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Scope of Study: Science appreciation, interest and concepts beyond the prescribed course in classroom teaching is an important phase of a high school students science education. One logical means of motivating the student toward these objectives is to approach the field of study from a historical background. This report involved the study of the history of science from the dawn of history until the present day. The object was to select from the history of science, the data in regard to a basic idea from the time it was first conceived until it became scientific fact, and compile this data as a synopsis of the history of science. This historical data to be introduced into classroom teaching as the instrument of motivation to create within the student these more desirable objectives. The materials used in this report were acquired from a series of reference books concerning the history of science.

ADVISER'S APPROVAL

A SYNOPSIS OF SCIENCE HISTORY AS AN INSTRUMENT OF MOTIVATION IN HIGH SCHOOL SCIENCE CLASSES

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CHAPTER I

INTRODUCTION

The purpose of this study is to collect certain basic facts in the history of science to present to a class as a means of motivating the student to more intrinsic objectives. The object has not been to compile a complete history of science, but to establish the age in which certain basic ideas were brought forth and the age in which they became accepted facts. It is conceivable that a student would feel more interest and develop more desire for a science course if he realized that thousands of years of experiment and study by eminent scientists went into producing a scientific law he perhaps could be taught to understand in one class period.

An underlying assumption is that a means is needed to stimulate a student to succeed in a course for the value of the subject matter and its usefull applications. All to often a successful student gradewise, has made the grade his ultimate goal; thus the classroom has produced animated encyclopedia like students without any potential scientists being developed. The only true appreciation of any thing must come from a knowledge of what has transpired before.

Teachers today should be concerned about attaining what, may be referred to as the intangible objectives of science instruction. That the student should attain a thoughtful appreciation of science, scientific attitudes, and interest in science are vital objectives for science instruction.

With but a moments thought it is evident that one cannot depend on scientific appreciation, attitudes and interest to arise spontaneously even when students are subjected to the best planned course in science. Unless a specific goal is designed into the course, it is unlikely this goal will have been achieved accidently at the completion of the course. If the pupils are to attain these intangible objectives through instruction specific designs must be made to achieve them.

The students, through the history of science, may attain a better view of scientific enterprise and realize that scientific knowledge today is an accumulation of man's fruitful labors since the birth of man. The insensitive complacency of student may be disturbed by tracing the slow gropings steps of science through false leads, futile quest, quagmires of ignorance, mountains of superstitions, obstruction of dogma and incorrect reasoning until science has reached its present enlightment. Perhaps the story of man as a thinker and a blunderer will stimulate the student to a higher intitive in his own undertakings.

Each pupil should realize that science has not been a recent invention dumped into his lap merely for the purpose of complicating his educational tour. He should be made to understand that science is the basis for the progress of civilization, since every new development in science brings about a necessary adjustment in society. It must be noted also that the demands of society call for an advancement in science.

A teacher should try to impress the student through history of science by emphasizing the following:

(1) The methods used by scientists.

(2) That science is a product of man, not machines or magicians.

(3) Science is an international activity; it is not confined to a nation, race or group.

(4) Science must have a free exchange of ideas.

(5) Constant improvement of instruments and equipment are needed for progress in science.

(6) Scientific activity is really the product of a culture in which it exists.

(7) Science advances more rapidly when there is controversy.

(8) Scientific progress depends on money.

Since in the present day most high school curriculums are already overworked; it is not likely that a special course in the history of science can be introduced. However; the science teacher could incorporate into the classwork some knowledge of the past history.

A very logical procedure would be to spend a preconceived amount of time discussing the men, the struggles and the time factor that went into producing the scientific facts under study. That is, whenever a new theory or idea is being studied for the first time, the instructor could refer to the history behind it. Although most class periods are crowded for time, the background information is in most instances an important phase of conquering the students motivation problem.

In many cases it would be possible and beneficial to use science history in preparing students for laboratory experiments. Many of the basic experiments are performed much in the same manner as they were in past ages. Also many pieces of equipment date back to the early days. Thus an introduction of more detail of the history of science at this point would be very fitting and worthwhile.

CHAPTER II

THE DIGRESSIONS OF SCIENCE

The question may be asked; what is science? Science may be defined as ordered knowledge of matural phenomena. But many thousands of years passed before science emerged with this meaning. Science is the sum of the thoughts and deeds of those who take the scientific point of view toward the universe in which man lives. This point of view is always changing, but in general it is based on the belief that, within limits, the law and order of nature can be fathomed by the mind of man. Science in all its complexities points toward two main objectives, that is to learn all possible about the living and nonliving things.

It will never be known when this never ending task to understand the universe began for there is no written record of man's early gropings for scientific knowledge. It is only from the dawn of recorded history, approximately 4000 years B.C., that there is authentic record of what is how called science.

The early scientist had many problems that are not faced by todays men of science. First they had no previous records on which to build. Second they were at never ending odds in their battle against the forerunners of true science, which were mystic fantasies, religious dogmas, and astrology. Even many of the early scientists themselves were caught up by a belief in fate or blind chance to be the answer to many unsolved mysteries. Many times the misconceptions of a great man were followed for centuries because the following scientists were dazzled by his greatness, and blindly accepted his erroneous teachings.

In the early epoch man failed to distinguish between materialistic fact and sense impressions. For example, a ray of starlight may be traced by physics from its distant source to its effect on the optic nerve, but, when the consiousness apprehends its brightness, color and feels the beauty, the sensation of sight and the knowledge of beauty exist, and yet they are neither mechanical nor physical.

The men of science of early days were falsely led into the assigning of gods to function over the things that they, themselves, could not understand. They shielded their ignorance under a camouflage of spiritalism and refused to pry too far into these realms for fear of angering these man appointed gods.

It was a common approach to a problem in early science to conceive an answer to the phenomena in nature then try to fit nature to this solution. They often failed to search for the facts of nature and derive the correct solution from a scientific approach. For example, suppose two men whom had never seen the horse, were to solve the mystery as to its appearance. The early scientist would have shut himself up in a room and from his own mind conjured up a picture of the horse while the scientist of today would travel until he found the animal and observed its appearance.

Scientific progress was handicapped in the early epochs by men who overindulged in religious dogmas. The leading scientists of that day were sometimes forced to take their own lives by these religious leaders for announcing some discovery that proved a religious superstition wrong. Socrates, for example, was accused of disbelieving in the gods of the state and was forced to drink the poison hemlock.

Among the falsifiers of science was unlikely enough "common sense." In the common sense idea of ancient times inanimate objects moved about on the face of the earth only when they were carried. Knowing that no human agency was capable of carrying the sun they assigned some supernatural agency the job. Or they devised the idea of the universe in such a way that the sun was being transported by a boat on a river. So in many cases common sense logic based on the known facts at hand led to false deduction, that in some instances prevailed for centuries and left its scar of time upon the face of progress.

Another erroneous method of science was to try to explain some phenomena of nature by fitting it to a preconceived idea of another natural phenomena. This, of course, is still practiced today. For instance, the atom composed of the nucleus and electrons is compared to the solar system as a means of explaining it. This procedure, of course, is very useful providing the first conception of the solar system is not in error.

It is entirely conceivable that the earlier men who tried to unlock the secrets of nature failed to see the significance of what is called the "Seven Seals of Science." These being mathematics, astronomy, physics, chemistry, geology, biology, and psychology.[1] The sciences of the seven seals are given in the sequence in which they must be followed. That is, no science could progress without mathematics, biology could not progress to any depth without physics which produced the microscope, the mind could not be properly studied until the chemistry of the body was known, and so it goes. The beginning of science failed to establish this interrelationship and dependency of the sciences one with another. Failure was therefore evident in some theories and fields because they had outgrown progress in the preceding sciences.

On the analysis of the progress of man it seems that the seeds of science that are sown in one generation must wait for future generations to either germinate or decay. The true value of the sprouted innovation not recognized until centuries later. The strife between science and religion, science and misconception, science and man's blunders, science and prejudice is a never ending contest which will probably

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[1]Joseph Mayer, The Seven Seals of Science (New York, 1936), p. 7.

continue until the end of time.

It should be pointed out here, however; to see life steadily, to see life as a whole we need not only science, but ethics, arts, philosophy and a sense of communion with a Divine Power.

CHAPTER III

ANTIQUITY TO 450 A.D.

Looking back into the prehistoric period of man it is difficult to determine any specific advancements of science. The prehistoric period, however; must be given credit for the greatest scientific discovery, the use of fire, and the greatest invention, language. It was during this epoch also, that the first tools were fashioned which enabled man to survive and to win mastery over his fellow creatures of land and sea. For science to progress the important step was for the Homo sapiens to reach a position of mastery, and to fashion an easier method of survival, so that the curious might turn their attention to the realm of the mysteries that envelope the universe.

The first records of science must be found in the valleys of the Nile, the Tigris and the Euphrates, for it is in these areas that evidence of the earliest civilizations are found. The Nile flows through the country which has been called Egypt from the dawn of history. The Tigris and Euphrates flow through a region that was earlier called Mesopotamia but now is known as Iraq. The earliest inhabitants of the area were the Akkadians and Sumerians. Later an empire called Babylonia flourished followed by the mighty empire of the Assyrians.

The ancient inhabitants of these lands had been able to work metal; chiefly gold, silver and copper. They were also familiar with the potter's wheel. The Egyptians erected tombs and temples, fashioned objects from colored glass and preserved dead bodies. The Sumerians had mastered the art of weaving, and built irrigation ditches and dikes. The invention of the wheel is credited to the Sumerians as evidenced by their war chariots. At the dawn of history these civilizations were capable of building cities.

The most important of all inventions perhaps was the development of the written language. For it is through writing that knowledge can be stored for posterity to study and enlarge upon. Both the Egyptians and Sumerians had developed a written language at an early date; approximately six thousand years ago. These early writings, however; were really the drawing of pictures to tell the story.

The foundation for the origin of true science is found when civilization began to coordinate standardization of knowledge, common sense and industry. One of the earliest developments of this can be traced to the Babylonians as far back as 2500 years B.C. At this time the royal authority issued a decree standardizing units of length, weight and capacity.

The Babylonian unit of length was the width of the finger, equal to about 1.65 centimeter or 2/3 inch; one foot equalled 20 fingers, and one cubit equalled 30 fingers; the pole was 12 cubits and the surveyors cord 120 cubits; the league was a distance equal to 180 cords, that is 6.65 miles. In measures of weight the grain was equal to 0.046 grams; the shekel 8.416 grams and the talent 30.5 kilograms or 67 1/3 pounds[1].

Approximately 200 years B.C. both the Egyptians and the Babylonians had been successful in setting up a calender. In Babylonia, the day the sun shone straight down the street of Babylon was the New Years Day. This would be the summer solstice which comes on June 21 or June 22. This calender was solar in origin. The Egyptians on the other hand based their calender on the rising of Sirius which gave them a calender of 365 days. This calender was a sidereal calender.

So these early peoples had utilized the sun and stars to mark the passage of time. But they also started science down false pathways by developing a pseudoscience of astrology. Astrology was not only considered the queen of the sciences but the mistress of the world. In such a setting there was little chance for science to develop.

Approximately 2200 B,C. both civilizations began a system of mathematics. Both the Babylonians and the Egyptians had developed a number system. The Egyptians were using a decimal system much like our own. The Babylonians developed a decimal system but they also had an astronomical

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[1]William Dampier, A History of Science (New York, 1936), p. 2.

system based on the number 60. It is from this system that the hour is divided into 60 minutes and the minutes into 60 seconds. A system which still survives today.

The first name to be connected with science is Imhotep. He was an architect-physician and designed the first pyramid to be built in Egypt, 2980 B.C. Imhotep and his contemporaries were much advanced over the Babylonians in the field of medicine. The Egyptians had developed a method of surgery and had made some studies of the systems of the body. They had realized the importance of medical treatment and listed several medicines for different ailments among the sick. The Babylonians knew something of medicine by the year 2000 B.C.

The earliest knowledge of botany is credited to the Babylonians for by the year 2327 B.C. they knew from the study of the date palm that there were male and female trees and that they must be brought together to assure fruit.

In the year 600 B.C. the scene of civilization changes to the Greeks, particularly those of Ionia, a strip of land on the west coast of Asia Minor. The first great scientist among the Ionians was Thales of Miletus (640 - 546 B.C.). Thales was perhaps the first to develop a scientific attitude. He began to wonder what the world was made of and the relation of the world to the rest of the universe. He believed that the world-stuff of which all things were made was water. Thales was the first to note that many patterns of natural events were so regular they could be predicted.

He came to the conclusion that nature follows a pattern; that it obeys certain definite laws and does not respond to the whim of a capricious gods. Thales traveled much and studied many things. From the Egyptians, who had developed a system of land measurements by the use of rectangles, squares and triangles, he discovered some of the fundamental propositions of geometry. Thales' reputation was based on his ability to predict eclipses of the sun and his skill in measuring pyramids by the use of proportional triangles.

During this six century B. C. several men of Ionia came to the front with ideas to answer the riddles of nature. Anaximander (611 - 547 B.C.) thought the world made out of an indefinite substance and that it was shaped like a cylinder. Anaximenes taught air was the basic world-stuff and that the earth was flat, round disc floating in air.

By the beginning of the fifth century Persia (Iran) had subdued the ancient civilization of Assyria, Babylon and Egypt. They also conquered Syria which was the home of the Ionian Greeks.

Heraclitus (5th century B.C.) held that fire was the basic principle of all things. He believed everything was always in a state of flux, changing from fire into other elements then back to fire.

Democritus of Miletus (5th century B.C.) developed the first atomic theory . He thought that the world was made up of infinitely small particles of hard matter that could not be cut into anything smaller. In fact, the Greek word atomas used by Democritus is the parent of the present word atom. He held that atoms differed but upon coming together they made up the world.

Empedocles (5th century B.C.) taught that there were four elements; water, air, fire and earth. There also were four qualities; cold, wet, hot and dry. Any of the two qualities made up one of the elements. For example, water was wet and cold; air was wet and hot; fire was hot and dry; earth was dry and cold. The ideas of scientists of this era, although far from the truth, were the forerunners of the modern theory. The sad thought is the theory of the four elements was accepted for approximately 2000 years.

Empedocles' four elements were a natural misinterpretation of the action of fire. For when they burnt a piece of green wood smoke rose (air), liquid dripped from the ends (water), ashes remained (earth) and the fire was a visible something escaping from the substance.

Parmenides (5th century B.C.) proved to the doubters of this era that air really occupied space by demonstrating that water can enter a vessel only when air escapes.

Pythagoras' (6th century B.C.), born on an island in the Agean Sea, greatest contribution to science was the development of mathematics, especially in geometry. The main geometric proposition associated with Pathagorus is the relationship of the sides of the right triangle.

During the fourth century B.C. the Greeks were still the leaders in the world of science and Athens became the seat of knowledge. Anaxagoras (died 428 B.C.) was a bold thinker. He maintained that the sun was not a god, but a huge mass of glowing metal and that the moon merely reflected the light of the sun. The other bodies of the universe were simply stones that had ignited from rotating rapidly. These views, however; were in discord with the religious leaders of the time and Anaxagoras arrested for impiety, was acquited only because Pericles, the leader of the Athenians, took his defense. This great thinker then withdrew from any further observations and science was dealt a great blow.

Socrates (470 - 399 B.C.), although his main interest was human conduct, contibuted to science the scientific method. He was the creator of the method of inquiry. Socrates would begin with a hypothesis, test it, examine the consequences, if they proved valid and consistent he would accept it; if not he would reject it and begin anew.

Aristotle's (384 - 322 B.C.) contributions to science were many. He inaugurated two important innovations; he used diagrams to illustrate difficult points, he reviewed and criticized all previous writings on a topic before giving an account of his own. He was the first to divide the physical world into two realms; the organic and inorganic. Aristotle discovered the basic facts of life before birth by experimenting with the chick embryo. His biological works were perhaps his greatest, many of his observations having been verified in comparative recent years.

Perhaps it should be stated that Aristotle, who was excepted as the standing authority on many things, held up the progress of science by about 2000 years. For during the middle ages his word was accepted as law and many a doubtful believer was squelched by contemporaries using Aristotles' word to prove the truth of a scientific observation. An example of Aristotles errors that held back science was the fact that he claimed the basic property of air was lightness rather than weight. Therefore a large amount of air should weigh less than a small amount of air. Another false teaching was that the forces that move things on earth are different from the forces that move things in the heavens.

Alexander added Egypt to his empire in 332 B.C. and built the city of Alexandria in that year. After Alexander's death in the year 323 B.C. Ptolemy of Macedonia became the ruler of Egypt. Under the rule of the Ptolemies, Egypt became the center of world learning. Ptolemy I Soter founded the Meseum, an academy where the arts and sciences were studied. Greek, Babylonian, Jewish and Roman scholars journeyed to Alexandria that they might study. At this particular period the scholars began to specialize more in related fields and not try to be all embracing as of the day of Aristotle.

One of the scholars of Alexandria was Euclid (third century B.C.). His special field was geometry, which he developed beyond Pathagorus. His theorms form much of the basis of geometry as it is taught today.

Aristarchus (280 - 264 B.C.) was the first to maintain that the earth and all planets revolved in circles around the sun. He made estimates as to the size of the sun, moon, and earth. Although his estimates were incorrect, he correctly concluded that the moon was smaller than the earth and the earth smaller than the sun.

Probably the greatest of the scholars to study at Alexandria was Archimedes (287 - 202 B.C.). His contributions to science are many. He calculated the ratio of the diameter of circle to be 3 10/71. Archimedes is given credit as being the founder of theoretical physics. He worked out the law of the levers. He also established the basic principles of hydrostatics, the branch of physics that has to do with the pressure and equilibrium of liquids. Archimedes was the first to become aware of the property of specific gravity. Archimedes' Principle that a body wholly or partly immersed in a fluid is buoyed upward with a force equal to the weight of the volume of liquid it displaces still stands in physics today.

When Rome was attacking Syracuse, Sicily; his home, Archimedes fashioned many military weapons. The catapults, to fight off foot soldiers and iron beaked cranes to over turn ships, were among his inventions. At last Syracuse fell and in spite of the order of Marcellus to spare him, Archimedes was slain by a Roman soldier in 212 B.C.

Hero (second century B.C.) of Alexandria was the next great inventor to arise in that day. He invented the dioptra, a crude surveying instrument which measured angles. His most famous invention was the aeolipile, the forerunner of the steam engine. This steam engine was merely steam issuing forth from a globe to rotate. Its basic function was merely as a toy. Hero[2] understood the principles of conbustion for he wrote:

> Bodies are consumed by fire which transforms them into finer particles namely water, air and earth.

It seems impossible that the mind of man could work so slow, but it was not until 1698 that the principle of steam power was put to work. The scientists at this time were very close to new truths but instead of using experiments to uncover the hidden truths they used them to illustrate preconceived ideas which many times were false.

Superstitions were still plaguing science in Hero's age. Hero had an invention whereby steam pressure transmitted to a door by series of levers, pulleys, cogs and screws would cause the door to open. Instead of men enlarging on the phenomena to apply as an asset to man the priest of the day fell upon it as a means of mystifying the credulous. They would kindle a fire on the altar, which was also the boiler for the engine, causing the door of the temple to open.

Philo of Byzantium (second century B.C.) performed an experiment of burning a cnadle under an inverted vessel over water. After the candle went out water rose a short distance

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[2]Jastrow, <u>The Story of Human Error</u> (New York, 1936), p. 171.

in the neck of the vessel. He correctly assumed a partial vacuum had been created but then went astray in thinking the corpuscles of air had been converted by the flame in to particles of fire which had passed through the pores of the glass. Proof was that the glass was warm. This theory was accepted for centuries.

Diophantus, (third century A.D.) has been called the father of algebra. He reduced problems to equations and was the first to introduce symbols in place of words to stand the unknown quantity.

It is probably at Alexandria that the pseudoscience of alchemy had its origin. The Greeks at Alexandria were interested in the formation of alloys that looked like gold. It is thought that the early workers in alloys knew they were looking for a substitute for gold but later experimenters believed they could actually transform baser metal into gold. Mary the Jewess, an early alchemist developed a piece of apparatus, the water bath, that is still used in laboratories today. Alchemy flourished at Alexandria for about three centuries ending in 192 A,D.

The reasoning of these early alchemist was not entirely bad. They reasoned that men's bodies are all made of the same stuff, and men are good or bad by changing not their bodies but their souls. Therefore the baser metals could be changed by helping them to improve toward the fire proof spirit of gold. The chief property of the noble metals was thought to be color. Therefore if the color could be changed gold would be the result. The changing of color was thought to be much like the changing of man's soul. It must be noted these early alchemists were true experimenters on false leads not the charlaton as the later alchemist.

During the first century B.C. the Romans had come to power and had conquered much of the known world. Although the Romans ruled the world the Greeks still ruled the fields of learning. However; under the government of the Romans, who were statesmen not scientists, the advancement of science in general fell into a stalemate during the third, fourth and fifth centuries A.D. Christianity blossomed forth during this period and the early christians were more interested in the salvation of the soul than in the advancement of science. The pagan cults that continued to exist flourished on mystery and superstition. The philosophers that were disciples from the schools of Aristotle and Plato specialized in expounding the views of past master rather than independent inquiry. So even though the Christians, the pagans and the philosophers were worlds apart in their views; they joined hands in scorning science.

The grest school of science at Alexandria reigned supreme under the rule of the Ptolemies but after the death of Cleopatra (30 B.C.) it began to decline. From her death until the capture of the city by the Arabs in 640 A.D. its contributions to science were negligible.

CHAPTER IV

THE MIDDLE AGES

The name middle ages is used to name the span of time from the collapse of the Roman Empire in the west to the invention of the printing press, approximately from 450 A.D. to 1450 A.D.

The Roman Empire had been divided into the Western Empire and the Eastern Empire in 395 A.D. The Western Empire consisted mainly of Italy, Spain, France, Britian and parts of northern Africa. The Eastern Empire included Greece, Asia Minor, Syria and Egypt. The Western Roman Empire had fallen into the hands of the northern barbarian tribes by about 450 A.D., however; out of the Eastern Empire rose the Byzantine Empire. Since the Greeks had been the scholars of ancient times the Dark Ages fell on Western Europe. By 529 A.D. all schools of Greek learning in Athens were caused to shut their doors by emperial edict, and the East was also a victim of the Dark Ages.

It is generally agreed that the Middle Ages preserved for the use of later times the science of the ancients. Therein lies both the scientific achievement and the scientific failure of the medieval civilization. The achievement was all the greater for being indirect. Men in the

Dark Ages did not find in the parts of the Western Empire which they occupied a scientific tradition as rich as that which the Arabs inherited in the eastern provinces. What the Middle Ages took over they did not very much enrich. Indeed so small was their own contribution that historians of sciance are apt to regard the Middle Ages as something of a pause.

In the Byzantine Empire learning still flourished to a small degree. The courts, however; were more interested in theological studies so the progress of science was practically nil. About the only things that can be said for science at all is that a few scholars compiled early scientific writings.

Beginning the seventh century A.D. the Arabs rose up under the prophet Mohammed (570 - 632) and proceded to capture the world. The Nestorians a group of Byzantines who had settled in Persia, quickly made peace with the Arab conquerors. The next 200 years was mainly spent by the Nestorians in translating Greek learnings into Arabic. Syriac had at first been the scientific language but it was discovered the Arabic was better suited to the purpose.

In the ninth century the Arabs became the standard bearers of science. The period of Arabic science lasted until about 1100 A.D. It should be mentioned that many of the Arabs scientist were neither Arabs nor Moslems, but rather Syrians, Persians or Jews.

Without doubt the greatest step in the upward direction during this time was the introduction Hindu number system. Al-Kwarizmi (ninth century) introduced this number system from India and it is the one still used today. According to some historians the number system was developed in India as early as 300 B.C. When the Arabs rose up as world conquerers they carried the number system back to Asia Minor. From there it spread to the rest of the world. The Hindu's had also developed the system of negative numbers. The only defect of the early system was the fact that it lacked the zero. This was introduced into the number system approximately 1000 A.D.

Alchemy had many devotees among the Arabs. At this time it was believed the primary chemical elements were sulfur (fire), mercury(liquid), and salt(solid). They argued that all metals were composed of these elements in different proportions, and by changing the mixture gold could be made from the base metals. Jabir (ninth century) was a foremost alchemist of the day. He is credited with perfecting new methods of filtration, evaporation, and crystallization. He was able to prepare such substance as alums, alkalis, saltpeter and mercuric oxide.

Rhazes (865 - 925) was another foremost alchemist. He classified all matter as animal, vegetable or mineral. A classification that still prevails in popular speech today.

The leading physicist was Alhazen (965 - 1038) a true Arab. He studied reflection and refraction of light rays. He discussed atmospheric refraction which causes the mirages on the desert. Alhazen advanced the idea of vision as being the result when the form of the object perceived passes into the eye and is transmitted by the lens. This was definitely far advanced from Euclid who taught that the eye sends out rays to the object in view.

It must be remembered the scholars of this epoch were either Arabic or under Arabian domination. Thus, except for Spain, the learned men belonged mainly to the east. However during the twelfth century the accumulation of scientific knowledge was being translated into latin and the scholars of Western Europe were beginning to arise in new efforts. It was also during this time (1090 - 1290) that the crusaders were fighting their battles for the Holy Land. They carried back information that opened a new world of thought for the men of the West.

A daring Friar of Oxford, Roger Bacon (1214 - 1294) moves to the front as the foremost scientist. Bacon was among the first to turn to experimental science. It was his belief that science alone knows how to test what can be done by nature. Although Bacon's attitude was that experimentation was the acid test for scientific theories, few of his contemporaries heeded his call. In spite of his belief in experimentation for truth he was still a firm believer in alchemy.

Bacon startled the men of his age by such fantastic predictions of things to come, such as the horseless carraige, machines that would fly, and suspension bridges across great rivers.

The middle ages contribute little to the advance of mathematics. The only thing of importance was that the Arabic numbers were introduced into Western Europe during the thirteenth century.

The progress of science as a whole during the middle ages were practically insignificant. The alchemist had developed some new chemical substances and created some apparatus which still remains in use today.

The contributions of the alchemist may have been greater had it not been that the general attitude toward the alchemists was that he was some sort of a heretic. Also the alchemist thrived on secrecy, so all his discoveries, methods, or preparation that might have been beneficial to progress were recorded in his own individual code system. Therefore at the passing of the alchemist all his developments remained unknown except those he had chosen to reveal beforehand.

Some progress had been made in practical arts. Gunpowder was in use by the fourteenth century, paper making was brought in from Moorish Spain, the same time the compass had come into use during the twelfth century. Clocks were becoming a popular instrument. Perhaps the one invention that was to assist the development and expansion of science was the printing press in 1450 by Johann Gutenberg.

CHAPTER V

THE RENAISSANCE

The reawaking of learning had its start in Italy. The chief reason perhaps being that much of the world was under the feudal system while in Italy the wealthy people had collected in the cities. Under the feudal system each Lord and his slaves functioned much as a separate unit plagued by their everyday battles for survival. While in Italy the wealthy members of the cities turned to learning as a diversion.

Another factor that must be considered, is the fact that a few staunch believers in the early Greek scientists, who had stated the earth was a sphere, took to the sea and had opened new channels of trade and wealth. With the increase of wealth more men found themselves with the necessary time and money available for study. There is strength in numbers.

Again the printing press should be mentioned as a great assist in this new revival of learning, for it took the laborious job of book copying out of the hands of the few educated scholars, and made books abundant and economically in reach of many.

Leonardo da Vinci (1452 - 1519) although better known for his works of art was probably the foremost scientist of his day. He was not a scholastic nor a blind follower of classical authority but he strengthened Roger Bacon's theory that observation of nature and experiment are the true methods of science.

Leonardo differed in Bacon with respect to theology. Bacon regarded theology as the true summit and the end of all knowledge and accepted the restrictions of the religious leader of the day. Leonardo on the other hand was open minded. He accepted the Christian Doctrin of the guiding light for spiritual life but threw off the shackels of the infallibility of the pope.

Leonardo also realized the folly in accepting past authorities. As an engineer he was faced by many problems. For the problems he reasoned that the behavior of things are of more importance than the opinion of Aristotle as to what they ought to be.

During Leonardo's span, however, the papacy was very lenient in its views toward science, which enabled him to study and contradict quite freely. But the capture of Rome in 1527 by the Imperial troops, broke up this new world of intellectual life, and the papacy reversed its policy of liberal guidance and again opposed blindly what it could no longer understand.

Although Leonardo perhaps didn't develop any great advances in one field he did much to solidify science. He pointed to Archemedes as the great scientist rather than Aristotle, and revived much of Archemedes' work. He dismissed the follies of alchemy and astrology and declared nature as orderly and non-magical. It might be said that he laid the pathway for the advancement of science, for to him the sciences that could not be proved by experiment were vain and full of errors. "Experiment is the mother of certainty" were his by words and the call that later scientists heeded.

Claudius Ptolemy had established that the earth was the center of the universe and all other bodies revolved around it. Copernicus (1473 - 1543) returned to the theory put forth by Aristarchus in 264 B.C. that the sun was the center of the universe.

Copernicus put his theory in form of a book in 1540 but died before it won any favor. Giordano Bruno took up where Copernicus left off but expanded the theory in the sense that the universe was infinite and the stars were scattered in space. For this he was condemned by the Inquisition and burned at the stake in 1600. It was not until 1822 that the papacy gave the sun sanction to be the center of the universe.

Paracelsus (1490 - 1541) an alchemist and quack doctor discovered ether in his experiments, noted it put chickens to sleep, but failed to recognize its possibility as an anesthetic.

Van Helmont (1577 - 1644) recognized different kinds of aeriform substances to which he attached the name gas, but stumbled back to the belief of Thales (600 B.C.) that water was the one basic element.

Francois Dubois (1614 - 1672) claimed that health depended on body fluids, either acid or alkaline which when united produced a nuetral substance. A doctrine which still is in agreement today. The important fact here is that Dubois' claim was the first general theory of chemistry and the first theory not to include the phenomena of flame.

William Gilbert (1540 - 1603) founded the sciences of magnetism and electricity. The compass was in existence by the end of the eleventh century. The Chinese are given credit for its discovery. He theorized that the earth itself acted like a huge magnet and that its magnetic poles must be close to its geographical poles. He was the first to introduce the possibility that there might be a difference between weight and mass. Gilbert explained magnetism as being a sort of soul, he thought perhaps gravity was the same thing and the forces that held the solar system intact must be the same.

Francis Bacon (1561 - 1626) did not advance science much in any particular phase but he did set down a rough systematic way to carry on scientific research. It was the first attempt to form a code of scientific method. Bacon believed that before men could make scientific progress, they must first discard certain prejudices. For him there were four prejudices; prejudices that are common to all men; prejudices that are peculiar to individuals; prejudices arising from the influence of words upon men's minds; and prejudices that arise from the adoption of definite systems of thought.

John Kepler (1571 - 1630) though an astrologist at heart was somewhat won over by Copernicus' words and went on to derive three laws that are respected today. Keplers' laws (1) The planets travel in paths which are ellipses with the sun in one focus. (2) The area swept out in any orbit by the straight line joining the centers of the sun and planet are proportional to the time. (3) The squares of the periodic time which a planet takes to describe the orbits are proportional to the cubes of their mean distance from the sun.[1]

Galileo Galilei (1564 - 1642) was the father of true physical science. He studied the prior works of science and worked out the problems in a methodical way. He published his works for all to read. He combined the experimental, the inductive and the deductive methods into one approach which is still used today. Galileo is given credit for separating science from mediaevel Scholasticism. Galileo's contributions were many; the most important probably proving that bodies did not fall with a speed proportional to their weight. He showed that heaviness and lightness were not the intrinsic value that determined velocity. He formulated the

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[1]William Dampier, A History of Science (New York, 1936), p. 140.

theory that the distance traveled by a falling object increases as the square of the time. One of the greatest strides was, however; Galileo's discovery that it was not motion but the change in direction of motion that required some external force. The problem of solving the motion of the universe was now open for solution. Galileo accepted the atomic theory that Democritus had advanced in the fifth century B.C. He stated that the qualities of an object that were perceived by the senses such as taste, color and odor; were mere sensations to the observers mind, but atoms compose the real body. Galileo improved and put to use the telescope that was invented by Lippershey, a Dutchman, he is also credited with inventing the first thermometer.

Rene Descartes (1596 - 1650) combined geometry and algebra thus hurtled a serious problem in the mathematical field.

It was in the course of the seventeenth century that science had its own true beginnings. Science had broken the gilted chains of philosophy and had become free to accept facts as facts. Although many times these facts couldn't be incorporated in the scheme of knowledge; a few pieces were beginning to fit the puzzle. Science was on the move. It had pssed through nearly 2000 years of stagnation. During this period the pseudoscience of alchemy, with its mystical hokum and its confused symbolism, began to be transformed into the genuine science that is called chemistry. Perhaps the truest measure of its development as a science was the fact that it came to concern itself with fundamental principles as well as with practical applications.

Certainly, at the beginning of the seventeenth century, alchemy, or chemistry, as it was also known, was a confused art. Some of its devotees were still trying to transform base metals into gold; others were seeking a universal remedy or an elixir of life, which would restore youth or prolong life indefinitely. But there was also a more practical outlook on what we should now call chemical investigations. Partly under the influence of Paracelsus, a system of medicinal chemistry had arisen. It represented the application of chemical products to the treatment of disease and it was called iatrochemistry. By the end of the seventeenth century chemistry was a bona fide science.

Robert Boyle (1627 - 1691) a physicist and chemist, proved the important fact that air is a material substance having weight. Boyle's gas law, which is still taught in physics today, states that a volume of a given quantity of air is inversely proportional to temperature. The accomplishments of Boyle are numerous. He improved the air pump invented by von Guericke, he observed the effect of atmospheric pressure on boiling point of water, he improved on the thermometer, and was the first to record the temperature of the human body. Boyle was the first to recognize that since heat results in the change of volume it must be due to molecular action. He therefore discarded the four elements and strengthened the theory of the atom. As a chemist he distinguished between a mixture and a compound and studied crystals as a guide to chemical composition.

Fire received a new treatment under Boyle. He observed that fire really produces very different effects at different temperatures and actually gives rise to new bodies more complex than the originals. This discovery tended to eleminate fire as an element. He also showed that gold could withstand fire. He proved gold could be alloyed with other metals, dissolved in aqua regia and yet be recovered in its original form; thus he stated that gold was made up of unalterable atoms. From this he concluded that substances, which make up the more complex materials could be called the elements. A thought which is still basically correct today.

Pascal (1623 - 1662) contributed one great advancement. He had a barometer constructed (invented by Torricelli in 1643) and showed that the height of the mercury decreased as the instrument was carried up the mountain. This indicated that the stmospheric pressure was becoming less; so in reality the mercury was held up by the air pressure and not by natures abhorrence of a vacuum. Thus another one of Aristotle's theories fell before the wheels of science progress.

Christian Huygens (1629 - 1695) presented to the world the first wave theory of light. Although this was a new approach, he had assumed that light could not travel in a vacuum so he produced an invisible something in space he named ether. This theory has hung on in science until the present day, although it is now accepted only by a few.

That light had a velocity was suggested by some early scientists such as Galileo, Pierre Fermat (1601 - 1665) and others, but it was left for Olaus Roemer (1644 - 1710) to successfully demonstrate this principle. Olaus noticed that the eclipses of the moons of Jupiter (1670) succeeded each other more slowly when the earth, in its orbit, was moving away from Jupiter than when it was approaching this planet. He successfully concluded that distance between the two planets caused this time difference in receiving the reflected light. Roemer calculated the speed of light to be about 210,000 miles per second.

Sir Isaac Newton (1642 - 1727) proved that the same force that causes an apple to fall from the tree holds planets on their courses. Newton showed that gravitation worked throughout the universe and thus established the theory of universal gravitation.

The fact that Newton derived the system of calculus is not in doubt, but about the same time Leibniz also discovered this mathematics and is often given the credit. Leibniz method of writing it down was better and his method has been accepted.

Although it had been suggested in antiquity that the sun and moon effected the tides it was left for Newton to finally prove and explain by his law of gravitation.

Newton's three laws of motion are still taught today.

and may be found in nearly any elementary physics book.

It was during this time that England was becoming a sea power. King Charles II saw the value in astronomy for sailing. So Greenwich Observatory was founded about 1675 with John Flamsteed (1646 - 1719) as royal astronomer. Greenwich still remains the base line for world time zones.

The telescope which Galileo had devised (about 1610) was a refracting telescope. It did not always five a true picture of things due to imperfect lens. Newton not realizing this defect could be overcome built the first reflecting telescope in 1669.

Galileo had first developed the crude thermometer (thermoscope) in 1603. It was merely a tube with a bulb on one end and open at the other, by warming the bulb and then placing the open end in the liquid to be tested, an idea of the heat content could be determined by the height the liquid rose in the tube upon cooling. In 1632 Jean Rey suggested placing a liquid in the tube with the bulb end down into the liquid being tested, and reading the temperature by the expansion of the liquid. The Grand Duke of Tuscany Ferdinand II sealed the top and used wine instead of water. These early thermometers had no fixed points. Huggens suggested the freezing and boiling points of water might be used as fixed points. In 1714 Daniel Fahrenheit (1686 - 1736) introduced the mercury thermometer with a standard scale. Anders Celsius (1701 - 1744) perfected the centigrade thermometer in 1742.

John Napier (1550 - 1617) also gave a big assit in mathematics when he developed the system of logarithms. Henry Briggs (1561 - 1631) prepared the first table of logarithms for about 30,000 numbers.

Although the abacus a simple counting frame, was known in antiquity it was probably about 1642 that the first practical calculating machine was introduced by Pascal.

In 1590 Zacharias Janssen invented the first compound microscope. Robert Hooke (1635 - 1703) constructed a far better one about 1650 and about the same time Anton van Leauwenhoek probably built the best. They magnified about 270 times. Hooke also produced the cell theory of matter. Cork was the substance he was studying at the time.

With the development of the microscope, through physics, the biologist were ready to renew their studies.

The phlogiston theory of the iatrochemist (1690 - 1804) proved a stumbling block in chemistry. Iatrochemistry was really the application of chemistry to medical science. Fire and its principle still plagued the scientists. Becher (1635 - 1682) was probably the first to propose the Phlogiston theory but it was a student of his, George Stahl (1660 - 1734), who elaborated it, named it phlogiston, and sent it forth as a false lead.

The theory suggested that all substance contained phlogiston which escaped when the substance united. In normal combustion the reasoning was justified perhaps due to the fact the ignited substance lost weight. The proof of the theory lies in the fact that when the calx or ash was reunited with another substance the original material could be regained. Thus its palogiston had been restored. In the case of the metals however; after oxidation the calx weighed more. This the iatrochemist easily explained but the fact that the phlogiston of metal had a negative weight. It was repelled but the force of gravity thus causing the metal with phlogiston to weigh less than the ash or oxide.

The theory may have been justified at the time of its origin; the depressing fact is that it persisted for more than a century. Even Cavendish (1731 - 1810) thought he had isolated phlogiston when he discovered hydrogen by the action of acid on metals.

In 1654 von Giericke (1602 - 1686) strengthened Pascal's theory of atmospheric pressure. He used two hemispheres that fit tightly together. The air was evacuated as completely as possible. To this object he then attached sixteen horses, eight pulling from each side of his vacuated ball. The horses were unable to pull the hemispheres apart. The sphere was reported to be about two feet in diameter. The demonstration of von Giericke proved conclusively that the atmosphere exerts a pressure. This demonstration was carried out in Madgeburg, Germany, thus the reference to them as the Madgeburg hemispheres.

It should not go without mentioning that from about 1500 - 1700 the advancements of science were proving to much for the rulers of religion. So to combat this scourge to mystic belief, they concocted a religious law that any one speaking out contrary to ancient beliefs was a heretic or sorcerers and must be put to death. So science was advancing with a heavy axe hanging over its head. During this reign of terror it is estimated that better than three quarters of a million witches were put to death.

CHAPTER VI

REVOLUTION IN SCIENCE

Perhaps at this time a short account of world progress should be given to better understand the changes in science progress.

Going back to the fifteenth century it should be mentioned again that the printing press had been introduced making it possible for many more books of knowledge to be printed, and at the same time making these books economically possible for more people. It was possibly for this reason also that many more schools were being established. During antiquity and the middle ages the schools were mainly private and only for the wealthy or royalty. So with an advance of sorts in education more talent was being introduced into the field.

Also during this century Columbus had found the New World. The fact that the earth was round had been proven. The important thing was however; that the New World offered additional wealth which put more money to work for science, either by private grants, a wealthy scientist, or even from an occasional ruler that favored science.

Later, approximately 1650, scientific societies began to be formed. These early scientists saw the need for communication with one another to hasten the advancement of science. The members of these early societies met to discuss the proposals and accomplishments of each other and often to pool their knowledge on the problem at hand. Many of these societies still persist today plus numerous additional ones.

During the eighteenth century the industrial revolution was in progress. The French had fought their revolution and the American colonies had won their freedom from England. Although the effect these facts had on science can't be measured; they were bound to cause a change.

A point of interest worth noting is that up to the Renaissance the Greeks had been the chief contributers to science. Then their position in the field began to fade. In spite of the fact this reawaking started in Italy, western Europe really produced the bulk of the learned men of science from 1450 on until about the nineteenth century. The more probable reason for this is that the church authority was not as strong in western Europe. The pope being seated in Rome didn't have quite the strangle hold on the men of science in Europe that he had on the closer nations, mainly Greece.

During the nineteenth century the United States began to produce scientists in greater numbers.

It should be stated here that by this time most of the invalid ideas were overthrown, the foundation of true sciience had been laid, the scientific methods were well developed; the scientist had become a man of intellect; respected and admired. The stage was set for science to stride off at a pace beyond any comprehension.

In 1698 Thomas Savery took out a patent on the first steam engine. The first attempt to put steam to work since Hero (200 B.C.). Thomas Newcomen invented the first steam engine to be used in industry. Both of these engines were very crude and had poor efficiency. James Watt (1736 - 1819) produced the first practical engine in 1769. He had really improved upon Newcomen's engine but is sometimes given credit for the invention.

The fact that Hero, in the second century B.C., had produced the principle of the steam engine and yet it was approaching 2000 years before anyone realized its importance is an example of the slow progress of science in these early periods of history.

The inventions in the machine line from this time forward become to numerous to mention.

Joseph Black (1728 - 1799) had identified carbon dioxide which he called "fixed air." The importance lies in the fact that Black proved that it could exist free or recombine with other chemical substances. He had discovered it had its own particular properties. This was the first detailed study of a chemical reaction.

Joseph Priestley (1733 - 1804), Karl Scheele (1742 - 1786), and Antoine Lavoisier (1743 - 1794) all were able to isolate oxygen at about the same time. Lavoisier was the first to understand the true significance of oxygen. He proved that in any form of combustion such as breathing, rusting of metals or burning were all a result of oxygen in the air combining with other materials. These truths dealt the death blow to the phlogiston theory. Lavoisier gave the law of conservation of matter, and established for certainty the modern idea of chemical elements.

Lavoisier[1] was among the first true scientists for a sentence taken from a book he had written in 1789 reads thus:

> I have imposed on myself the law of never advancing but from the known to the unknown, of deducing no consequence that is not immediately derived from experiments and observations.

Electricity again causes a stir among scientists. In 1734 Charles DuFay proposed the theory of two kinds of electricity. Since electricity was thought of as being a fluid it was considered to be a two-fluid system and the response an object made depended on the fluid present.

In 1729 Stephen Gray discovered that electricity could be conducted from its source to another place by certain materials. This started men off on the conductor, insulator side of the mystic fluid.

Pieter van Musschenbroch (1692 - 1761) in 1745 developed the "Leydon jar" which is the forerunner of the modern

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[1]A Symposium, The History of Science, (London, 1951), p. 105.

condenser. He discovered the principle of storing electricity.

An American experimentor Benjamin Franklin (1706 - 1790) entered upon the scene at this time. Franklin's scientific developments were quite numerous. The important contribution was possibly that he proved lightning to be an electrical charge by his kite experiment and he tagged the name positive and negative to electric charges. Franklin did believe that electricity was a fluid but he assumed the difference in the charge to be caused by the amount of a single fluid present.

Charles Coulomb (1736 - 1806) measured the force between two electrically charged spheres. He also showed that electricity is concentrated on the outer surfaces and does not penetrate the interior.

This early experiments all dealt in static electricity, however; in the later part of the eighteenth century current electricity was discovered. Valta (1745 - 1827) is given credit for this and developed the first electrical battery. The dry cell of today would compare in principle to Valta's battery.

Joseph Proust (1754 - 1826) be using substances that were chemically pure was able to show that every compound contained the same elements and always in the same proportions by weight. Thus the law of multiple proportion was established by Proust but he failed to see the full significance.

John Dalton (1766 - 1844) became interested in the theory of the atom. Dalton's theory was successful in explaining the observed facts of chemical combination and may be briefly described as follows: (1) Chemical elements are composed of minute particles of matter called atoms, which remain undivided in all chemical changes. (2) There is a definite weight for every kind of atom. Different elements have atoms differing in weight. (3) Chemical combination takes place by the union of the atoms of the elements in simple numerical ratios.[2] He realized the atom could not actually be weighed on a scales but he saw the possibility of using a comparative weight. He assigned hydrogen the weight of one and proceeded to compare other elements to it. During his experiments he also fell upon the law of multiple proportions. He carried it further than Proust and showed that if two elements combine to form more than one compound the ratio between the elements will always consist of small whole numbers.

At a later date oxygen was taken as a standard at 16 and is the present standard in chemistry.

During the day of Dalton some of the gases had been discovered and the scientists were familiar with some of their basic reactions. Dalton attempted to explain his theory by the action of gases but again a pitfall developed that proved a stumbling block to him. He recognized the

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[2]H.D. Anthony, Science and Its Background (New York, 1954), p. 218.

fact, that in the case of oxygen and nitrogen, 2 volumes with 2 particles gave 2 volumes of 1 particle by experiment, but by theory after the gases combined there should have been only 1 volume.

Dalton advanced his theory in 1804 and is credited with setting chemistry on a sound basis and ushering in a new line of research. The following are some of the symbols used by Dalton: hydrogen O, oxygen ⊙, nitrogen ⦶, carbon ●. An example of some of the nitrogen gases by Daltons symbol would be (N_2O) ⦶⊙⦶, (NO) ⦶⊙, (NO_2) ⊙⦶⊙.[3]

Guy Lussar (1778 - 1850) in 1905 confirmed Dalton's data by experiments in combining volumes. He proved that the gases always combined in the same ratio to form the new compound.

In 1811 Amadeo Avogadro (1776 - 1856) stated the solution but it fell on deaf ears. He reasoned that the elementary particles of the gases were compound particles that is nitrogen instead of being N was N-N, oxygen instead of O was O-O. Avogadro named these compound particles, molecules. Then by theory 2 volumes of 2 molecules equal 2 volumes of 2 molecules. Although he had hit upon the solution being that these gases were actually molecules it was fifty years before it was accepted.

Avogadro also became interested in the actions of gases.

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[3]Jastro, The Story of Human Error (New York, 1936), p. 186.

He was aware of Boyle's law and reasoned that if equal volumes of all gases responded equally to equal temperature and pressure changes, it must be because they all contained the same number of molecules. He calculated the number of molecules in 18 grams (1 gram molecule weight) of water to 6.02×10^{23}. This is Avogadro's number and still accepted today.

CHAPTER VII

CHEMISTRY COMES OF AGE

In 1815 William Prout (1785 - 1850) introduced a simple theory of matter. Since something was now known about atomic weights he held that all atoms are built up of hydrogen. But when more accurate weights were made and chlorine proved to be about 35 1/2 times heavier than hydrogen his theory was dropped.

But as seems many times to be the case Prout may have actually been perfectly right. In chemistry today the isotope has been discovered and each isotope is the multiple of hydrogen. Also in studying the sun it has been pretty conclusively shown that the sun's energy comes from a series of reactions whereby four atoms of hydrogen are turned into a single atom of helium. So again the folly of one generation may prove the wisdom of another.

In 1789 Lavoisier could identify twenty three elements, by 1813 Sir Humphrey Davy (1778 - 1829) could name forty seven. By this time the old alchemist system of symbols was far too complicated, and chemists began to realize the importance of a simplified standard system of symbols. John Dalton's system met with some favor but still left much to be desired. Joens Jakob Berzelius (1779 - 1848) finally rose to the situation. He designated the elements by the capitalized first letter of there Latin or Latinized name, or by the first letter plus one other letter. This symbol stood for one atom of the element and a small numerical subscript indicated the number of atoms of the element involved, thus H_2O. This system of chemical shorthand is the standard approach as of today.

Berzelius also discovered the group atoms radicals that go through a chemical reaction as if they were a single atom. He is given credit for discovering the catalysts.

Freidrich Woehler (1800 - 1882) performed an experiment (1828) that proved a dictum a lie. Until Woehler's success of creating urea from cyanic acid and ammonia it had always been taken as impossible to achieve organic compounds from inorganic compounds. This was the red letter day for organic chemistry. Although today it is a very important phase of chemistry, Woehler's epoch making discovery did not have immediate results. It was several years before any method of organization or classification was established.

One of the greatest steps forward was the introduction of the doctrine of valence (1850) by Edward Frankland (1825 - 1899). With this new idea of valence it then became possible to predict the weight, number of atoms and many other properties of compounds, as well as to predict compounds that shouldn't exist.

It should not go without mentioning that although the advancement of science in general produces a brighter future for civilization, it also has been a disaster to specified areas. For example the synthesis of alizarin dye (from anthracene a waste in distillation of coal tar) rendered a long established agriculture product, madder plant, valueless. The farmers of Turkey, France, Holland, and Italy were forced to seek new incomes as a result of the trimph of chemistry. The same incident occurred in India when indigo dye was synthesized.

A point of interest is the fact that the relationship between dyestuff and drug is very close. For example the parent material of the sulfa drugs were originally intended to be a red dye.

In 1845 Christian Schoenbein discovered guncotton and the following year Ascanio Sobrero prepared nitroglycerin. Nitroglycerin at first was used merely as a medicine, but in 1867 Alfred Nobel (1833 - 1896) prepared dynamite by mixing guncotton and nitroglycerin. Here again chemistry has dealt a two folded effect to humanity. This new dynamite increased the ferocity of was but at the same time speeded up the advance ment of modern civilization.

For many years after the chemical element had been defined, they were thought of as mere incidental facts of nature. After Dalton had introduced his theory of atomic weights. Wolfgang Doebereiner (1780 - 1849) grouped a few elements in triads and pointed out a relationship between their weights. In 1865 John Newlands (1837 - 1898) proposed a method for grouping the elements in sets of eight in order of their atomic weights. Newlands was on the right track, but he made no allowance for elements that had not yet been discovered. Reputable chemists scoffed at his idea.

Only three or four years later Dmitri Mendeleev (1834 - 1907) and Lothar Meyer (1830 - 1895) working independently showed that there is a natural classification of elements. Since Mendeleev gave the more comprehensive account of the theory he is usually credited with devising the periodic table of elements.

Mendeleev brought forth many new ideas about the elements, but basically he established the fact that the elements arranged according to their atomic weights exhibit a periodicity of properties. By this he was convinced that characteristic properties of elements could be foretold from their atomic weights. He therefore argued that what appeared to be error in his table was merely because the element that fit the description had not been discovered. In classifying the elements he left gaps in the table for the elements he predicted needed to be discovered. Mendeleev's theory has been proven correct, although it has undergone great changes since he introduced it, the modern tables are based on his classification.

In the year 1887 Arrhenius (1859 - 1927) suggested the theory of the ion in some chemical compounds which gave them the ability to conduct electrical current. The ionization hypothesis has clarified many problems in the field of chemistry.

Why was the progress in electricity so slow up to 1800 but developed rather rapidly afterwards? One answer is very likely because the very nature of it makes it an uncommon phenomena in nature, except of course for lightning. Therefore man was for the most part unaware of its existence for centuries. When man began to explore this field the battle for science was on a higher plane. The stage had already been set, the scientists had receptive minds and the experimental method was well established. Also the very nature of electricity adapts itself well to laboratory experimentation.

During the days of Napoleon electricity was considered a diversion for the scientists to play with in their laboratories. In 1819 Hans Oersted (1777 - 1851) showed that magnets are affected by an electric current. This was the initial step that was needed to set things in motion. Oersteds experiments proved the electro magnetic property of electricity, and revealed that it exhibited a force at a distance so it must be somewhat like gravity. Immediately following in 1820 Dominique Arago (1786 - 1853) in his experiments created the first electro magnet ever devised by man.

Andri Ampire (1775 - 1836) in his study of electricity came upon the relationship of current to the circuit, which by his law is that under certain circumstances the magnetic effect of an element of a circuit varies inversely as the square of the distance. Georg Ohm (1787 - 1854) followed in 1827 with his law of resistance which states that the intensity of the current in a circuit is equal to the electromotive force that drives it divided by the resistance that the current meets.

Michael Faraday (1791 - 1867) began his career as a laboratory assistant at 25 shillings a week. But his genius was soon recongized and he rose to a position of a leader in science. Faraday is credited with adding the third relationship to the electricity and magnetism. This was motion and from this theory he went on to develop the first electric motor in 1821 and the first generator in 1831.

Heimich Hertz (1857 - 1894) became interested in the theory that electromagnetic waves traveled through space much the same as light. Hertz employed the oscillator as a source of waves and by using merely a copper loop with a break in it, for a detector; the sparks could be seen to jump the gap in the copper wire at the same time they jumped the gap in the oscillator. Thus Hertz had produced in approximately 1885 the first radio waves.

Today the sum total of these electro magnetic radiations arranged in order of increasing length are; gamma rays, Xrays, ultraviolet rays, visible light, infra red rays and radio waves. They all travel at 186,200 miles per second.

These early experimenters laid the foundation for the great advancements that followed. Morse's telegraph, Bell's telephone, Edison's lightbulb, and Marconi's wireless are developed from the basic knowledge of electricity these eminent scientists laid down.

One more shattering blow to an old established theory was to be dealt by Michelson and Morley in the 1880's. Newton and others had decided that light waves needed a medium in which to travel. Since experiments had revealed light would pass through a vacuum they had assigned this needed medium the name ether. Now these two physicists by experiment proved fairly conclusively that ether does not exit. With this new theory the physicist were left dangling with a new problem to solve, which is still in controversy today. However; the new conceptions of space have made a luminiferous medium unnecessary.

The first attempt to construct an engine by burning fuel within a cylinder was made by Huygens in about 1680. Huygens had noticed that the powder explosion in a cannon generated great volumes of gas and that impelled the cannon ball out. He tried to create an engine that would operate by a series of powder explosions, but failed. Jean Lenoir, in 1860, built the first practical internal combustion engine. It used illuminating gas as a fuel. In 1876 Nikolaus Otto constructed the first engine operating on the four-stroke principle. His engine also operated on illuminating gas. Various inventors had tried to develop a carburetor which could vaporize gasoline so it could substitute for illuminating gas. Both Gottlieo Daimler and Fernand Forest achieved this goal in 1885. Following this Karl Benz in 1886 produced the first self-propelled vehicle powered by gasoline, and thus inaugurated the automobile age.

Although photography (lightwriting) is not essentially a scientific development, it played an important part in the advancement of science. Through the use of film astronomers were able to uncover many secrets of the universe, that otherwise might have gone by unnoticed. The different types of radiation may have been longer in discovery if this lightwriting had not already been accomplished. Many applications of photography are used in science today, in practically every field.

In 1790 Thomas Wedgwood succeeded in making profile silhouets by using silver nitrate. In 1819 John Herschel (1792 - 1871) discovered the property of sodium thiosulfate as a fixing agent. In 1816 Joseph Niyne (1765 - 1833) had succeeded in producing negatives and in 1827 had produced the direct positive.

The early photography called daguerreotype was a cumbersome process carried out on metal plates. It took its name from Louis Daguerre (1789 - 1851) who developed the process.

William Talbot (1800 - 1877) developed a method known as calotype. His method used sensitized paper. From his negative several positives could be made. Talbot perfected his negative-positive principle in 1835. His method is probably the forerunner of modern photography.

CHAPTER VIII

TWENTIETH CENTURY

At the onset of this era the gasoline engine had been developed, the basic principles of electricity established and the power of steam was being utilized. From these fields stemmed many advancements and discoveries such as the airplane, radio, television and many many more. Since the progress is so great during this age and many of the end results are evident in the present day as daily necessities there seems to be no real need to discuss them. Instead, a few of the more significant aspects that changed the outlook of science will be dealt with.

During the latter part of the nineteenth century science had fallen into a lull. People thought the end point of new knowledge had been reached and for the most part science could only improve on method or accuracy of established constants. But in 1895 a series of bombshells to science broke loose releasing whole new era's for study and development. It has been said that the time between 1895 and 1905 might well be called the miracle decade. If all new scientific theories and all scientific facts that were developed in this decade were wiped out science in its present form could not exist. Centuries of scientific thought and experiment culminated in this period.

In preceeding chapters the folly of the alchemist has been mentioned. Perhaps the alchemist should be treated with more respect. Today alchemy really exists in a sense. Although todays scientists do not try transformations of the baser metals to make gold, they have succeeded changing the atoms of one element into atoms of another by adding or subtracting subatomic particles. Thus the old alchemist was legitimate in theory.

This field of modern alchemy really had its beginning in 1890 with William Crookes (1832 - 1919). Crookes was among the greats in scientific investigation, yet; he just missed making numerous discoveries that made other men famous. Crookes was greatly interested in the study of electric discharges through gases. By this time a glass blower, Heinrich Geissler (1814 - 1879) had succeeded in making vacuum tubes. Geissler had noticed that when electricity was discharged through this tube a green glow appeared at the cathode. These were named cathode rays by Eugene Goldstein (1850 - 1930). Crookes made many studies with these tubes for which he had developed a better counterpart he called the Crooks tube. Crookes and other scientists working with him at that time noticed that their photographic plates were always becoming fogged. Outside of complaining to the manufacturer they never tried to determine the reason.

However, in 1895 Wilhelm Roentgen (1845 - 1923) began playing with this tube. He noted that even when the tube was covered with black paper, through which no visible light could pass, a nearby sheet of paper that was coated with barium platinocyanide would glow when the electricity was passing through the tube. Roentgen drew a proper conclusion that the tube produced some kind of "penetrating rays" to which he attached the name Xrays; X standing for unknown. Roentgen then proceeded beyond Crookes. He discovered these rays effected photographic plates even when the tube was wrapped in black paper. The next step was to hold the hand between the tube and the photographic plate. When Roentgen developed the film he saw the bone structure of the hand revealed. So the Xray machine was born and has proved a great benefit to mankind.

Upon hearing the news of the Xray Antoine Becquerel (1852 - 1908) began a study of luminescents substances that glowed in the dark long after being exposed to light. He used an uranium salt in his experiment. He had assumed that the sunlight had some effect on uranium. He first placed a piece of uranium salt on a photographic plate wrapped in black paper, and exposed this to sunlight. The photographic paper had been exposed in one spot when developed. Later he did the same experiment without benefit of sunlight and found the results to be the same. So the radiation of certain elements had been discovered for the first time in 1896. The name of Becquerel rays was given this phenomenon at discovery but it is now known as radioactivity.

These new radiations were now studied by the Curies; Pierre Curie (1859 - 1906) and Marie Curie (1867 - 1934). Marie had noticed that pitch blende and chalcolite gave off more radiation than pure uranium. This led to the belief that there were other radioactive ores. She and her husband in July 1898 finally succeeded in isolating the element from the ore and found it to be 400 times more active than uranium. They named it polonium.

They discovered that pitchblende contained still another radioactive substance. They succeeded in isolating this in December 1898. This they named radium. It is about 900 times more active than uranium. The Curies wanted to obtain its atomic weight accurately. They began with one ton of pitchblende, were able to extract less than one four thousandths of an ounce of radium chloride pure enough for this purpose.

Marie Curie died of exposure to these rays she had been working with. Several others died from these type of experiments before it was realized how dangerous they were.

Ernest Rutherford (1871 - 1937) and Frederick Soddy (1877 -) followed up Marie Curie's theory that radioactivity stems from inside the atom. In 1902 they proposed the theory of radioactive decay. These men stated that the atoms undergo spontaneous disintegration and as a result they emit two kinds of particles which they named alpha and beta. Occasionally a third kind of ray called gamma rays are emitted.

The alpha particles are actually the nucleus of the helium atom, beta particles electrons, and gamma rays electromagnetic radiations.

Soddy in 1913 discovered the fact that there are more than one type of atoms for some of the elements. The basic difference being atomic weight. To these he attached the name isotopes.

Rutherford in 1919 succeeded in changing one element into others. He bombarded the nitrogen atom with alpha particles which produced flourine temporarily, this in turn would break down into oxygen and hydrogen. So modern alchemy was now a reality.

Joseph Thomson (1856 - 1940) discovered a subatomic particle he called a corpuscle of electricity. This is what is called the electron today. This shattered the idea that the atom was the smallest possible division of an element. The discovery of the electron opened up a great channel of reseearch that has solved many problems.

Later positive charges were discovered. Rutherford showed in 1911 that the positive charges are the core with the electrons moving about this core. Niel Bohr (1885 -) suggested orderly shells for the electrons. From this shell theory came the important concept of valence, worked out in 1916 by Newton Lewis (1875 - 1946) and Irving Langmuir (1881 -); and the possibility of predicting chemical activity by the number of electrons in the outer shell.

The problem of deciding the number of electrons was solved by Henry Moseley (1887 - 1915). He reasoned that within the atom there is a fundamental unit which must increase by regular steps to change from one element to another. By use of the Xray (electromagnetic ray) being passed through crystals he noticed a change in the wave length. He showed that the change corresponded to a single electron unit. If the nucleus contained a positive charge then this change could be contributed to it. Since the atom is neutral the electrons must be of the same number. He also noticed that the number of charges he measured was equal to the number those elements occupied in the periodic table. Thus a new method of prediction and check had been established.

In 1932 James Chadwick (1891 -   ) proved that in addition to the proton the nucleus of the atom contained neutral particles he called neutrons.

From this point on many new discoveries concerning the atom itself have been made but much mystery still enshrouds this tiny unit.

Albert Einstein (1879 - 1955) upset the world of physics when he announced his theory of relativity in 1905. Einstein believed that matter and energy are different phases of the same phenomenon; one can be converted into the other. For this he wrote his famous equation: $E = mc^2$. In this E is energy, m equals mass, and c the speed of light. This is where his theory of relativity enters. He maintained that the fourth deminsion of space is space time, since the velocity of light is the only quantity of the universe that remains constant.

Later the development of the atom bomb depended a great deal upon Einsteins theory of relativity.

On the morning of July 16, 1945 the first successful atom bomb was exploded. The devastating power of the atom was released. With this first explosion the atomic age was ushered in. Although the first use of this released energy of the atom was for destruction, the entire realm of civilization will probably be changed by its peace time uses.

In 1941 Dr. Kenneth T. Bainbridge by use of an atom smasher successfully converted mercury into gold. Thus the dream of the old alchemist was a reality. The cost of the process is however, prohibitive. So it seems that even the silliest of theories or most fantastic fantasies can eventually come to pass under the hand of science.

CHAPTER IX

OVERVIEW

With a backward glance at the progress of science it is easily deduced, that more advancement has been made since 1895 than in all the thousands of years that preceded this date. The question may arise as to why man was so slow in grasping these scientific facts. An old adage, which states: in the dark all cats look black, may help to answer the question. In other words the early scientists were grappling in the dark for bits of knowledge, as each new discovery occurred the next one was easier to recognize.

Until the means of communication became sufficient the scientist was usely one lone man off in an isolated spot working out his theories. Eventually the need for pooling information became evident and the growth became more rapid. It must be remembered too that religion and science were often in conflict, and many great scientists were executed before their days of full achievment had been reached.

There were times when the scientist was considered a heretic, and the public in general frowned upon such a man. For centuries science was more or less a means of entertainment or hobby for those who had time to indulge.

For the most part the early scientific development came about as the result of curious mind wanting satisfaction. The need was not particularly present. These early men in many instances even had to finance their own projects. As the wealth of the mations began to increase from world trade and colonization more money became available to the scientist, either from wealthy friends, or a favorable grant from a ruler.

Perhaps one of the greatest boosts to the progress of science was the industrial revolution. When manufactorers began to compete for wealth they realized the need for science until today every major corporation has its own research laboratories. Perhaps the laboratories of the world's industrial organizations contribute more towards the future than any other group.

Each conflict between nations seem to grow more scientific until today the nation that depends only on the military genius for victory would soon be defeated. In actuality it is the scientist behind the scenes that determines the outcome of a war. The scientist then has become a coveted man by most nations, so much so in fact that a nation no longer lets its scientists enter active duty on the battlefield.

A factor that perhaps held science up for centuries was the blind obedience of a proven law. For example Dalton and his contemporaries proved that the atom existed, but stated the law that the atom was the smallest particle of an element. The law was true from aspects of all tests it could be given; thus it reigned supreme for three centuries. Even today the scientist may be content to accept the present laws as positive proof and fail to journey into a whole new field beyond. The question of "what is truth" can probably never be answered.

Today then the governments of nations realize the importance of science as a means of security, business sees it as a means of profitable survival, and the citizenry sees it as a means of better living; thus today science is nutured by the world as whole and not be a struggling individual. So with the addition of an ever increasing amount of light, and the support of all men it is only reasonable that scientific development so increases at an ever present acceleration.

What is left undiscovered or what may transpire in the future can not be predicted with any authority. For out of the wilderness of science some extra ordinary mind may rise to stimulate a practically dormant idea into undreamed of wonders. Also the sensational discoveries usually do not come by organized attacks but rather by some curious mind, with a so called distorted idea that refuses to be conquered by failure or daunted by his fellowman until he arrives at his wildest destination.

Upon examining the situation of the present day it is difficult to say whether man is the master of science or a slave of science. The latter probably stands out as nearer the truth. In this atmosphere of world tension the scientists no longer produce for the shear joy of an adventure in science but by the necessity of survival as a nation.

The march of science goes forever onward, as the man of science today passes on another will grasp his torch of knowledge and carry it to future generations with an ever brighter glow. The man may die the knowledge never.

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