really doesn't enter into our discussion. Suppose however, they had called earth solidness, air as gaseousness, water as liquidness, and fire as energy.

Why was Aristotle so important to our study. The following excerpt from a book by Isaac Asimov may help us understand this importance.

The Rule of Aristotle

"This Aristotelian structure of abstract qualities and primal elements ruled the West's ideas of matter for the next 2000 years. It was an integral part of an orderly model of creation in which man and his mind were given a noble role, above the beast but below the angels, and in which every part emphasized the common sense of ordinary experience. Since this mode of thought put man at the center of an ordered universe and mixed philosophy and science, no part of the model could be changed without changing all of it -- really, without destroying it.

But the long rule of Aristotle is due partly to the fact that his is the most comprehensive `system' of thought in history, East or West. Not even modern science is yet as comprehensive. And it is also due partly to the fact that, if we ignore experimentation, the mind can even today accept what Aristotle stated about the world, because he relied on the senses and on common sense. And partly, perhaps largely, Aristotle's rule lasted so long because the Christian Church made the Aristotelian cosmogony its own and all education in Europe was in the hands of the Church, which to this day maintains the conviction that man has a key position in the real universe.

It was not until the seventeenth century that a system of thought, a methodology, an attitude, a point of view, a logistics of reasoning, as it were, developed into the first principles of our scientific approach to reality, an approach that brushed aside moral speculation inside the laboratory. Therefore the power of the Four Primal Elements must be seen in their relation not only to ancient philosophy but to Christianity as well.

Why was the rule of alchemy never challenged when intelligent men recognized that it was a cloak for charlatans who seduced even kings with promises to manufacture gold?

For the simple reason that alchemists were the chemist and pharmacists, who brewed medicines and poisons and worked with acids and metals as a matter of course. They were adept in all the `natural sciences' of astronomy, mathematics, and physics; they were physicians, teachers, scholars, in general. The courts of Europe and rich men employed alchemist for practical purposes, and the most honest was expected to keep his ears open for rumors of new cure-alls. No man really knew, after all, that the Philosopher's Stone did not exist, or that lead could not be transmuted into gold. Furthermore, knowledge itself was desirable in those days, just as it is today. There is a lust for knowledge in all men, against the tedium of brute existence."
Today and Tomorrow and ..., by Isaac Asimov. Dell Publishing Co., 1973.

Who were the other alchemist of note. Most of these have faded into obscurity.

Democritus (250 BC) – proposed original idea of atom being a nondivisible particle. He suggested that different substances were composed of different atoms or combinations of atoms and that one substance could be converted into another by rearranging the atoms.

Zosimus (300 AD) – wrote down lab procedures, giving us first concrete writings dealing with alchemy

Rhazes (825 AD) – created many of our laboratory tools

Geber (Abu Musa Jabir or Jabir ibn-Hayyan) (760-815 AD) Known as our stereotypical alchemist, did important work with mineral acids, worked to create pure forms of chemicals, and was a careful experimentalist.

Paracelsus (Theophratus Bombastus von Hohenheim) (late 1490's AD) He was not really interested in the Philosopher's Stone, but insisted true goal of alchemy should be to prepare healing drugs. He accepted information from anyone and tossed away the books of medicine of the time and traveled to learn from nature. He may have been the last of the alchemist or the first of the medical chemist.

One idea you might want to consider: Suppose you were 14 or 15 years old, lived in Europe or the Arabic world of the Middle Ages, and wanted to become an alchemist. How would you go about becoming one? What skills/knowledge would you need?

Other important people include Copernicus, Galileo, Kepler, Brahe, and Newton.

Robert Boyle: gave the first modern criterion of an element: "it is a basic substance that cannot be broken down into simpler substances by chemical reactions after it has been isolated from a compound."

Georg Ernest Stahl (1700's): put forth the phlogiston theory to explain burning and rusting: "all inflammable objects contained phlogiston which made it possible for them to burn, and as the object burned phlogiston was poured out into the air. Wood and coal contained a great deal of it, the ashes left after burning did not.)" His greatest contribution to chemistry was in comparing the process of wood burning to the rusting of metals (oxidation). Flaw in theory was that when a metal rusted it gained weight (some said phlogiston had negative weight or levity).

Joseph Priestley - 1770
a) heated mercury in open dish to form a kind of mercury rust (called a calyx)
b) collected the rust, then heated it and saw that the calyx gave back a gas that caused a candle to burn very brightly when placed in the gas
c) found a mouse could live in the gas (even took a whiff of the gas himself)
d) a life-long believer in the phlogiston theory, he had actually discovered oxygen

Antoine Lavoisier (1743 - 1794)
a) A French scientist who believed science should be quantitative instead of qualitative
b) did three famous experiments:

1) the 101 day reflux experiment: for hundreds of years some scientists had done an experiment that proved (to them) that water could be turned into sediment (remember the 4 Primal Elements). The experiment was to heat pure water to boiling, then allow the steam to recondense back into the original container. This was repeated for months and dirt would begin to show up in the bottom of the flask. Lavoisier measured all the equipment and the water before running the experiment for 101 days. The sediment that appeared came from the wearing away of the equipment, not transmutation

2) tin box experiment: Lavoisier placed powdered tin in a box, sealed it, and heated it. When he started to open the box he measured it and found that no mass had been lost or gained. If the phlogiston theory were correct, it would be expelled when he opened the box. If his idea of part of the atmosphere being united with the tin during rusting were correct, air would rush into the box to takes its place. This was correct.

3) Candle in the water experiment. Lavoisier placed a burning candle down into a shallow pan filled with water. The water came up about one tenth of the height of the candle. He then inverted a large graduated cylinder over the candle and submerged the open end of the cylinder in the water. The flame heats air inside the cylinder causing bubbles of heated air to bubble out of the cylinder. The flame then goes out, smoke appears, and water rises inside the cylinder. The cooling of the air inside after the flame goes out reduces the pressure inside allowing atmospheric pressure outside to force water inside the cylinder. The flame went out even though some oxygen was still present. For a flame to continue to burn there must be a threshold amount of oxygen present in the air. When the oxygen content drops below this threshold the flame goes out. Also a flame must have convection occurring to remove heated carbon dioxide gases away from the flame area allowing oxygen to come in. A candle inside a large container that is dropped will go out faster than a similar candle in the same flask with a lid over it due to the fact that the carbon dioxide fall at the same rate as the candle and is not removed from the wick as it is in the held flask.

Lavoisier is thought to be the Father of Modern chemistry.
He named the gas oxygen, is known for his measurement emphasis, developed a naming system for chemicals, wrote the first chemistry text book, and derived the nature of combustion

Henry Cavendish: proved Lavoisier correct with his hydrogen jet experiment (proving water to be a chemical combination of gases). His experiment completely ended the idea of the 4 Primal Elements of the Greeks.

Cavendish Hydrogen jet experiment: This will be a classroom demonstration. Approximately 10 grams of mossy zinc will be placed in an Erlenmeyer flask with a side exhaust. Several milliliters of $CuSO_4 \cdot 5\ H_2O$ (copper (II) sulfate pentahydrate) will be added to act as a catalyst (to speed up the chemical reaction). Attached to the exhaust port will be a piece of tubing into which I will place a pipet (the jet). I will then add $H_2SO_{4(aq)}$ (6M hydrochloric acid) diluted with water through a thistle tube. This mixture will cause hydrogen gas to be generated in the flask and expelled out through the pipet. I will ignite the gas and burn off the hydrogen that is generated. We will look at the many safety issues that must be dealt with during the demonstration as well as the chemical reactions taking place to make water. These reactions will be studied in detail in the spring.