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The Scientific Revolution in the Development of Atomic Physics: Is it Continuous or Discontinuous?

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Abstract: ***The paradigm shift is a term to describe fundamental changes in assumptions, theories, and methods in the old paradigm frame to assumptions, theories and methods in the new paradigm frame. Fundamental changes are revolutionary, in which the old paradigm is partially or completely replaced by a new paradigm that is contradictory, because of anomalous scientific facts (anomalies) with the fact or science theory that has existed previously known as the process of scientific revolution. Thomas Kuhn's Science Revolution is essential to understand in studying philosophy of science. An example of a scientific revolution can be seen in the field of physics concerning the atomic concept which was initially defined only on the view of micro scale, since the ideas proposed by Greek philosophers were based only on abstract thought things they could not see, but they believe in its existence in this universe. Whether it is believed by the supporters of Democritus who believe the material is discontinuous or is believed by a group of supporters of Aristotle who believe that the material is continuous. The development became 'normal science' after Dalton conceptualized again based on empirical studies that directly confirmed that the atom is the smallest part of the indivisible matter (matter is discontinuous). But then, in time the Dalton atomic theory was killed after finding anomalies related to electricity and radioactivity. Dalton's paradigm shifts to the paradigm of the Thompson atom model, Rutherford's atomic model, Bohr's atomic model, the atomic theory of wave mechanics up to the latest atomic model that 'as if' matter can be divided continuously in accordance with the development of science and technology of its time (matter is continuous).***

Keywords: Paradigm shift, the scientific revolution, atomic physics

1. Introduction

Atom is one of the concepts in physics that experienced changes dynamically. This is because the theories and models developed have wide use in explaining physical and chemical symptoms. Moreover, the new inventions of particulate matter permit the extent of application of the invention.

Today the application of the results of thought and discovery around the concept of atom penetrated into all fields. In addition to having positive benefits for the welfare of humanity, it also has a negative impact and has the potential to bring misery to society like the invention of the atomic bomb.

The discussion of the concept of atoms in this paper aimed to analyze and interpret the historical facts of the development of atomic theory based on the frame of mind as proposed by Kuhn (1993) in his work The Structure of Scientific Revolutions.

Thomas Kuhn explains that science is not always cumulative [1]. This is because there is a scientific revolution that changed the paradigm of normal science. In the period of normal science, scientists work to verify or test theories based on the prevailing paradigm. In this period the existence of anomalies or deviations of results will be ignored. But the accumulation of anomalies can allow for a paradigm crisis, so normal science cannot continue. At that time there was a scientific revolution, and a new paradigm emerged. The new paradigm that arises after the anomaly will persist if the results of verification or facts can support it. The more verification that supports the paradigm, the stronger the position, so that at one time it can become the normal science. Furthermore, if there is anomaly accumulation, then there is another crisis paradigm that resulted in the revolution of science.

Based on Kuhn's mindset of the Science Revolution, this paper presents an analysis of the historical development of atomic concept thinking. The formulation of the problem is:

a) In which period the concept of the atom is an abstract view that is only based on belief and then become normal science?
b) What inventions are considered anomalies and cause a revolution?
c) When did the concept of atomic thought revolution occur?
d) Is the development of atomic concepts leading to continuous or discontinuous nature

2. Method

The research method used in this research is a qualitative method with descriptive research design [2].

3. Result and Discussion

3.1 Thought of the Atomic Concept of the Greek Age

Most Greek philosophers think of the universe through a macro-scale review, based on what they see only in the eye. But there are also some philosophers who consider the deeper meaning of the universe in a micro-scale concept, meaning abstract thinking of things they can not see but they believe in their existence, they are called atomists.

The first atoms were Leucippus of Miletus-Greece (440 BC) and Democritus of Abdera (420 BC). They contribute their thoughts separately but are compatible with each other [3]. In essence, the ideas of Leucippus and Democritus on the matter are discontinuous. The material is composed of small, indivisible particles known as atoms. The constituent atoms of matter are constantly moving in the void (vacuum space = a room containing absolute absence). The term atomos (a = no and tomos = divisible) is given to the material particles because the atoms are very subtle and cannot be divisible again [4].

Natural philosophers of this era such as Aristotle (384-322 BC) of the Greek Staigera, Plato, and Galen (200-130 BC) rejected the concept of the atom. Generally, they see matter as one unified whole (continuous) can be divided continuously into the smallest part without borders and in the universe, there is no void (empty space). The universe consists of 4 elements, namely earth, fire, air, and water because each tends to be found in nature. This view is reinforced by Thales of Miletus (about 580 BC), Anaximenes (550-475 BC) and Anaximander (610-545 BC) declared the world to be made up of earth, water, air and fire [5].

The view of the philosophers of nature, especially Aristotle is more believed in society, because of its popularity and credibility. This went on, especially until the middle ages (27 BC - 476 AD) or the dark ages (in Europe). His ideas are extensive in many fields, and he writes in books related to the development of knowledge such as astronomy, biology, metaphysics, law, politics, logic, ethics and aesthetics. His books were used as a reference for a long time (even the concept of logic is still embraced today).

In the dark ages in Europe, generally, the development of science and technology experienced obstacles. This is, because at that time the minds of scientists, confined by Orthodox Catholic religious teachings, which bind the freedom of thinking about worldliness, especially science. Thought that seems to contradict the "teachings" of religion, is regarded as a mistake and sin to be redeemed by physical punishment even with life. Aristotelian paradigm is still recognized because it is considered not contrary to the "teachings" of religion. In addition to the atomic concept that gets justified from the teachings of religion, other ideas are about the concept of geocentric and rejection of the concept of vacuum space.

3.2 Atomic Reconceptualization By John Dalton

Based on the ideas of atoms Leucippus and Democritus and the empirical facts discovered by subsequent scientists Dalton reconceptualized back to a theory known as Dalton atomic theory. In the 17th century to the beginning of the nineteenth century, there has been a new perspective to explain the physical properties of solid, gas and liquid states and to identify facts of chemical incorporation quantitatively.

Before the beginning of the nineteenth century, not all scientists believed in the idea of the atom, because it had not yet been clarified on the facts that could support it. Thus the idea of atomic concepts put forward by Dalton (1766-1844), is seen as a continuation of the philosophical view of atomic, although there is little difference in the basis of his thinking. Some of the ideas that Dalton poured were based on empirical facts based on experiments conducted by other scientists, while the philosophical view of the atoms is entirely a critical reflection of natural phenomena [3,6]. The points of thought presented by Dalton, published in 1808 in his writings New System of Chemical Philosophy.

Of course, when Dalton's first conclusions were announced it was attacked everywhere, especially for Berthollet. But most chemists are more convinced of Dalton's paradigm, rather than Proust or Berthollet because the scope is much wider. Not only does it provide a new criterion for distinguishing mixtures with compounds, but by reexamination of chemical data, it can reveal comparative examples of combining atoms chemically in multiple comparisons between steady and simple integers.

Besides, Dalton's paradigm is framed for new experiments, especially the Gay-Lussac experiment in volume merging. The results of the experiment turned out to produce another order that chemists had never imagined before. For example, in solving atomic weight problems and providing information about what is called atoms, molecules, compounds, mixtures, and solutions.

What needs to be underlined from Dalton's ideas is that what chemists can gain from Dalton's ideas is not new experimental laws, but a new system of chemical practice. Therefore Dalton calls it the 'new system of chemical philosophy' (New System of Chemical Philosophy) [1].

3.3 Inventions Cause of Atomic Revolution Thought

The discovery of electrical phenomena alters the view that atoms are particles of the smallest part of matter since it has been proved that sub-atomic particles such as protons, electrons, and neutrons. Several intensive studies carried out led to a new phase of an investigation of atoms that brought understanding very different from Dalton's philosophical view. Here are some discoveries that led to the revolution of atomic thinking:

a) Electrolysis

From the investigation of Michael Faraday (1791-1867) in 1832 on electrolysis, it was discovered that electric currents could cause the separation of chemicals. It is also proven that the amount of substances described in electrolysis is proportional to the magnitude of the current strength and the length of time the electrolysis takes place. Faraday's discovery is a continuation of previous scientists who have found the basics of electric current, including: Luigi Galvani (1737-1798), Alessandro Volta (1745-1827), Grotihuss (1805), Anthony Carlisle (1768-1840), William Nicholson (1753-1815), Sir Humphry Davy (1778-1829), Helmholtz (1881) and Johnstone Stoney (1891). Nevertheless, so far from these findings, no scientist has attributed these electrical phenomena to the atomic structure [3,6].

b) Properties of Atomic Electricity and the Invention of Sub-Atomic Particles

At regular pressure, the gas does not conduct electricity, except with very high electrical voltage. However, experiments conducted around 1859, among others, by J. Plucker, revealed that gases could conduct electricity at relatively low voltages provided that the pressure is small enough. For the experiment, a glass tube containing the air with a very low pressure of about 1/1000 atmospheric pressure was used. In the tube are installed two electrodes each connected to a direct current source. If the tube is connected to a high-voltage current source (1000 volts), it produces a light that can be clearly visible along the tube. Then when the gas pressure is continuously reduced to approximately 1 / 100,000 atmospheric pressure, all the light disappears, the gas becomes dark, but the faint green light appears (fluorescence). It seems to the part of the cathode that gave the rays, so Goldstein in 1876 named the rays cathode rays.

Scientists are much interested in the phenomenon and from their intensive investigation of these rays it is concluded that there are three types of rays that can be observed from experiments with the tube, i.e., rays that move straight from the cathode to the anode; rays that travel in opposite directions from cathode rays and rays that are formed and are accidentally discovered when cathode rays are blocked by a metal.

The presence of a ray moving opposite to the cathode ray was invented by Goldstein in 1886. This ray was identified as positively charged. Goldstein discovered this positive ray by piercing the tubular cathode and filling it with low-pressure hydrogen gas. Of the various gas used, it turns out the lightest positive light comes from hydrogen gas. After the investigation by Rutherford (1914) then it is known that the positive light particles are part of the atom (contained in the atom) or sub-atomic particles which are then given the name of protons.

The properties of cathode rays were first studied intensively, especially by J. J. Thomson (1856-1940) and his team at the Cavendish laboratory at Cambridge-Britain in 1897 investigating the natural properties of cathode rays. The investigation of Thomson's cathode ray properties is by bringing an electric field closer to a charged glass tube. It turns out that the rays that initially move straight into a turn approached a positively charged electric field. This fact led him to conclude that the cathode ray was negatively charged.

Thomson and Rutherford found that the current through the gas, treated with X-rays between two metal plates can not increase beyond a certain point. They think of metal plates that then collect ions as quickly as they are produced through X-rays. Thomson believes the cathode rays in the cylinders are the negative ions of the gases. The experimental results show the ions are lighter than atoms and move at very high speeds and are 1000 times lighter than the hydrogen atoms. Regarding the large charge of electrons is confirmed by R.A. Millikan in America between 1913-1914 by observing the movement of oil droplets under the influence of electric fields and different gravity. The result is that hydrogen is 1836 times heavier than an electron in which the mass of electrons is 9.11 X 10^{-28} grams.

The subsequent Thomson discovery was corroborated by the results of Hertz and Lenard's experiments showing that cathode ray particles can penetrate the plates of aluminum or gold, while atoms cannot do so. Therefore they conclude that the particles must be smaller than atoms. On April 30, 1897, Thomson broadcast his discovery that there are particles lighter than atoms and called as corpuscular (now called electrons).

Based on this series of discoveries, Thomson studied the atomic structure and concluded in 1904 that the atom is a compact ball that is electrically charged and the electrons are dispersed between these positive charges in equal quantities, the entire atomic mass is determined by the number of electron masses. The concept of Thomson atom is also called the Atomic Roti Raisin Model. But Thomson's proposed atomic model was disqualified by a study of radioactivity in subsequent years [7].

Thus, in those days (until 1913) scientists believed that the atoms contained two fundamental particles of electrons with a positive electric charge and a positive electrically charged proton and its mass 1836 times larger than the electron. While another nuclear atom particle, the new neutron discovered in 1932 by J. Chadwick. Based on the shooting experiment of beryllium element with alpha particle [4]. From the experiment, it produced radiation that turned out to consist of neutral particles. These particles have a mass that is slightly larger than the mass of the proton (1839 times the mass of the electron) and is called a neutron.

c) Symptoms of radioactivity

The symptoms of radioactivity were first discovered in February 1896 by Henri Becquerel. He notes that the apparent X-rays come from a small piece of phosphorescence in a glass tube where cathode rays hit him. Becquerel decided to investigate all phosphorescence substances and turned out to be generated by similar rays. In some experiments, it was found that uranium salts also produce rays. Marie Curie (1867-1934) named this phenomenon as radioactivity.

d) Rutherford's experiment

In 1911, Rutherford conducted an alpha-shooting experiment on a target of a very thin gold plate. It shows that a small part of the alpha ray is reflected and deflected and is largely passed on. After reviewing the reflection phenomena of Geiger and Marsden (in the same year), Rutherford tries to explain the facts, that is when most of the light is transmitted, meaning that most of the atoms are made up of empty space. There is some reflected light, which means that in the atom there is a tight and dense section. While the beam is deflected, meaning the alpha ray passes through a part of the positively charged metal plate and diverted in its direction, since it is rejected of the same charge.

From the experiment, Rutherford finally arranged the atomic model, that is; Atoms are composed of atomic nuclei whose center of mass is positively charged, and the skin is composed of electrons and moves around atoms. The atomic model is in line with the prevailing general notion that the atom is synonymous with a miniature solar system in which electrons as planets and empty spaces within atoms must be proportional to the amount of space in space. A heavy core or sun is at the center with lighter electron planets spinning around it. Rutherford can also estimate the size of the atomic nucleus of approximately 10^{-13} cm and the size of atoms approximately 10^{-8} cm. In the theory of this electron planet, the preconceptions implanted in the mind are Newtonian physics. Hence the explanation of the facts with the atomic model is done by the approach of classical Newtonian physics [6.7].

e) Atoms and Isotopes

In 1913 Henry Moseley (1887-1915) in a series of experiments investigated X-rays emitted from various metals. The metal is mounted as an anode in an X-ray tube. The emitted wavelength is measured. It turns out that he finds the regularity of rising wavelengths by increasing the atomic weight of the metals being investigated. The X-ray wavelength increases when the atomic weight of the elements being investigated increases, only a few elements do not follow that order.

Furthermore, Soddy discovered that there are atoms that have the same atomic number but different mass, he called them isotopes. This discovery is supported by J. J. Thomson and Aston (1913) which states that almost all elements are present as mixed isotopes. The discovery of a mass spectrograph amplifies the allegations about the isotope.

From the above explanation, two scientists put forward the atomic model, namely Thomson and Rutherford. The two atomic models are different from Dalton's notions, especially in claiming the existence of subatomic particles, i.e., protons, and electrons, but both still follow the classical mechanical paradigm that prevailed at the time. Rutherford's atomic model is already ahead of Thomson's atomic model. From this model, we can see that most of the atomic volume consists of empty space containing electrons and positively charged masses at their core [7,8].

Based on the above exposure, which then becomes the question is; whether the Thomson atom model or Rutherford's atomic model is already a revolution that produces a new paradigm? To answer this, there are two things to consider;

1) What proposed by Thomson and Rutherford is not yet a paradigm in effect at the time, because many things are the weakness of that view and their view seems not yet followed by many other scientists to explain physical or chemical phenomena. Among other failures in explaining the spectra of hydrogen atomic spectra found by Balmer, and in the model the atom itself attaches an "inherent defect."
2) The non-acceptance of the Rutherford concept is also closely related to the paradigm of classical Newtonian mechanics and Maxwell's theory of electromagnetic waves that survived to the end of the nineteenth century.

Therefore it can be said that Rutherford's view as well as other scientists who discovered the phenomenon of electricity, subatomic particles and radioactivity are a set of facts that caused the crisis to the previous paradigm. It says the crisis because the previous paradigm (Dalton atomic theory) is unable to explain these symptoms.

3.4 Bohr Atomic Theory

The application of Planck's quantum theory to solve the problem of atomic structure was first performed by Niels Bohr (1885-1962) in 1913 a scientist from Copenhagen who at that time worked at Rutherford's Laboratory in Manchester. It works on the theory of electron planets that have been rejected by many physicists [6]. The purpose of Bohr's work is to find new information about the position of electrons around the atoms. Niels Bohr begins by studying intensely the atomic spectrum (specifically the spectrum of hydrogen atoms) and applying the Max Planck quantum theory to explain it.

The atomic theory proposed by Niels Bohr (1885-1962) in 1913 is based on the following assumptions: a) The electrons can not move around the nucleus of atoms in any trajectory or orbit, but only in paths that meet certain requirements according to quantum theory. Only the path where the electron has angular momentum which is a multiple of the price h / 2p, so the path is called the quantum path; b) When electrons move in one of their quantum paths, the electrons will not radiate energy. The electrons in this path are in a stationary state and a certain energy level. c) If the electrons move from the energy level E_1 to the energy level E_2 whose energy is less than E_1, then there will be energy radiation with a frequency that can be calculated by quantum theory: E_1 - E_2 = E photon = h. n. If the energy of E_2 is greater than E_1, then the electron will absorb the radiated energy.

By assembling the three postulates with the calculations of classical mechanics, Bohr finally can easily calculate the radius of the path from the first, second and so on and each of the total energy of the orbit by the formula of classical mechanics. Bohr still uses the model of the solar system to formulate the orbital energy. Then by using a similar calculation method, Bohr can interpret the spectrum of hydrogen atoms and from other particles similar to that of a hydrogen atom, which has only one electron, such as Li2 + and Be3 + ions.

Bohr's calculation by combining the quantum theory approach with classical mechanics has revealed the secrets of various spectral sequences to obtain a picture of energy level diagrams.

Based on that, Bohr stated that the electrons move around the atomic nucleus in a circular trajectory. The energy of electrons in atoms is sequenced at some number of energy only so that the energy of the electrons in a path is determined by the quantum number n. This number also determines the radius of the path. The electron path is often expressed as the K-path (n = 1), the L-path (n = 2), the M-path (n = 3) and so on. The electrons can jump from the second to the first path corresponding to their quantum number by assigning a spectrum line [7].

3.5 The Atomic Theory of Wave Mechanics

One objection to Bohr's atomic model is that this model is based on several assumptions that are contrary to the rules prevailing at the time. It is therefore difficult to accept without an explanation of its limitations. According to Bohr's atomic model, electrons are described as moving particles with trajectories that follow simple mechanical rules. In fact, the movement of electrons is much more complicated and can not be described in the form of a circle or ellipse.

In 1924, Louis de Broglie argued, that moving matter has the properties of waves; meaning that the electron has wave properties as well as light.

This opinion is consistent with what Einstein (1909) once put forward when applying the method of statistical fluctuations in the new rules of Planck's black body radiation, which is the dualism of particle waves. This idea, later reinforced by Davisson and Germer (1927), found that a beam of electrons can be shaped through a crystal. This diffraction event can only be explained by wave theory; hence it can be deduced that electrons are waves. The quantum requirement for the electron movement previously described by Bohr as a postulate proved to be true with de Broglie's theory.

Such deterministic ideals are very difficult to accept, especially by Heisenberg, Schrodinger, and Dirac. They in 1925 provided a new frame of mind about the atom based on a new quantum theory known as wave mechanics. The theory of new quantum mechanics as a revolution in physics [6].

The rejection of Bohr's atomic model is based on de Broglie's thought and wave mechanics theory, each of which is stated by a different scientist and worked separately, namely Heisenberg Matrix Mechanics, Schrodinger Wave Mechanics and Quantum Algebra by Dirac [6].

3.6 Latest Atomic Models

Since the 1930s hundreds of other elementary particles have been discovered, apart from the three subatomic particles that are the major components of an atom, namely protons, neutrons, and electrons. Some of the most important elementary particles are grouped into five groups based on their interaction strength, i.e., 1) Hadron groups, i.e., groups of highly interacting particles and taking part in strong nuclear interactions. This powerful force serves as a binder of protons and neutrons in the nucleus. For example proton, neutron, and meson; 2) Lepton group, the group whose interaction style is weak and responsible for the disintegration of some particles and the radioactive disintegration in which electrons emitted from the nucleus, for example; neutrino, electron, muon, and tau. Other elementary particles are known to exist through indirect effects on the properties of other particles, including bosons, taches and resonant.

Furthermore, the advance of knowledge in the field of particle physics produces a theory of quarks. This theory was separately developed by US physicist Murray Gell-Mann of the California Institute of Technology and George Zweig of the European Center for Nuclear Research in Geneva around the 1960s. They claimed hundreds of elementary particles that had been discovered until then, only to be understood by their behavior if they were not considered to be elementary particles. They say that the particles still consist of another basic thing called "Quark."

This quark model states that each barion consists of 3 quarks, while each meson consists of one quark and one antiquark. The three types of quarks are named 'up' (u), 'down' (d) and 'strange' (odd). The charge of this particle is very different from the known particle, i.e., its charge respectively; 2/3, -1/3, and -1/3 of the basic charge unit. To explain how the possibility of elementary particles is arranged is used the properties of the quark. Until now declared the number of quarks found there are 18 kinds.

The presence of quark properties inside a particle is the result of the conclusions of the behavior of the particles that can be observed with the help of the equipment. What is seen in the experiment is a particle rather than a quark itself. So one of the main problems of this quark model is the fact that until now no experimental results have been accepted by scientists as a definite proof of quarks. The idea of quarks starts from a purely theoretical abstraction, which is verified through experimentation. Of course, this is also the same problem with our knowledge of the nucleus, where no one ever sees protons, neutrons, and electrons in experimental equipment [9].

4. Conclusion

Based on the above description of the development of the concept of atoms, it can be concluded that:

a) Before the beginning of the nineteenth century, the concept of atoms was regarded as an abstract view, since the ideas proposed by Greek philosophers were based only on the abstract thought of things they could not see but believed in their existence in the universe. The development became 'normal science' after Dalton conceptualized again based on empirical studies.
b) Accumulation of anomalies that abort the Dalton paradigm includes electrical symptoms and radioactivity.
c) The atomic concept thought revolution occurred at a time when the paradigm shift from the atomic theory of Democritus to Dalton atomic theory, the paradigm of Dalton atomic theory to the Thompson atom model and the shift from the paradigm of the Bohr atom model to the atomic theory of wave mechanics.
d) At the beginning of its development, the atom is discontinuous. This is evidenced by the result of atomic conceptualization by Dalton which shows that the atom is the smallest part of the matter that can not be divided again. But then, in time the Dalton atomic theory was killed after finding anomalies related to electricity and radioactivity. Dalton's paradigm shifts to the paradigm of the Thompson atom model, Rutherford's atomic model, Bohr's atomic model, the atomic theory of wave mechanics up to the latest atomic model that 'as if' matter can be divided continuously in accordance with the

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