A Postage Stamp History of the Atom Part I: The Early Years

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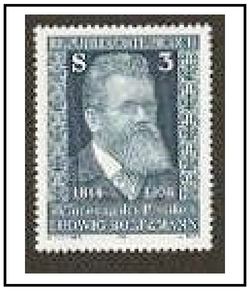
The first recorded discussion of the atom was due to a Greek called Democritus (stamp #1) about the fifth century BC. He is generally given credit along with an individual named Leucippus of coining the word “Ατομοσ” (or in English "Atomos") meaning uncutable. Beyond this, very little was said about atoms or their structure by Democritus.

Stamp 1 Stamp 2

Nearly 2000 years later Isaac Newton (stamp # 2) tried to use the idea of an atom to explain the expansion of gases and his theory of the reflection of light. Newton did little more than this to further our understanding of atoms, but it is the great respect that the scientific community had for Newton that made any idea he endorsed widely accepted. By this time others started to use the concept of atoms to explain phenomena already familiar to us. Ludwig Boltzmann (1844-1906) (stamp #3), an Austrian physicist, used atomistic assumptions to explain his ideas of heat. It may be of interest to the reader that Boltzmann committed suicide in 1906, distraught that most physicists did not agree with his theories. However one of the three famous papers published by Albert Einstein (stamp #4) helped to prove Boltzmann's theories correct. Boltzmann’s statistical mechanical equation $S= k\ln W$ is emblazoned on his tombstone.

Stamp 3



Stamp 4

It was in 1808 that John Dalton (1766-1844) (stamp #5) gave the first real step forward in our understanding of atomic structure. His four part Modern Atomic Theory (published as "A New System of Chemical Philosophy") laid the groundwork for what would become one of the focal points of physics and chemistry research for the next 200 years. The statements of Dalton's theory are:

1. Each element is made up of tiny particles called atoms.
2. The atoms of a given element are identical; the atoms of different elements are different in some fundamental way or ways.
3. Chemical compounds are formed when atoms combine with each other. A given compound always has the same relative numbers and types of atoms.
4. Chemical reactions involve the reorganization of atoms-changes in the way they are bound together. The atoms themselves are not changed in a chemical reaction.

Stamp 6

Stamp 7

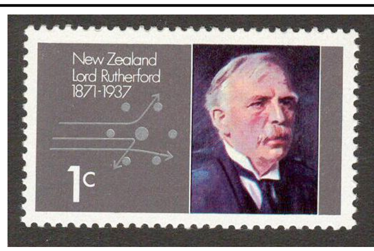
Dalton's ideas have held true until today with only minor modification. His second statement needs to be slightly modified to allow for the inclusion of isotopes but is still very close to the truth. It wasn't until the halcyon days of English physics and with the formation of the Cavendish labs that our understanding of the atom would truly change.

In 1874 Cambridge University established a laboratory for experimental physics in response to the great efforts being put into physics in Europe. The funds to start the project were found while the chancellor of the university was William Cavendish, a relative of scientist Henry Cavendish (1731-1810) who in 1766 discovered the properties of the element hydrogen and determined its specific gravity. This gave the obvious choice for the name The Cavendish Laboratories for Experimental Physics. It was initially hoped that Sir William Thomson (1824-1907) of Scotland, later known as Lord Kelvin, would be the first head of the labs, but he declined the position, several times actually, to stay in Glasgow. Instead another Scot, James Clerk Maxwell (stamp #6), accepted the position. Interestingly enough, Maxwell's abilities and his greatest accomplishments were in theoretical physics and not in experimentation. After Maxwell's death John William Strutt, better known as Lord Rayleigh (1842-1919)(stamp #7) accepted the position and furthered the progression of the labs, even making the bold move at the time of admitting women on the same basis as men. But he did not prove himself as the boldest of experimentalists and lasted only a short period of time as the director. After his retirement the position was passed on to a man of mostly mathematical ability but a genius at leading the labs, Joseph John Thomson (1856-1940)(stamp #8). Thomson, by all accounts, was a well-loved and highly respected individual. Knighted, elected President of the Royal Society, Nobel Laureate, and Master of Trinity College, he was consistently shown to be a first rate scientist.

It was J. J. Thomson who gave us the classic cathode ray experiment that led to the discovery of the electron. In 1897 Thomson published three papers (including one in the prestigious journal Nature) that outlined his revolutionary ideas of the Plum Pudding Model of the atom. Thomson thought the atom was a mostly uniform dense sphere with electrons intermixed like raisins in plum pudding. By measuring the deflection of a stream of cathode rays he was able to calculate the charge-to-mass ratio for the electron. A cathode ray tube is a partially evacuated tube that has a metal plate in each end. When a voltage difference is applied to the metal plates, electricity passes from the negative plate to the positive plate. The stream of electricity is visible to an observer as a bright ray of light. This stream can be deflected by placing a strong magnet next to the tube. The stream is always attracted by a positive pole and repelled by a negative one. By measuring the amount of deflection and the strength of the magnet, Thomson could calculate the charge-to-mass ratio. This was not actually a measurement of the mass for an electron but proof that the particle we now call the electron is a particle and exists. Although Thomson is given credit for the discovery of the electron, it was Benjamin Franklin (stamp #9) who gave us the name many years prior to this when he named a stream of these particles electricity. Thomson's tenure at the helm of the Cavendish brought many of the best minds in physics to work for him, including a young New Zealander named Ernest Rutherford.

Stamp 8

Stamp 9



Stamp 10

Stamp 11

Rutherford (1871-1937) (stamp #10-11) was a student of Thomson's and left the Cavendish after receiving his degree to head a group of physicists at the newly formed labs at McGill University in Canada. It was while he was in Canada that the work for which he received the 1908 Nobel Prize in Chemistry was performed. Many people mistakenly think he received the Nobel in Physics and that it was for the discovery of the nucleus. In reality his Nobel Prize was awarded in Chemistry for his "investigations into the disintegration of the elements, and the chemistry of radioactive substances". Feeling isolated from the other major physicists of the time he moved back to Britain to the University of Manchester and supervised the experiments that led to the discovery of the nucleus. It was the scattering of alpha particles by gold foil that led to our understanding of the center of the atom as a hard dense sphere that contains most of the mass and is able to deflect the fast moving and very light alpha particles at up to a 180-degree angle. Rutherford had originally been researching the angle of deflection for alpha particles passing through thin metal foils. He was trying to gain an accurate measurement for the size of an atom, but a change in the procedure made by a student actually detected the alpha particles that were deflected 180 degrees. One of Rutherford's assistants, Hans Geiger, was looking for a research project for a young student named Ernest Marsden. Rutherford suggested the scattering experiment with the added screen behind the radioactive source. Rutherford had never placed a detecting surface behind the alpha source, only in front of it. The student did test for backwards deflection and noticed 1 out of every 20, 000 particles bounced back. The only plausible explanation for this was that the alpha particles were striking an incredibly dense area in the atom. But the very low number of deflected particles indicated that this area was also very small. This is beautifully illustrated on the stamps depicting Rutherford. The Soviet stamp shows deflecting patterns and the New Zealand stamps shows the particles striking nuclei. Rutherford brought this great discovery back with him to the Cavendish when he took over the leadership upon Thomson’s retirement.

It was an American who gave us the next real advance in the search for our atomic understanding. Robert Andrews Millikan (1868-1953)(stamp #12) at the University of Chicago used his Oil Drop Experiment and Thomson’s data from the original cathode ray experiments to calculate the charge on an electron to an amazingly accurate value even by today’s standards. The experiment that Millikan performed is a beautiful example of tenacity and the scientific method. He started with a large milk can that had two electric plates mounted in it along with an atomizer for spraying a fine mist of water. An eyepiece was placed so that he could observe tiny droplets of water falling between two pre-measured lines in the jug. Millikan reasoned that when a charge is applied to the plates, the rate of descent of a droplet of water could be controlled. The water droplet would contain a large whole number of electrons all charged equally. It would not be possible to exactly match the number of electrons in each droplet of water but since it always had to be a whole number a common factor could be found for each trial. Thus it would be possible to measure the exact charge on one electron. A major problem arose when the heat produced by the plates caused the water droplets to evaporate, a problem easily solved by substituting mineral oil for the water. Millikan collected data for the oil droplets thousands of times. Then by using Thomson's value for the charge-to-mass ratio for electrons Millikan was also able to calculate the mass of the electron. Millikan later left Chicago to be the first president of the newly formed California Institute of Technology.

Stamp 12

Stamp 13

The final step of the process of discovering the simple structure of the atom brought the focus back to England with James Chadwick (1891-1974) (stamp 13) and the discovery of the other nucleon, the neutron. Chadwick had been a student of Rutherford’s at Manchester and served as Rutherford’s assistant in running the Cavendish labs. Mimicking

ThomsonChadwick used radiation, produced from Beryllium being bombarded with high speed alpha particles (which had been discovered by Irene and Frederic Joliot-Curie), this time on paraffin, to produce a stream of particles. In his analysis he found that many of the particles that he was observing had no charge. He reasoned that these particles could be the composite of a proton and an electron, an idea first proposed by Rutherford in 1920. Chadwick published his idea in 1932 and the particle has been called the neutron (for neutral) ever since. Although Chadwick was only trying to find more accurate values for the mass and charge of protons and electrons, he ended up discovering a new particle.

Many other experiments and individuals contributed both directly and indirectly to these landmark experiments. It is often the case that a new laboratory technique or method is necessary to advance our knowledge of a specific subject. The discovery of x-rays (in 1895) by Wilhelm Conrad Roentgen (1845-1923) (stamp #14) helped pave the way for new techniques in this field. The discovery of radioactivity by Henri Becquerel (1852-1908) in 1896(stamp #15) was a surprising but most noteworthy discovery. It was his placing of a photographic plate near a uranium sample that led to this. Both of these discoveries made it possible to work in the small-scale world of atoms and atomic particles. Furthermore the work of the Curies (stamp #16) work leading to the discovery of new elements that were wonderful sources of radioactivity, so vital to the discovery of subatomic particles, was crucial. Henri Becqueral and the Curies shared the 1903 Nobel Prize for their discoveries (stamp #15).

Stamps 14-16

Identification of the stamps.

#	Country	Scott	Topic
1	Greece	717	Democritus
2	West Germany	1771	Isaac Newton
3	Austria	1184	Ludwig Boltzmann
4	United States	1774	Albert Einstein
5	Malagasy	1100	John Dalton
6	Mexico	C332	James Clerk Maxwell
7	Sweden	673	John Strutt "Lord Rayleigh"
8	Sweden	710	J. J. Thomson
9	United States	1073	Benjamin Franklin
10	New Zealand	487	Ernest Rutherford
11	U.S.S.R.	3888	Ernest Rutherford
12	United States	1866	Robert A. Millikan
13	Gabon	805d	James Chadwick
14	Spain	1460	Roentgen
15	Sweden	638	Becquerel and Curies
16	Cuba	B2	Curies

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