SCIENCE BEFORE MARIE CURIE'S DISCOVERIES

The savante Marie Sklodowska Curie was born in the second part of the 19^{th} century, 1867 year and began her research work on uranium rays at the end of 19^{th} century, 1897 year. The 19^{th} century was a period, which experienced rapid progress in science and technology; important breakthroughs were in the iron & steel technology, electricity, weapons, physics & chemistry, sociology, psychology and biology.

In the study of physics, was better understanding of the nature of matter. There was revived the atomistic theory, references to the concept of atom dating back to ancient times, in antiquity.

In the 5th century BC, the Sicilian philosopher **Empedocles** (490-430 BC) first proposed that everything is made up of a mixture of four "roots", later renamed "elements" by the Greek philosopher, mathematician and founder of Athens Academy **Plato** (427-347 BC). The four "elements" were earth, water, air and fire. Ancient Greek word for "root" was "ῥιζώματα" (rhizōmata) and for "element" was *"*στοιχεῖον" (stoicheion) meaning smallest division.

In the 4^{th} century BC, the Plato's student, Greek philosopher and polymath **Aristotle** (384-322 BC) added a fifth element, aether, reasoning that the stars must be made of a different, heavenly substance. So was introduced the concept of *element*, but the understanding of the nature of matter did not advance.

Inspired by the spiritual activities of ancient Greece in pursuit of a novel form of natural philosophy, the Greek philosopher **Leucippus** (~ 440 BC) and his student, **Democritus** (460-370 BC) however, did one of the most amazing intellectual accomplishments of the antiquity, closer to the truth than anyone else in the following millennium. Leucippus and Democritus held that the nature of things consists of an infinite number of extremely small particles, which they called "atoms", physically indivisible, indestructible and full - containing no empty space inside them - and the "void" that surrounds them.

The Greek word *"*ἄτομος" (atomos) means indivisible, unable to be broken further.

Leucippus and Democritus were atomists and according to the atomists, Nature exists only of two things, the *atoms* and the *void* that surrounds them. Because of their indestructibility, the *atoms* were considered eternal and undergoing a continual and endless random motion, determined by mutual collisions. The fundamental concepts of the theory seem to have been formulated by Leucippus and historically Leucippus is considered the father of the theory. Unfortunately no original documents describing his doctrine have come down to us.

Marcus Tullius Cicero (106 BC- 43 BC), Roman philosopher, politician, lawyer, orator, consul wrote: "Leucippus admits two principles: the filled and the void".

Diogenes Laertius (c. 200 AD), biographer of ancient Greek philosophers, wrote explicitly in his book “Lives and Opinions of Eminent Philosophers”:
“Leucippus was the first to elevate the atoms to the level of principles”.
On the other hand Democritus, Leucippus successor, has left more substantial writings. About him, the physician and philosopher Sextus Empiricus (160 AD - 210 AD) said:
“Democritus for his part, abolishes the phenomena that concerns the senses and believes that no problem can appear in conformity with truth, but only in conformity with opinion, that what is true in substances consists in the reality of shapes and void: convention is the sweet, he proclaims, convention is the bitter, convention is the warm, convention is the cold, convention is the colour and in reality there exist only atoms and void”.
The reality of material corpuscles forms the underlying basis of the theory of atoms.
From the time of its inception, the Greeks had made a distinction between primary and secondary properties of matter, objective and subjective attributes, or those that exist by essence and those that exist by convention.
Leucippus and Democritus thought that there are many different kinds of atoms, each distinct in shape and size and that all atoms move around in space. The moving atoms inevitably collide in space, which in some cases causes them to be deflected like small balls and in other cases, when the shapes of two atoms match in a way that they can interlock, they build clusters upon collision, thereby forming *substances* which make up the objects of our perception. Also Democritus had mentioned that "the more any indivisible exceeds, the heavier it is". At this point, the atomists entered what their predecessors had postulated to be the origin of matter, namely water (Thales), air (Anaximenses), fire (Heraclitus) and earth (Empedocles).
But what the atomists said was that these four elements are not primordial substances, they are composed of atoms like everything else. Prior to the atomists nobody was able to provide a satisfactory explanation for what substance is.
Nonetheless, Leucippus and Democritus came closer to the truth than anyone else for centuries; their atom theory remains one of the most amazing intellectual accomplishments of the antiquity, an extraordinary adventure of the human spirit. Two Greek thinkers from the distant past handed to future generations a concept proved to be one of the most important gifts ever given to mankind.
Atomism constitutes an original attempt to resolve the central problem addressed by the pre Socratic thinkers – the nature of coming into being and of change.

As follower of Democritus the most brilliant was the Greek philosopher **Epicurus** (341-271 BC). One century after Democritus, the ancient Epicurus adopted every single fundamental proposition of Democritus believing that the fundamental constituents of the world were atoms flying through empty space. He added the concept of weight of atoms on a par with their size and shape. Also he explicitly asserted that in void, atoms move about at the same speed no matter what their weight and volume and do not always follow straight lines.

The atomic hypothesis, born 25 centuries ago, remained for the next 23 centuries essentially a vision of the imagination. No empirical evidence based on either observation or experimentation existed to prove or disprove the key hypothesis of the theory – the corpuscular structure of matter. It was first a philosophical idea, its philosophical epoch is ancient, but its scientific epoch is relatively recent.

Only in the 17^{th} century, appears something similar to the theory of atomism, the *corpuscularianism*, a physical theory that supposed that all matter to be composed of minute particles called *corpuscles*, which could in principle be divided (atoms were supposed to be indivisible). The Latin word "corpusculum" means small body.

Pierre Gassendi (1592-1655) French philosopher, scientific chronicler, observer and experimentalist was a man of church serving as canon in city of Digne France.

He accepted the fundamental postulate of atomists, which holds that atoms and void are the only principles on which the structure of cosmos rests and was the main driving force behind the revival of the atomic concept.

During the 1670 years, the corpuscularianism theory was used by the English physicist and mathematician **Sir Isaac Newton** (1642-1727) in his development of the corpuscular theory of light. He considered that fundamental particles are those assigned by the ancient atomists.

He added however a new property, inertia, meaning persistence of motion or rest.

Robert Boyle (1626-1691) was together with Newton one of the founders and leading protagonists of the theory of atoms in England. As chemist his opinions were shaped by his experimental approach to science. In his book "Sceptical Chemist" Boyle brushed aside the old ideas about elements, which had originated in obscure philosophical meditations. To him an element was simply a substance, which by no method could be separated into other substances.

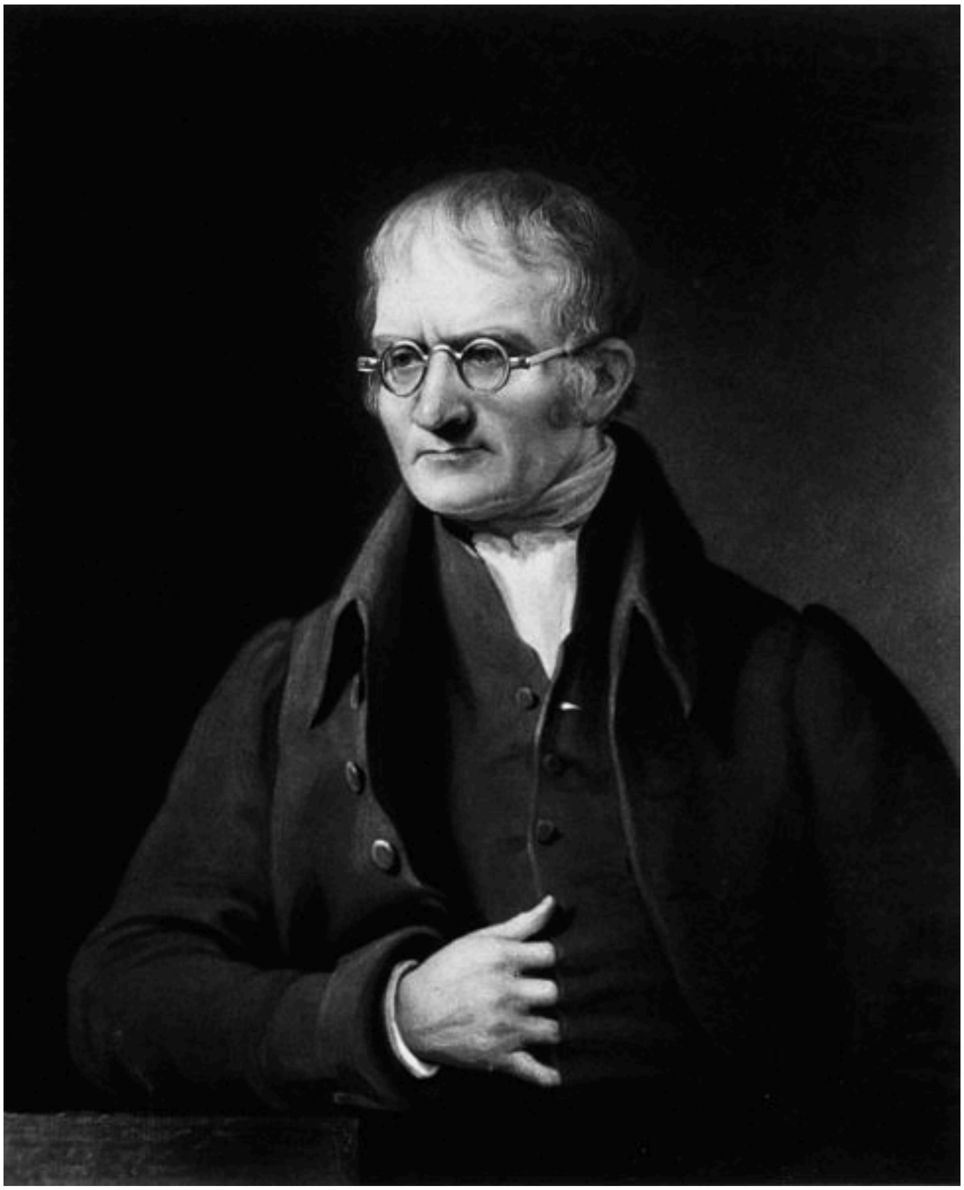
In the time of Boyle and even later there was still uncertainty about which substances were the elements. Thus water was considered generally an element.

Boyle's corpuscular theory preserved many ties with philosophic traditions.

ANTOINE-LAURENT DE LAVOISIER

John Locke (1632-1704) English philosopher and physician, one of the founders of empiricism - the theory that states that knowledge comes only or primarily from sensory experience - endorsed the principles of corpuscular structure of matter but regarded them as a hypothesis and believed that in any event we will never be in position to know how the particles making up this structure produce the properties exhibited by matter of which each of us can only form his own picture. Thus Lock expressed a profound doubt about our ability to ever demonstrate experimentally the existence of those elementary corpuscles. Lock's scepticism or outright pessimism earned his doctrine the label "agnostic atomism".
The only "scientific data" produced during the seventeenth century dealt with the existence of void, the second postulate of the original atomic theory, not enough to prove the atoms existence.

Further progress in the understanding of matter did not occur until the science of chemistry began to develop and was to change suddenly and profoundly at the beginning of the 19th century with the birth and consolidation of scientific atomism in the modern sense of phrase. Its birth or its growth proved not easy. It experienced many vicissitudes in its accumulation of empirical data, which often suffered from the imperfection of the research tools and the difficult maturation of the theoretical concepts.
In 1789 year the French nobleman and scientific researcher, father of modern chemistry **Antoine-Laurent de Lavoisier** (1743-1794) discovered the law of conservation of mass and defined an *element* as a basic substance that could not be further broken down by the methods of chemistry.
The English chemist, meteorologist, physicist and schoolteacher **John Dalton** (1766-1844) in 1805 year, revived the atomistic theory using the concept of atoms to explain why elements always react in ratios of small whole numbers (the law of multiple proportions) and why certain gases dissolved better in water than others. He proposed that each element consists of atoms of a single, unique type and that these atoms can join together to form chemical compounds.
Dalton's atomic hypothesis did not specify the size of atoms.
John Dalton is considered the originator of modern atomic theory.
Various atoms and molecules are depicted in John Dalton's book "A New System of Chemical Philosophy" appeared in 1808 year, an early scientific work on modern atomic theory, which is considered the birthday of the modern atomic theory.
In book, John Dalton proposed that atoms have weight.
He postulated the theory in which the atom was conceived as being a tiny billiard ball and



JOHN DALTON

the materials are made from *atoms*, the material of the same atom is an *element*, the material of different atoms is a *compound (substance)*.
Dalton theorized that the elements combine in fixed ratios into compounds, as for ex. in water are two atoms of hydrogen always combined with one atom of oxygen.
Element or *chemical element* is called the simplest thing in Nature which stays at the base of all other things that surround us, thought of as basic chemical building block of matter; it is a material which cannot be broken down or changed into another substance using chemical means.
Dalton proceeded to print his first published *table of relative atomic weights*.
Six elements appear in this table, namely hydrogen, oxygen, nitrogen, carbon, sulphur and phosphorus, with the atom of hydrogen conventionally assumed to weight 1.
The "molecule" has been accepted by many chemists since the early 19th century as a result of Dalton's laws of Definite and Multiple Proportions (1803–1808) and Avogadro's law relating volume of gas to the amount of substance of gas present (1811) but not entirely among positivists and physicists such as Ernst Mach, Ludwig Eduard Boltzmann, James Clerk Maxwell and Josiah Willard Gibbs who saw molecules merely as convenient mathematical constructs.
The work of physicist Jean Baptiste Perrin on Brownian motion (1911) is considered to be the final proof of the existence of molecules.
Molecule is an electrically neutral group of two or more atoms held together by chemical bonds. The word molecule comes from the Latin word "molecula", diminutive for "moles", meaning small unit of mass.

As unrecorded discoveries, people have known from early antiquity about some chemical elements like copper (~ 9000 BC), lead (~ 7000 BC), gold (~ 6000 BC), silver (~ 5000 BC), iron (~ 5000 BC), carbon (~ 3750 BC), stannum (~ 3500 BC), antimony (~ 3000 BC), arsenic (~ 2500 BC), sulphur (~ 2000 BC), mercury (~ 2000 BC), zinc (~ 1000 BC), a total of 12 elements.
In 1669 year the German alchemist **Hennig Brand** (1630-1719) had discovered phosphorus, the first chemical element discovered since antiquity, the 13th element to be discovered and the first element discovered chemically. In 1753 year the French chemist **Claude Francois Geoffroy** (1729-1753) identified bismuth, the 14th element to be discovered.
Systematisation attempts for chemical elements began apparently in 1789 year with the French chemist **Antoine-Laurent de Lavoisier** and continued with the German chemist **Johann Wolfgang Dobereiner** in the year 1829, the German chemist **Leopold Gmelin** in 1843 year, the French chemist and senator **Jean Baptiste Dumas** in 1857 year, the German chemist

Dmitri Mendeleev

August Kekule in 1858 year, the French geologist **Alexandre-Emile Beguyer de Chancourtois** in 1862 year, the German chemist **Julius Lothar Meyer** concurrently with the English chemist **William Odling** in 1864 year, the English chemist **John Newlands** in 1864-1865 years, the Danish born academic chemist based in America **Gustavus Hinrichs** in 1867 year.

The Russian chemistry professor **Dmitri Ivanovich Mendeleev** in 1869 year and the German chemist **Julius Lothar Meyer** in 1870 year, independent of each other, published *periodic tables of chemical elements*. Mendeleev's table was his first published version and that of Meyer was an expanded version of his 1864 table. Both tables were listing the elements in rows or columns in the order of atomic weight and starting a new row or column when the characteristics of the elements began to repeat.

The preference for Mendeleev's table was because Mendeleev was the first to use the trends in his periodic table to predict the properties of missing elements and occasionally to ignore the order suggested by the atomic weights and switch adjacent elements, to better classify them into chemical families. With the development of theories of atomic structure, it became apparent that Mendeleev had listed the elements, unintentionally, in order of increasing atomic number or nuclear electric charge, as today.

A periodic table incorporates recurring trends, any such table can be used to derive relationships between the properties of the elements shown in table and predict properties for others not shown. As result, a periodic table is widely used in chemistry, providing a useful framework for analysing chemical behaviour of known chemical elements and of new, yet to be discovered elements.

The Russian chemistry professor **Dmitri Ivanovich Mendeleev** (1834-1907) is generally credited with the publication in 1869 year of the first widely recognized periodic table of chemical elements. He developed his table to illustrate periodic trends in the properties of then-known elements and to predict some properties of then-unknown elements that would be expected to fill gaps in this table. Most of his predictions were proved correct when the elements in question were subsequently discovered.

The history of periodic table is also the history of discovery of chemical elements.

The first four "main discovery periods" were:

Antiquity to Middle Ages: unrecorded discoveries	14 elements were discovered
Middle Ages – 1800 year: age of enlightenment	20 elements were discovered
1800–1849 years: science and industrial revolutions	24 elements were discovered
1850–1899 (1897) years: help of spectral analysis	26 (19) elements were discovered

A unique arrangement of atoms or molecules in a liquid or solid is called a *crystal structure*.
The crystal structure has a three-dimensional shape. A crystal structure is composed of a pattern, a group of atoms or molecules arranged in a particular way, and a lattice, an array of points repeating periodically in three dimensions exhibiting long-range order and symmetry. Patterns are located upon the points of a lattice. The points can be thought of as forming identical tiny boxes, called unit cells, that fill the space of the lattice. The lengths of the edges of a unit cell and the angles between them are called the *lattice parameters*.
The structure and symmetry of a crystal play a role in determining many of its physical properties, such as cleavage, electronic band structure and optical transparency.
The defining property of a crystal is its inherent symmetry, by which we mean that under certain ‘operations on it' the crystal remains unchanged. These operations include: reflection, rotation, inversion and improper rotation, combination of rotation about an axis and reflection in a plane.
Polymorphism is the ability of a chemical substance to exist in more than one crystalline form or structure. For example *quartz* (silica or silicon dioxide SiO_2) has more important crystalline forms or structures including: α-quartz, β-quartz, tridymite, cristobalite, coesite and stishovite.
Polarization, in general terms, means to separate into opposites. A change in temperature modifies slightly the positions of the atoms within the crystal structure and so the polarization of the material changes. The material polarization change gives rise to a voltage across the crystal.
The scientists tried to explain that.
The Austrian Baroque painter **Johann Georg Schmidt** (1685-1748) rediscovered in 1707 year, tourmaline's properties to attract only hot ashes. In 1747 year, the Swedish scientist **Carolus Linnaeus** (1707-1778) related the phenomenon to electricity. He called tourmaline “Lapidem Electricum” (the electric stone). That was proven only in 1756 year by the German and Russian Empire natural philosopher **Franz Ulrich Theodor Aepinus** (1724-1802).
In 1824 year, the Scottish physicist, mathematician, astronomer, inventor, writer **Sir David Brewster** (1781-1868) gave to effect the name *pyroelectricity.*
The word “pyroelectricity” derived from the Greek words “πυρ/ο” (pyr) meaning fire and “ήλεκτρον” (electron) meaning amber, an ancient source of electric charge.
In 1878 year, the Scotish mathematician and physicist **Lord William Thomson** (1824-1907) and later in 1897 the German physicist **Woldemar Voigt** (1850-1919) helped to develop a theory for the processes behind pyroelectricity.
In the 1880 years, two young brothers, the French physicists **Paul-Jacques Curie** (1856-1941) and **Pierre Curie** (1859-1906) studied the pyroelectricity.

They used their knowledge and understanding of the underlying crystal structures that gave rise to it to predict crystal behaviour, associating the phenomenon of pyroelectricity with a change in the volume of the crystal in which it appears and demonstrating the effect using crystals of tourmaline, quartz, topaz, cane sugar and Rochelle salt (sodium potassium tartrate tetrahydrate). Their experiment led to the discovery of another effect, ability of certain crystal structures to generate a temporary voltage when they are under a mechanical stress.
Piezoelectricity was named the new effect. The word "piezoelectricity" derived from the Greek words "πιέζειν" (piezein), which means to squeeze or press and "ήλεκτρον" (electron) meaning amber, an ancient source of electric charge.
Quartz and Rochelle salt exhibited the most piezoelectricity.
The *piezoelectric effect* is a reversible process, in that materials exhibiting the direct piezoelectric effect (internal generation of electric charge resulting from an applied mechanical force) also exhibit the reverse piezoelectric effect (internal generation of mechanical strain resulting from an applied electrical field). The *converse piezoelectric effect* was mathematically deduced in the year 1881 from fundamental thermodynamic principles by the Franco-Luxembourgish physicist and inventor **Jonas Ferdinand Gabriel Lippmann** (1845-1921). The Curie brothers confirmed experimentally the existence of the converse effect and obtained quantitative proof of the complete reversibility of electro-elasto-mechanical deformations in piezoelectric crystals.
The Curie brothers invented the Piezoelectric Quartz Electrometer shortly afterwards.
The French Academy of Sciences awarded later, in 1895 year, the **Gaston Plante** Prize to the Curie brothers for the discovery of piezoelectricity. Gaston Plante award was a biannual monetary prize to scientists or inventors with an important contribution in the field of electricity.
But for the next few decades, piezoelectricity remained only a laboratory curiosity.
The physicist Pierre Curie first work was carried out in 1878 year, on a process then entirely new, in collaboration with the French physicist **Paul Quentin Desains** (1817-1885) "Determination of the lengths of heat waves with the aid of a thermo-electric element and a metallic-wire grating ".
Beginning his own research Pierre Curie managed to perfect the analytical balance by creating an Aperiodic Balance with direct reading of the last weights.
In 1884 year he published a memoir of questions on the order and repetition that are at the base of the study of the symmetry of crystals and in 1885 year appeared his article on symmetry and its repetitions and also a very important theoretical work on the formation of crystals and the capillarity constants of the different faces.

PIERRE CURIE

In 1894 year in the paper ”On Symmetry in Physical Phenomena” Pierre Curie proposed that: *when certain causes produce certain effects, the elements of symmetry of the causes must be found in the effects produced.* He also formulated what is now known as the “Curie Dissymmetry Principle”: *a physical effect cannot have a dissymmetry absent from its efficient cause*.
Pierre Curie studied ferromagnetism, paramagnetism and diamagnetism with the aim of discovering if there exist any transitions between the three types of magnetism.
He discovered that ferromagnetic substances exhibit a critical temperature transition above which the substances lose their ferromagnetic behaviour, later known as the *Curie point*. He discovered the effect of temperature on paramagnetism, which is now known as *Curie's law* and the material constant in Curie's law is known as the *Curie constant*.
To measure magnetic coefficients, Pierre Curie designed and perfected an accurate Torsion Balance*,* used by future workers.
In 1895 year, Pierre Curie defended his thesis on magnetism and obtained a **Doctorate of Science**.

The earliest mention of electricity was in an Egyptian text about 4750 years ago, about 2750 BC year. The text was about the Nile catfish "Thunderer of the Nile", used for healing: it was placed in a bathtub and then patients would lie in the electrified water.
Very early in human history, people would have witnessed “lightning”, an obvious natural manifestation, but would have been unable to explain it.
The known history of electricity goes back to at least 620-550 BC, when in ancient Greece it was found that “rubbing fur on amber caused an attraction between the two”. That discovery is credited to the Greek philosopher **Thales of Miletus** (624 BC-546 BC). That was static electricity but nobody had been able to explain it and it was to be many centuries before anyone was able to connect this phenomenon with lightning and a century more before electrical currents were put to practical use.
In the year 1600, the English physician, physicist and natural philosopher
William Gilbert (1544-1603) first made the “connection” between the attraction of oppositely electric charged objects and magnetism. William Gilbert is known as the father of electricity, magnetism and electrical engineering. He coined the term “electric” from the Greek word ”ήλεκτρον” (electron) meaning “amber” to identify the force that certain substances exert when rubbed against each other.
The Swedish physicist **Johan Carl Wilcke** (1732-1796) invented in 1762 year an Electrostatic Generator*,* later called Electrophorus.

The Italian physicist **Alessandro Giuseppe Antonio Anastasio Volta** (1745-1827) discovered that particular *chemical reactions could produce electricity* and created the *first transmission of electricity* by linking positively electric charged and negatively electric charged electrodes.
In 1800 year, Alessandro Volta constructed an *early electric source that produced a steady electric current called Voltaic Pile.* Alessandro Volta invented the battery.
In 1831 the English scientist **Michael Faraday** (1791-1867) described the nature of electricity and contributed to the fields of electrochemistry and electromagnetism.
He discovered the *laws of electrolysis* and the *principle of electromagnetic induction* and *diamagnetism*. His inventions of *electromagnetic rotary devices formed the foundation of electric motor* technology. He stated that an electric current flows in a conductor if that conductor is in a moving magnetic field and is part of a circuit; he explained it using “lines of force” concept, establishing the *basis for the concept of the electromagnetic field* in physics.
Scientists at the time widely rejected his ideas.
In 1838 year Michael Faraday passed a current through a rarefied air filled glass tube and noticed a strange light arc with its beginning at the cathode (negative electrode) and its end almost at the anode (positive electrode). In 1857 the German physicist and glassblower **Heinrich Geissler** (1814-1879) sucked even more air out with an improved pump, to a pressure of around 10^{-3}atm and found that, instead of an arc, a glow filled the tube. Later researchers painted the inside back wall of the glass tube with fluorescent chemicals such as zinc sulphide, to make the glow more visible. This accidental fluorescence allowed researchers to notice that objects in the tube in front of the cathode, such as the anode, cast sharp-edged shadows on the glowing back wall.
The Scottish mathematical physicist **James Clerk Maxwell** (1831-1879) understood Faraday’s ideas and on that basis in 1865 year did the notable achievement to formulate the *classical theory of electromagnetic radiation* in his publication “A Dynamical Theory of the Electromagnetic Field” bringing together for the first time electricity, magnetism and light as manifestations of the same phenomenon, waves traveling in space at the speed of light.
Maxwell's equations for electromagnetism have been called "the second great unification in physics" after the first one realised by Isaac Newton.
The first major unification in physics was Isaac Newton's realization that the same force that caused an apple to fall at the Earth's surface, the gravity, was also responsible for holding the Moon in orbit about the Earth and this universal force would also act between the planets and the Sun, providing a common explanation for both terrestrial and astronomical phenomena.

In 1869 year, the German physicist **Johann Hittorf** (1824-1914) was the first to realize that "something" must be travelling in straight lines from the cathode to anode in the rarefied air filled glass tube of Faraday to cast the shadows. In 1870 year, the German physicist **Eugen Goldstein** (1850-1930) named that something "kathodenstrahlen (cathode rays)" because they are emitted by the negative electrode or cathode of the tube. By the 1870s the British chemist and physicist **William Crookes** (1832-1919) and others were able to reduce the air pressure in some tubes below 10^{-6} atm. Those tubes were named "Crookes tubes".

In 1886-1887 years, the German physicist **Heinrich Rudolf Hertz** (1857-1894) by experimentation, proved the *existence of the electromagnetic waves* theorized by Maxwell's electromagnetic field theory.

In 1888 year, the German physicist **Philipp Eduard Anton von Lenard** (1862-1947) began the study of the *cathode rays*. He contributed substantially to cathode ray theory. The glass tubes to produce cathode rays were tubes where the cathode rays were difficult to study. Lenard devised a method of making small metallic windows called *Lenard windows* in the glass to pass the rays out into the laboratory, to conveniently detect them and measure their intensity by means of paper sheets coated with phosphorescent materials.

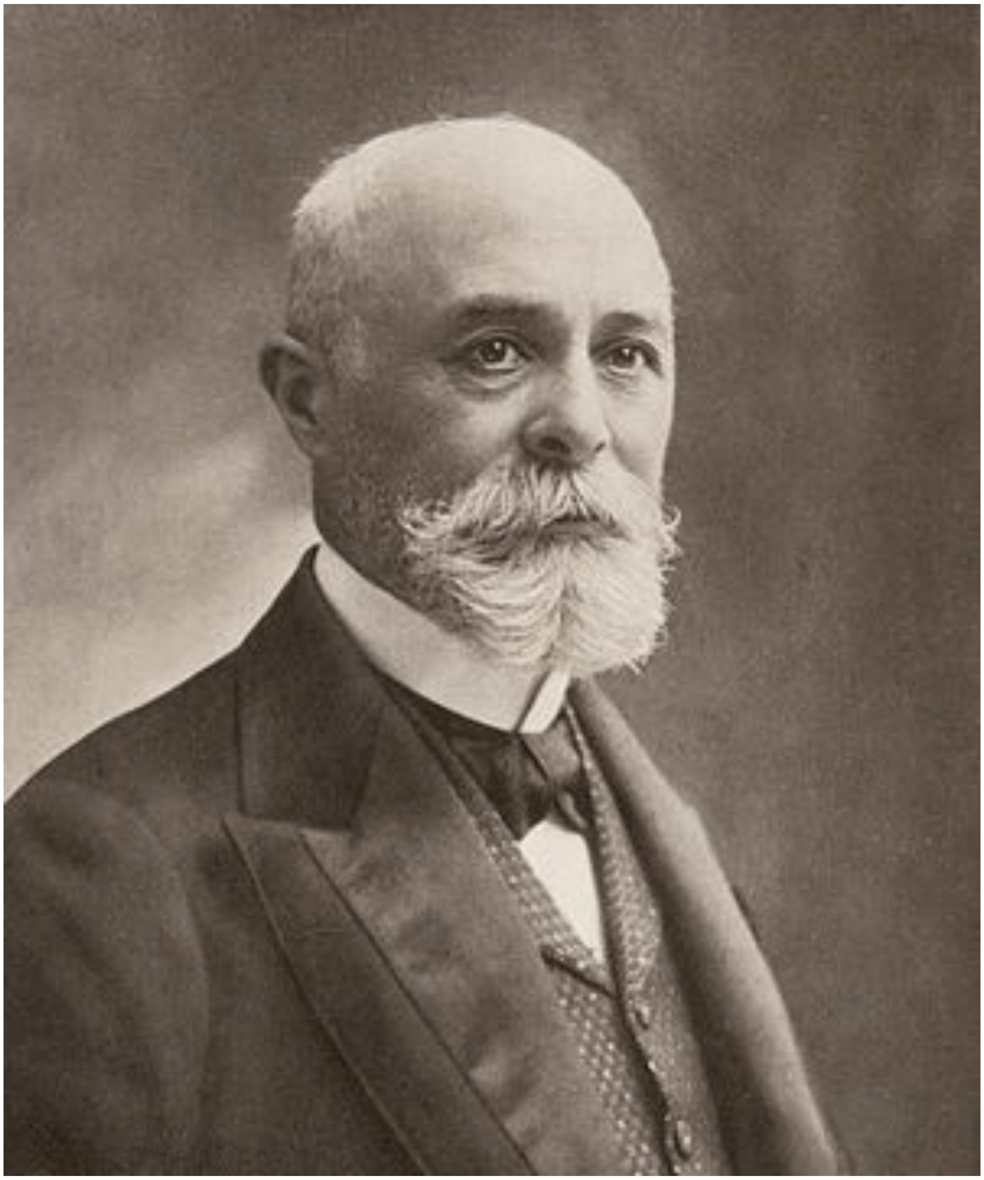
He showed that the rays produced by irradiating metals in a vacuum with ultraviolet light were similar to cathode rays and the energy of those rays did not depend on light intensity, but is proportional with the frequency of light. Lenard observed that the absorption of the cathode rays by a material was proportional to that's density, contradicting the idea that they were some kind of electromagnetic radiation. He also observed that the cathode rays appeared to be scattered by air, so they must be particles smaller than air molecules.

During the last quarter of the 19th century many experiments were done to determine what cathode rays were. There were two theories. The British physicists William Crookes and Arthur Schuster believed they were particles of "radiant matter", that is electrically charged atoms. The German scientists Eilhard Wiedemann, Heinrich Hertz and Eugene Goldstein believed they were "ether waves", some new form of electromagnetic radiation separated from what carried the electric current through the tube since in 1887 year the German physicist Heinrich Hertz proved the existence of electromagnetic waves, clarifying and expanding James Clerk Maxwell's electromagnetic theory.

In 1895 year the French physicist **Jean Baptist Perrin** (1870-1942) showed that the cathode rays were of negative electric charge nature.

On 8 November 1895, the German physicist **Wilhelm Conrad Roentgen** (1945-1923) when he had been fiddling with a set of cathode ray instruments, was surprised to find a flickering image separated from his instruments by some distance. He knew that the image he saw was not being cast by the cathode rays since they could not penetrate air for a significant distance.
After some considerable investigation, he understood that he discovered a new kind of rays, which he named "X" (unknown). Wilhelm Röntgen's original paper, "Über eine neue Art von Strahlen" (On A New Kind Of Rays), was published on 28 December 1895 year. Wilhelm Röntgen published a total of three papers on X-rays, between 1895-1897 years.
On 5 January 1896, an Austrian newspaper reported Röntgen's discovery of a new type of radiation. Roentgen discovered a kind of ray that could travel through solid wood or flesh and, because impressed photographic plates as light, yield photographs of living people's bones.
After his discovery, Wilhelm Conrad Röntgen was awarded an honorary **Doctor of Medicine** degree from the University of Würzburg. In 1901 year in recognition of the extraordinary services he has rendered by the discovery, Roentgen was awarded the **First Nobel Prize in Physics**.
Today Roentgen is considered the father of diagnostic radiology, the medical specialty which uses imaging to diagnose disease.
But at the time of their discovery nobody knew what actually were the X rays.

In early 1896 years, in the wave of excitement following Wilhelm Conrad Röntgen's discovery of X-rays, the French physicist **Antoine Henri Becquerel** (1852-1908) who just moved on to examine the spectrum resulting from the stimulation of phosphorescent crystals with infrared light, following the theoretical physicist Henri Poicare's suggestion that luminescence and X-rays have something in common, thought that phosphorescent materials, such as some uranium salts, might emit penetrating X-ray-like radiation when illuminated by bright sunlight. Becquerel had long been interested in the phosphorescence, the emission of light of one colour by a body following body's exposure to light of another colour (while the related fluorescence is the glowing under bombardment of light).
Henri Becquerel and his father Edmond Becquerel were a dominant force in adapting photography to scientific studies during its first and very formative years. The discovery of X-rays was the result of serendipitous exposure of photographic plates to an active Crookes tube and Henri Becquerel was one of the innovators of scientific photography.
Visualising was an important tool for Becquerel's method of thinking about radiant matter long before he used photographic plates in his new experiment.



HENRI BECQUEREL

Henri Becquerel was convinced that exciting a substance with sunlight to emit a phosphorescent glow was the key to generating penetrating rays similar to Roentgen rays. He exposed a crystal of *aluan of uranium* to sun and put it on a photographic plate hermetically wrapped in black paper. Developing the plate after a time he realised that it was impressed. But in another day when was no sun Becquerel put the crystal and plate in a drawer and forgot about them two weeks, when he observed that the plate was again impressed without exposure to sun.

Becquerel's discovery that the rays could be emitted even without energy entering the system, "spontaneously" as he called it, was the first indication that his rays differed from the Roentgen rays emitted by the Crookes tube and were therefore genuinely novel. By May 1896, after other experiments involving non-phosphorescent uranium salts, he arrived at the conclusion that the penetrating radiation came from the uranium itself, which produces rays without any need of excitation from an external energy source.

The rays were called *uranium rays*, but nobody knew what were they actually.

Henri Becquerel had come upon this discovery accidentally. His discovery is a famous example of serendipity, of how chance favours the prepared mind.

The French physicist Antoine Henri Becquerel reported to the French Academy of Sciences that uranium compounds, even if they were kept in the dark, emitted rays that would fog a photographic plate.

Beside being proficient in photography and laboratory technique, Becquerel experimented as well with the polarisation of light, studied earth's magnetism and infrared radiation.

He obtained a **Doctorate in Science** in 1888 year with his doctorate thesis concerned with crystals and their absorption of light.

Becquerel discovery left many mysteries to be solved but opened up a new area to investigate, perhaps the most important contribution a scientist can make to scientific community.

But despite Becquerel's intriguing finding, the scientific community continued to focus its attention on Roentgen's X-rays, neglecting the much weaker Becquerel's uranium rays.

The scientific community wanted to know what X-rays are in fact.

But to know what the X-rays are, first must know what the cathode rays are.

In 1897 year, the British physicist **Sir Joseph John Thomson** (1856-1940) estimated the mass of the cathode rays, showing they were made of particles, which were around 1800 times lighter than the lightest atom, atom of hydrogen. Thomson made his suggestion following his discovery that Lenard rays could travel much further through air than expected for an atom-sized particle.

Lenard rays are a mixture of cathode rays that have emerged from tube into the outside space through a window consisting of a piece of thin metal foil and rays emitted by the foil as a result of the incidence with the cathode rays.
His experiments suggested not only that cathode rays were around 1800 times lighter than the hydrogen atom, but also that their mass was the same whatever the cathode metal.
He concluded that the cathode rays were composed of very light, negatively charged particles, which were unknown. He called the particles *corpuscles*.

With the appearance of the heat engines, airships, railroads, automobiles, motors, electric lights and even telephone communication, the end of the 19th century was an era of buoyant confidence in the power of science and technology to better the human condition and to explain the nature. But although the applications of electricity were extraordinary, was not known what electricity actually is.
And also, although the atomic unit, the atom, had been used pragmatically in chemistry to determine the ratios in which various elements combine, was not known what atoms really were. There were not understood the links between atoms, the intricate relationships between the atomic behaviour and the macroscopic properties of materials and what gives the periodic table so a valuable predictive power.