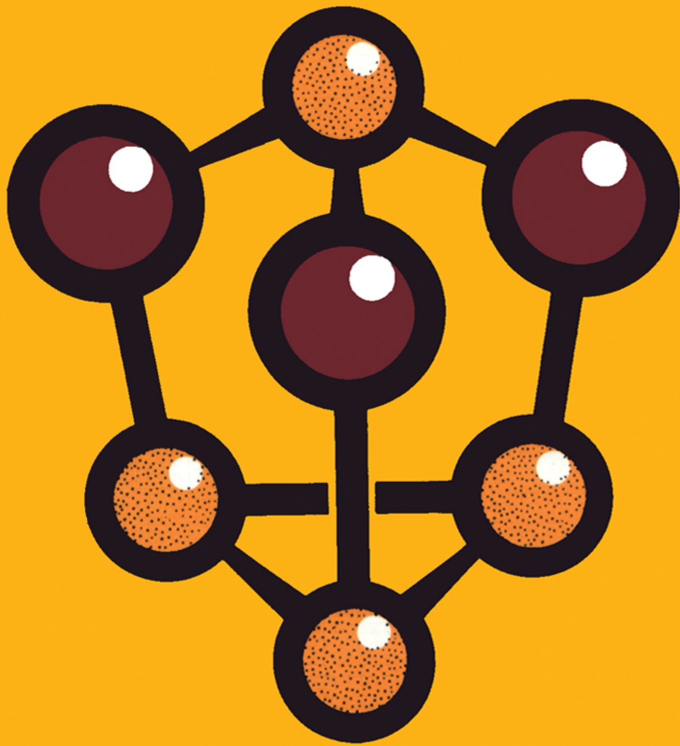

Studies in Inorganic Chemistry

17

The Chemistry of Artificial Lighting Devices

Lamps, Phosphors and Cathode Ray Tubes

R.C. Ropp

Elsevier

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R.C. Ropp

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Preface

This manuscript describes how mankind has used light and lighting to further the development of his cultural progress. I have covered the early use of artificial lighting and current methods of manufacture of both incandescent and fluorescent lamps. The protocols for manufacture of fluorescent lamp phosphors and those used in cathode-ray tubes are also presented in some detail.

Early man used torches and campfires for lighting and protection from wild animals. Twentieth-Century man uses electrically operated lamps for artificial lighting, display and amusement. The number of artificial lighting devices, both existing and obsolete, is truly amazing. This manuscript attempts to survey all of those known to date in terms of how they arose and are, or have been, used by mankind.

I have enjoyed preparing this manuscript and hope that you will find reading it both profitable and enjoyable.

Dr. R.C. Ropp
May 1993

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This work is dedicated to my wife Francisca Margarita, who has constantly supported my efforts and me during these past 40 years.

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Introduction

This book was written to introduce the reader to the inorganic chemistry of artificial lighting devices and the materials used to manufacture them. In Chapter 1, a brief history of the study of light is then presented, followed by a summary of the quark theory as applied to matter and its constituents. The nature of light is quantified, wherein it is shown that a photon is a force carrier between electrons and other particles. Homo Sapiens originally used light in the form of campfires, followed by use of oil lamps and candles. Finally, in the late 19th century, the first practical incandescent lamp was developed by Edison. A brief history leading to that milestone is given which includes both carbon arc and mercury discharge lamps.

In the second Chapter, the principles of design relating to both incandescent and mercury lamps is presented, followed by that of sodium vapor lamps and other gaseous discharge lamps.

In Chapter 3, the manufacture of "lamp parts" is described in depth. This includes the manufacture of tungsten metal, its formation into wire and the manufacture of tungsten coils for lamps. The fabrication of incandescent lamps is discussed in some detail, as well as the production of raw materials used in the manufacture of phosphors. Finally, the manufacture of fluorescent lamps and the protocols required to do so are elaborated.

In Chapter 4, the manufacture of lamp phosphors is addressed, including formulations, times of firing, and the processing needed to complete their manufacture before they are incorporated into fluorescent lamps. The manufacture of halophosphates is presented in entirety.

In Chapter 5, the manufacture of the various cathode ray phosphors used in the Industry is examined, including their formulations and methods of firing. These are listed in terms of "P-numbers", as devised by JEDEC, and their measured decay times. Finally, a brief discussion of the manufacture of the newest cathode ray tube phosphors is presented.

I hope that you find this manuscript interesting and rewarding to read.

Dr. R.C. Ropp - May 1993

Chapter 1

LIGHT AND THE ORIGIN OF ARTIFICIAL LIGHTING

LIGHT and light sources have always played an important role in day-to-day living for mankind. "In the beginning, there was darkness"- according to the Scriptures, and the first act of the Divine Creator was the production of light [Genesis I:1-5]. Separate creation of the sun, moon and the stars followed soon after [Genesis I:14-19]. That primitive man worshipped these natural light sources as deities is manifest. The Egyptian sun-god was named Ra and later Anton. The sun worship of the Inca, Aztec and Mayan civilizations in the Americas is well known. The Japanese sun-goddess, Amaterasu, is still worshipped today as the head of the imperial family and the founder of the state (1). Even the Japanese flag reflects this perspective, being that of the "Rising Sun".

Worship of heavenly bodies is also recorded, but was forbidden in the Hebrew Scriptures [Deuteronomy 17:2-5; Ezekiel 8:16]. However, these heavenly luminaries were considered as intelligent beings who worshipped the Creator [Psalms 148:3]. Light was also considered an attribute of GOD, as shown in many parts of the Christian Bible [Exodus 3:1-2, 14:21, 19:18; Psalms 4:6, 27:1, 119:105; Revelations 4:5; Acts 9:1-5; John 1:6-9, 8:12, 9:5].

In most modern European languages, the days of the week still remind us that each day was once sacred to an astral deity. Their number (seven) is that of the luminous heavenly bodies known to early man who had no telescopes to distinguish other possible celestial light sources. Some of the names that can be associated include: Sunday, Sonntag [Sun]; Monday, Montag, Lundi [Moon]; Mardi [Mars]; Mercredi [Mercury]; Jeudi [Jupiter]; Vendredi [Venus]; Saturday [Saturn]. Since the English language is a mixture of Teutonic as well as Mediterranean roots, other pagan gods are also represented in the week: Tuesday [Tyr], Wednesday [Wodin], Thursday [Thor], Friday [Freya or Frigga].

Numerous Scriptural references attest to the importance of light in religious ritual [Exodus 25:31-40, 27:20] and everyday affairs [Matthew 25:1-13]. The use of candles and lamps in religious observances persists in many instances today. For example: the "Eternal Light" before the sanctuaries of Catholic, Jewish and high Anglican (Episcopal) houses of worship [Exodus 27:20, Leviticus 24:2-4], the votive candles of Catholicism, the Jewish Sabbath and Yarhzeit candles, the Hanukkah menorah, the use of lights on Christmas trees, and the halos often depicted on "Saints", all affirm the importance of light in religious functions (2). Other modern symbolic uses of light may be seen in the Eternal Flame at the Arc de Triomphe in Paris, the torch of the Statue of Liberty in New York harbor and the use of candles on birthday cakes. A common trademark, "Mazda", once used in the electric lamp industry, is the name of a Persian deity connected with light (1). Thus, light has been for mankind more than a mere means of sight and illumination.

We shall be concerned not with natural sources of light but with artificial or man-made sources. We intend to present first a history of light-sources and then will survey present-day sources and uses of light. Finally, we will summarize the manufacturing methods used in the Lighting Industry. Unfortunately, although we know the name of the first blacksmith [Tubalcain-Genesis 4:22] and that of the first viniculturist [Noah - Genesis 9:20], the name of the first inventor of artificial light is not recorded. Perhaps this is due to the fact that man used light and artificial lighting long before the art of writing was invented (which occurred about 7000 years ago), and thus written records and early accounts of the history of Man do not reflect this aspect.

1.1.- The Nature of Light

Nowadays, we know that light is comprised of "photons", which are quantized waves having some of the properties of particles. If this perception is not clear, it will be made more lucid shortly. Such was not the case originally. The concept of photons with wave properties has its roots in the study of optics and optical phenomena. Until the middle of the 17th century, light was generally thought to consist of a stream of some sort of particles or *corpuscles* emanating from light sources. Newton and many other scientists of his day supported the idea of the corpuscular theory of light. It was Newton in 1703 who showed that "ordinary" light could be dispersed into its constituent colors by a prism, but the phenomenon was not clearly grasped at that time. About the same time, the idea that light might be a *wave* phenomenon was proposed by Huygens and others. Indeed, diffraction effects that are now known to be associated with the wave nature of light were observed by Grimaldi as early as 1665. However, the significance of his observations was not understood at the time.

Early in the nineteenth century, evidence for the wave theory of light grew more persuasive. The experiments of Fresnel and Thomas Young (1815), on interference and diffraction respectively, showed conclusively that there are many optical phenomena that could be understood on the basis of a wave theory, but for which a corpuscular theory was inadequate. Young's experiments enabled him to measure the wavelength of the photons and Fresnel showed that the rectilinear propagation of light, as well as the diffraction effects observed by Grimaldi and others, could be accounted for by the behavior of waves having very short wavelength. It was Maxwell in 1873 who postulated that an oscillating electrical circuit should radiate electromagnetic waves. The speed of propagation could be calculated from purely electrical and magnetic measurements. It turned out to be equal, within the limits of experimental error of the time, to the previously measured speed of propagation of light. At that time, the evidence seemed inescapable that light consisted of extremely short wavelength waves, having an electromagnetic nature. In 1887, Heinrich Hertz, using an oscillating circuit of small dimensions, succeeded in producing electromagnetic waves which had all of the properties of light waves. Such waves could be reflected, refracted, focused by a lens, polarized etc., just as waves of light could be manipulated. Maxwell's electromagnetic theory of light and its experimental justification by Hertz constituted one of the major triumphs of science. One should note that at about this same time Edison was busy inventing the first practical incandescent light bulb.

A. Nature of a Photon

Nonetheless, the classical electromagnetic theory of light failed to account for several phenomena, including the absorption and emission of light. One example is the phenomenon of photoelectric emission. That is, the ejection of electrons from a conductor by photons incident on its surface, where the number of incident photons can be correlated to the number of electrons released. In 1905, Einstein extended an idea proposed by Planck five years earlier and postulated that the energy in a light beam was concentrated in "packets" or *photons*. The wave picture was retained, however, in that a photon was considered to have a frequency and that the energy of a photon was proportional to its frequency. Experiments by Millikan in 1908 soon confirmed Einstein's predictions.

Another striking confirmation of the photon nature of light is the Compton effect. In 1921, A.H. Compton succeeded in determining the motion of a photon and an electron both before and after a collision between them. He found that both behaved like material bodies in that both kinetic energy and momentum were conserved in the collision. The photoelectric effect and the Compton effect, then, seemed to demand a return to the corpuscular theory of light. The reconciliation of these apparently contradictory experiments has been accomplished only since about 1930 with the development of quantum electrodynamics, a comprehensive theory that includes both photon wave and particle properties. Thus, the theory of light propagation is best described by an electromagnetic wave theory while the interaction of a photon with matter is better described as a corpuscular phenomenon.

The speed of light in free space is one of the fundamental constants of nature. Its magnitude is so great (about 186,000 miles/second or 3.0×10^8 meters/second) that it evaded experimental measurement until 1676. Up to that time, it was believed that light traveled with an infinite speed. The first recorded attempt to measure the speed of light was a method proposed by Galileo (1605) in which two experimenters were stationed on the tops of two hills about a mile apart. Each was provided with a lantern and was to cover and uncover his lantern when the light from the other was seen. Nowadays, we know that the speed of light is just too great for this method to work satisfactorily. In 1676, Olaf Rõemer, a Dutch astronomer, obtained the first evidence that light propagates with finite speed. He observed the eclipse of one of the moons of the planet Jupiter and found that the observable periodic times of eclipse were greater or lesser depending upon the positions of the Earth and Jupiter. A time difference of 22 minutes resulted in a rough calculation of about 69.9% of the refined value of the speed of light that we know today. In 1849, Fizeau made the first successful measurement using terrestrial instruments. Using a rotating toothed-wheel that chopped the beam of light, he obtained a value only slightly better than that of Rõemer, namely 3.1×10^8 meters/second. Foucault replaced the rotating toothed-wheel by a rotating mirror and this has remained the method of choice. Michelson, an American physicist (1852-1932) used this same method to determine the best value known to date, viz-

1.1.1.- $c = 2.9979246 \times 10^8$ meters/second $\pm$ 2.0 meters/second

The conclusion that photons are associated with mass and matter rather than with space alone is inescapable. All bodies emit some form of electromagnetic radiation, as a result of the thermal motion of their molecules. This radiation, called thermal radiation, is a mixture of wavelengths. At a temperature of 300 °C, the most intense of these waves have a wavelength of 50,000 Å which is in the *infrared* region of the electromagnetic spectrum. When the temperature is raised to about 800 °C, such a body emits enough visible radiation to be self-luminous and appears "red-hot". However, by far the most energy is still carried by photons having wavelengths in the infra-red region of the spectrum. But at 3150 °C, which is the temperature of a tungsten filament in an incandescent light bulb, the body then appears "white-hot" and a major part of the energy is in the visible region of the spectrum.

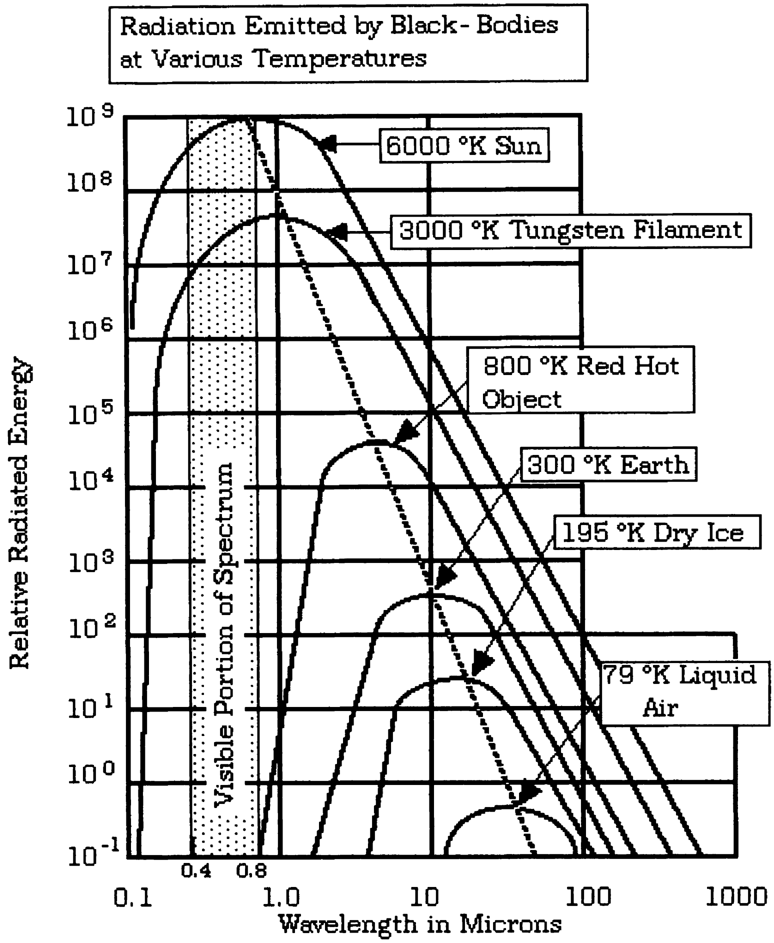
The following diagram, given on the next page as 1.1.3., shows the emission of optical radiation as a function of "black-body" temperatures. Note that even bodies at liquid-air temperatures emit photons between 10 and 100 microns in wavelength, i.e.- 100,000 and 10^6 Å in wavelength. The earth itself at a temperature of 300 °K. has an emission between about 20,000 and 300,000 Å in wavelength, i.e.- 2000 nm. and 30,000 nm.

Another related phenomenon is that of fluorescence by "phosphors" (3). These inorganic materials are energy-converters in fluorescent lamps in that ultraviolet light is absorbed from a mercury-vapor discharge and is converted to visible light. Still another light source is that of the laser. In this case, a crystal, or metal vapor, or gaseous vapor, is made to store energy in an excited state. By suitable optical means, the energy is released by a resonance method in which the waves all cooperate to emanate at the same time. This is called "stimulated emission of coherent radiation" and is the optical basis of the laser, whether solid or gaseous. In vacuum, all electromagnetic radiation travels at the speed of light. This is given by:

1.1.2.- $$c = \{1/\varepsilon_0 \mu_0\}^{1/2}$$

where ε_0 is the permittivity of free space, and μ_0 is the permeability of free space. The former comes from Gauss's Law and the latter from Faraday's Law. However, the speed of light in media *other* than vacuum is always **slower** than in space.

1.1.3.-



This is believed to be due to resonance interactions between the electromagnetic fields of the electrons associated with the transparent media and that of the traveling photon. When electrons or other charged particles are accelerated to relativistic speeds, i.e.- a fraction of the speed of light, they emit photons. One example of this is the "free-electron" laser. The apparatus is built so that alternating magnetic fields of opposite polarity pervade the interior in precisely spaced intervals. As electrons are accelerated down the length of the apparatus, each separate magnetic field causes a deviation in the path of the electron by interaction of the magnetic field and that of the electromagnetic wave of the electron. This "wiggle" in the path of the accelerating electrons causes them to emit photons. The wavelength will vary according to the speed and degree of "wiggle" induced in the electrons. Thus, it should be clear that both photons and particles of mass are inexorably interwoven by the matrix of space-time. What this means is that when particles having a given "rest" mass are caused to accelerate near to a limiting speed, i.e.- the speed of light, they are prone to release that excess energy gained through the emission of photons. Einstein was the first to realize this phenomenon, which has since been proven many times over.

B. Photon Interactions - Quarks, Electrons and Photons

Because particles, i.e.- electrons, have wave properties similar to those of photons, we need to differentiate between them.. It was de Broglie in 1906 who first postulated the wave nature of particles. In 1927, Davisson and Germer first showed that electrons are reflected from the surface of a solid in the same way that x-rays are reflected. The wave hypothesis clearly required sweeping revisions of our fundamental concepts regarding the nature of matter. The best explanation to date seems to be that a particle must be regarded as an entity not entirely localized in space whereas the photon is a point-source, i.e.- is localized in space. What this means is that a particle is strongly attracted or repelled by electromagnetic fields as it moves through space whereas a photon, being a localized point source, is only weakly affected. Thus, a photon moves at a constant speed through space while an electron does not. Yet, both have electromagnetic fields thereby associated with each, which are subject to reflection, diffraction etc. The photon-packet thus interacts with the space-time continuum as it moves through space at a constant speed.

In contrast, the particle interacts with both the time-space continuum and the electromagnetic fields thereby associated with mass, and its speed is **not** constant, but subject to mass-mass (gravity) interactions as well. The wavelength of the photon (which has no mass) is a function of its internal energy as it moves through space. The particle has a mass which is determined by how much it is spread out in the space-time continuum. Consequently, it has properties we normally associate with "mass". In the 1960's, a major advance occurred when the Quark theory came to the forefront of physical theory. Actually, this was a culmination of Einstein's "Grand Unification Theory" which strove to combine both "weak" forces, gravitational forces, and "strong forces", i.e.- those present within the nucleus of atoms.

Among the "leptons" (which are particles with spin equal to 1/2) are electrons and photons (Actually, photons are force carriers between electrons, as we shall see). Photons have been classified as "bosons" while electrons are called "fermions". The former is described by Einstein-Bose statistics and the latter by Fermi-Dirac statistics. Einstein-Bose statistics are defined as "The statistical mechanics of a system of indistinguishable particles for which there is no restriction on the number of particles that may exist in the same state simultaneously", whereas Fermi-Dirac statistics are defined as "The statistics of an assembly of identical half-integer particles; such particles have wave functions antisymmetrical with respect to particle interchange and satisfy the Pauli exclusion principle".

With the advent of the Quark theory, it has been shown that sub-nuclear particles can have fractional charge, as shown in the following Table, viz-

TABLE 1-1

Fundamental Particles of Matter

1. FERMIONS (Matter constituents with spin = 1/2, 3/2, 5,2 ...)

Leptons (spin = 1/2)			Quarks (spin = 1/2)		
Particle	Mass (GeV/c^2)	Electric Charge	Flavor	Mass (GeV/c^2)	Electric Charge
Electron	5.1×10^{-4}	-1	**d**down	0.007	-1/3
Electron-Neutrino	2×10^{-8}	0	**u**up	0.004	2/3
			sstrange	0.20	-1/3
			ccharm	1.5	2/3
Muon	0.106	-1	**t**top	>91	2/3
Muon-Neutrino	3×10^{-4}	0	**b**bottom	4.7	-1/3
Tau	1.784	-1			
Tau Neutrino	4×10^{-2}	0			

TABLE 1-1 Continued)

Fundamental Particles of Matter

2. BOSONS (Force carriers with spin = 0, 1, 2 ...)

Electroweak force (spin = 1)			Strong force (spin = 0)		
Name	Mass (GeV/c^2)	Electric Charge	Name	Mass (GeV/c^2)	Electric Charge
Photon	0	0	Gluon	0	0
W^-	80.6	-1			
W^+	80.6	+1			
Z^0	91.16	0			

3. Properties of the Interactions of Fundamental Particles

Fermionic Hadrons

Name	Quark Content	Mass (GeV/c^2)	Electric Charge	Spin
Proton	uud	0.938	+ 1	1/2
Anti-proton	uud	0.938	- 1	1/2
Neutron	udd	0.940	0	1/2
Lambda	uds	1.116	0	1/2
Omega	sss	1.672	- 1	3/2
Pion	ud	0.140	+ 1	0
Kaon	su	0.494	- 1	0
Rho	ud	0.770	+ 1	1

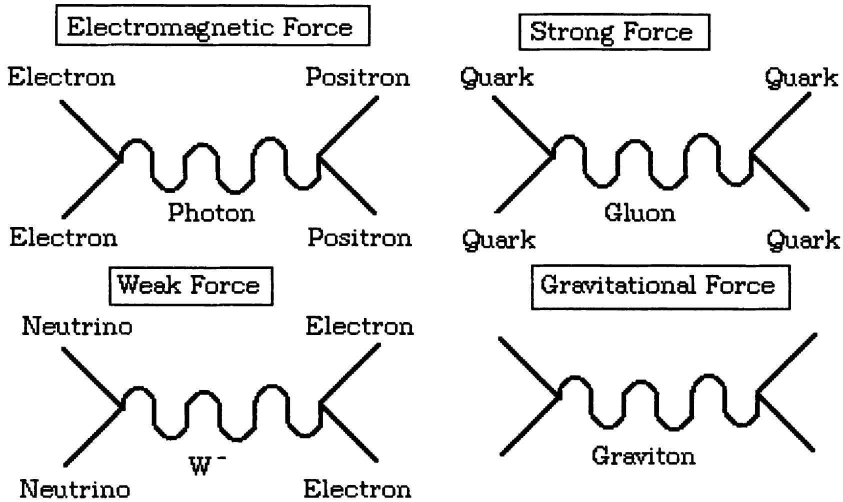
From the above, it should be clear that a photon is a "force-carrier" while an electron is a "matter-constituent". The notion of particles as mediators of force in nature has provided a framework for testing and developing the **Standard Model** and the associated "Big-Bang" theory of the formation of the Universe. It has also been important for the exploration in depth of many other important questions about the physical world. Complex in practice but simple in conception, this model identifies four forces in nature: 1) Electromagnetism; 2) the Strong Force; 3) the Weak Force, and 4) the Gravitational Force. Each is transmitted when a force carrier is exchanged between two elementary particles. Two of these forces function only at extremely close range (e.g.- between quarks inside the nucleus), whereas the other two are effective across long distances.

The most familiar interaction is Electromagnetism. Electromagnetic radiation in its various forms (including radiowaves, microwaves, infra-red-light, visible-light, ultraviolet-light, and x-rays) can be thought of as the exchange of massless photons between electrically charged particles, either quarks or leptons. The Strong Force, the interaction that binds quarks and hence the nucleus together, is transmitted from quark to quark by massless particles called gluons. The exchange of gluons acts on a property of quarks called "color", which is analogous to electric charge. Quarks make up the proton and the neutron, and thus the nucleus of an atom. They both have color and electric charge, and they give the proton its charge.

The Weak Force regulates the "burning' of hydrogen into helium in the interior of stars, among other processes. It is described by a similar model. The carriers of the Weak force are the electrically charged W^+ and W^- particles and the neutral Z^0, shown in the above table. In this case, these carriers do have mass, and are exchanged between quarks and leptons. The Standard Model postulates that the electromagnetic and Weak force are derived from a single, unified "Electroweak Force", a hypothesis that demands the existence of the "Top Quark". Of all of the quarks, only this one remains to be directly observed. This stems from the fact that the mass of the Top Quark is so large that accelerators do not exist which have sufficient energy in their beam of particles to reach the minimum energy required to observe this massive particle. However, accelerators are being built that are expected to be able to reach the level in energy required, namely about 90-95 Gev. i.e.- 90-95 giga-electron volts.

Orbiting the nucleus is the familiar electron, which is the only lepton that is a part of ordinary matter. Its charge is always -1, relative to the proton's charge of +1. Other leptons exist under extreme conditions: the Muon, the Tau, and the neutrino (postulated in 1931 by Wolfgang Pauli). The neutrino has no charge and nearly no mass. There are three neutrinos, since each charged lepton is believed to have an associated neutrino. Leptons feel all of the forces except the strong force. It is the electron-neutrino pair that is committed in the exchange of force between electrons exchanged within the weak force and the photon between electron-positron pairs within the electromagnetic force. This is made more cogent by the following diagram, given on the next page as 1.1.4.

1.1.4.-



The particles mediating exchange forces are thus photons, gluons, the W^- boson, and gravitons. And, as we stated previously, the electron has a mass whereas the photon does not since it is a force-carrier. The other particles, given in the above table, are observed only when atomic nuclei are bombarded at very high energies. We can summarize all of the above in that a photon is a quantum of radiation, whereas an electron is composed of matter-quanta. This aspect is made more lucid in the following Table:

TABLE 1-2

Elementary Particle Interactions

Force	Physical Phenomena	Relative Strength	Effective Range	Exchange Quanta	Matter Quanta
Strong	Nuclear fission, fusion	1.0	10^{-13} cm.	Gluons	Quarks
Electro-magnetic	Electricity, Light Magnetism,	10^{-2}	Infinite	Photon	Quarks, Charged Leptons
Weak	Radioactive Decay	10^{-5}	10^{-16} cm.	W, Z & Higgs Particles	Quarks, Leptons
Gravity	Curved Space-time	10^{-36}	Infinite	Graviton	All Particles

C. Photon Exchange

Perhaps the best distinction to be made between photons and electrons is the "Cerenkov " effect, discovered by P.A. Çerenkov in 1934. We have already pointed out that the speed of light is a fundamental physical constant, both in vacuum and in transparent materials, including air. Radioactive materials emit three kinds of emission when the nucleus transforms , namely α , β and γ particles. Alpha particles are energetic, doubly-ionized helium atoms. Beta particles are energetic electrons, while gamma particles are high-energy x-rays (or photons). When such particles are emitted from a nucleus (because that nucleus has transformed into another type), they frequently possess high energy and speed. When a charged particle such as an electron passes through a dielectric medium such as water, at a speed **greater than** the speed of light in that medium, this particle throws off a sort of "shock-wave" in the form of emitted photons. Thus, any matter-constituent particle traveling faster than the speed of light in a particular medium sheds part of its excess energy in the form of photons (which are the force-carriers).

1-2 Man's First Use of Light and Artificial Lighting

In order to address how man first began to use artificial light, we need to explain how man came into being.

A. The Origin of Homo Sapiens

Recent work (4) has shown that mankind probably originated in Eastern Africa about 160,000 - 240,000 years ago. Since it is obvious that the major attribute that separates Homo Sapiens from other animals is that of intelligence, it seems likely that the appearance of mankind was due to a massive mutation of genes which produced offspring with substantially improved intelligence and curiosity. The scientific evidence appears irrefutable in that Homo Sapiens can be traced back to a single female who was probably a Neanderthal (A debate still rages concerning whether Homo Sapiens materialized from Neanderthals or Homo Erectus - who evolved over a million years of history). However, both genetic evidence of the human family tree (4) and study of languages (5) have come to the same conclusion, namely that mankind originated in Africa and that massive migrations occurred throughout the history of man. The earliest genetic tree implies movement from East Africa into the Middle East (100,000 years ago), into the Far East, including Australia, about 60,000 years ago, and into Northern Europe and crossing into North America about 35,000 years ago. Details of the actual routes are speculative. Studies of peoples and classification of languages have reached the same conclusion, namely that early Homo Sapiens most likely evolved from a single source and that language differentiated from a single linguistic source. Prior to that time, language was extremely limited, if it existed at all.

The fact that **all** humans are mammalian mutants and suffer from a potentially fatal liver-enzyme disease may come as a shock to most people. This genetic disease is of universal occurrence in the human population. The disease is scurvy and the curative substance is ascorbic acid, or Vitamin-C. Man is one of the few mammals not biochemically equipped to make their own ascorbic acid directly in their livers. In most animals, after liver synthesis, ascorbic acid is poured directly into the bloodstream in large daily amounts. For example, goats synthesize about 13.3 grams (about 25 tablets of 500 milligram each) of Vitamin-C per day; dogs and cats = 2.8 grams daily (6 tablets), but man synthesizes 0.0 grams daily. This abnormality is due entirely to the genetic code inherited by each person.

How old is the genetic code? Genes are specific sequences of bases attached to the sugar-backbone to form the DNA molecule having the double helix or spiral staircase structure. By identifying the sequences of bases, one can relate the sequences of many organisms to one another. There are three major classifications (Kingdoms) of living things: a) Plants, b) Animals (which include mammals, birds, fishes, reptiles and insects), and c) Bacteria and related organisms. Each classification has many subspecies comprising that kingdom. In particular, there are about 1000 base-sequences known today, involving all three kingdoms. There are at least two ways of ordering this wealth of sequence data. First, one may focus on one species and produce an alignment of its DNA-transfer sequence functions. Fifteen such specie families have been thus identified, with each family consisting of 15-30 individuals. Secondly, one may identify a specific sequence and follow it through the various species. This has been done for 24 family-species in all three kingdoms. Kinship relations are revealed by alignment of sequences. The results show that individual and master sequences of DNA-transfer functions reflect kinship relations consistent with generally accepted evolutionary patterns of the appearance of life on earth. What this means is that the first life to appear consisted of one-celled creatures which evolved into the complex kingdoms of life known today. All three kingdoms have certain sequences exactly the same. Thus, the three main kingdoms appear to be "equally old". The early nodes of kingdom separation can be dated to be about 2.5 ± 0.5 billion years old, and the genetic code cannot therefore be older than 3.8 ±0.6 billion years. Because the earth is about 4.2 billion years of age, "life", as we know it, did evolve on the earth, and was not of extraterrestrial origin. Yet, this does not explain the genesis of Homo Sapiens.

In a recent study, Dr. E.L. Simons , Director of the Duke University Center for the Study of Primate Biology and History stated "New discoveries combine to indicate that all of the major steps in human evolution took place in Africa. Skeletal analysis of oldest human forebears around 3 million years ago (Homo Erectus) reveal many anatomical similarities to African Great Apes. These and biochemical resemblances indicate a common ancestry for humans and apes, perhaps only a few million years earlier. Enlarged knowledge through recent discovery of skeletons of successive stages in the line leading to modern peoples shows that many skills by which we define humanity arose much more recently in time than heretofore believed" (6). It has been generally agreed that the chain of succession includes : early man ape (Homo Australopithecus- the first hominid)- age = 2-3 million years; Java apeman (Homo Erectus)- age = 1.5 million years; Neanderthal man- age = 600,000 years, and finally, Homo Sapiens-age = 140-200,000 years. If this is true, then we are no more than 8000 generations of age (using 25 years as one generation). I, myself, will see at least five generations.

Undoubtedly, the remnants of an Ice Age had a marked effect upon the dates and paths of human migration. During an Ice Age, migration was restricted because of its effects upon the Earth's climate and the necessity for providing some kind of covering from the cold if Man was to exist and prosper. Over the past 900,000 years, four glacial periods have occurred. The following Table shows the periods of the Ice Ages comprising the Pleistocene Epoch. It is likely that Neanderthals also migrated into Europe and Eastern Asia during the Third Interglacial Period (about 175,000 years ago). Neanderthals made tools and weapons of flint (Old Stone Age) for hunting and domestic use. They knew the use of fire. They had many of the attributes that we consider, nowadays, to be essential to civilization.

TABLE 1-3

Recent Glacial Ages

	Began (Years Ago)	Lasted	Climate
1st Ice Age	600,000	64,000 years	cold
1st Interim	536,000	60,000	warm
2nd Ice Age	476,000	156,000	cold
2nd Interim	320,000	90,000	warm
3rd Ice Age	230,000	55,000	cold
3rd Interim	175,000	60,000	warm
4th Ice Age	115,000	75,000	cold
4th Interim	40,000	-----	warm

They had family groups. They buried their dead. They occupied caves as the weather became colder. The matter of speech is one of conjecture. By the time the Fourth Glacial Period arrived, Neanderthals were scattered over Africa, Europe and most of Asia. Nevertheless, there appears to be a change-over about 40,000 years ago from Neanderthals (particularly in Europe where the records are the most clear) to Homo Sapiens. This date coincides with the onset of the 4th Interim Period. It seems likely that Homo Sapiens migrated into Europe, and elsewhere, while the Neanderthals were declining and died out.

B. History of Lighting

Quite obviously, early man used fire. It is likely that the first fires originated from natural causes. Lightning strikes are known to cause forest fires. Early man undoubtedly used fires in caves, as has been determined from remnants of charcoal left therein. From there, he learned how to make torches that would burn a long time so that they could be carried from place to place. Thus, combustion in some form remained the sole practical source of light until the late nineteenth century.

1. Combustion and Flames

It is interesting to speculate how man learned to control combustion. In the beginning, cave-fires were undoubtedly started from fire-brands or torches carried from natural fires found in the environment. Later, Man learned how to start fires by either rubbing or twirling a hard piece of wood against a softer one, or by striking two chips of rock together. The latter may have come about as Man learned how to flake stone such as flint to form arrow-heads. At any rate, striking stones have been dated from before 7000 B.C. and the flintlock was used until about 1600 A.D. to ignite gunpowder to discharge fire-arms. The friction match was only discovered about 1827 when a mixture of sulfur and phosphorous sesquisulfide was found to be ignitable by friction. The final step in our progression of "fire-starters" was the invention of the mechanical lighter wherein a steel wheel causes a mischmetal rod to emit a series of sparks.

From cave-fires, man graduated to torches and similar "firebrands" such as oil lamps. The early fuels for lamps were vegetable in origin (olive oil or oil from nuts). At a later stage, animal oils (especially from the whale) were used. Although Pliny notes the use of mineral oil (actually fossil vegetable) in 50 A.D., kerosene was not introduced as an illuminant until after 1853, when the first oil well was drilled in both Pennsylvania and Ontario, Canada. Leonardo da Vinci is said to be the first to employ a glass chimney to protect oil flames from drafts in 1490. Street lighting in Paris and London first used oil lamps in 1736.

The candle is much younger than the oil lamp. Although the Greeks and Romans used threads coated with pitch and wax, it apparently took its modern form in 400 A.D. in Phoenicia. For centuries, such candles were made from natural materials such as tallow, beeswax, spermaceti (from the heads of whales) and/or vegetable waxes such as wax-myrtle, bayberries, etc. The fruit of the shrub *Aleurites Mouccana*, or candle nut, can be burned entirely as a candle. Synthetic paraffin, derived from petroleum, was introduced in the late 1850's. The original photometric "standard candle" was based on a spermatici candle 7/8 inches in diameter consuming 120 grains per hour. The candle is now defined in terms of the incandescence of a "blackbody" at the freezing point of platinum (2043 °K). The luminance is 60 lumens/cm^2, so that one candle emits one lumen/steradian for a total of 4π lumens.