The Discovery of Radioactvity and Isotopes

1886 William Crookes, proposes that atomic weights measured by chemists are averages of the weights of different kinds of atoms of the same element.

1895 Wilhelm Konrad Rontgen discovers X-rays in November. When cathode rays hit the glass tube wall, a mysterious radiation is given off which can fog photographic plates and cause various materials to flouresce. This discovery is a bit off the track taken by this chronology, but it alerted scientists to the possibility of other undiscovered forms of radiation.

1896 Antoine-Henri Becquerel discovers rays produced by uranium on March 1, the first observation of natural radioactivity. These rays are initially called Becquerel rays or uranium rays.

1898 Curie (Pierre and Marie) discover that thorium gives off "uranium rays," which Marie renames radioactivity. They also discover the elements polonium in July and radium (which is millions of times more radioactive than uranium) in December. These elements were isolated only after a long series of chemical reactions, yet since these reactions did nothing to help or hinder the radioactivity, it became clear that this must be due to some property of the atoms themselves. Ernest Rutherford shows that X-rays and radioactivity act in essentially the same way.

1899 Rutherford observes that thorium produces a gas, which he calls thorium emanation (we now know it as radon); the same discovery is also made independently by Frederich Dorn with radium. Rutherford discovers that radioactivity from uranium has at least two different forms, which he calls alpha and beta rays. Fritz Geisel, Becquerel, and Marie Curie prove that beta rays consist of high-speed electrons.

1900 Becquerel discovers that part of the radiation produced by uranium (and identified as beta rays by Rutherford) is identical to the electrons identified by cathode ray experiments. He does this by measuring the charge-to-mass ratio of the beta radiation and finds its value very close to that of the electron. It seems clear that beta radiation are electrons, but traveling much faster than cathode rays. Paul Villard is the first to observe a radiation that is more penetrating than X-rays; Rutherford names it gamma rays in 1903.

1901 Rutherford and Frederick Soddy discover that thorium left to itself changes into another form (another element, in fact); however, they do not realize at the time that thorium is changing into an isotope of radium. The thorium was left untouched over Christmas vacation.

1902 Rutherford and Soddy show that thorium emanation is a new element of the noble gas family named radon, discovered just two years earlier.

1903 Rutherford and Soddy publish two classic papers with the same title – "The Cause and Nature of Radioactivity"; they give the atomic disintegration theory of radioactivity, saying that atomic nuclei split to form other elements. This was a strong break with the past, since the unchangeable nature of the elements had become an axiom of chemistry. Through study of the decrease in intensity of radioactivity with time, Rutherford and Soddy develop the concept of half-life. William Ramsay and Soddy discover that helium is formed by the radioactive decay of radium; specificaly, alpha particles are the nuclei of helium atoms, although Ramsay and Soddy do not know this at the time. Rutherford shows that a strong magnetic field can deflect alpha particles, meaning that they are charged. He determines the charge-to-mass ratio as roughly equal to the hydrogen ion in electrolysis. Rutherford and Soddy state that radioactivity is caused by one element changing into another; Rutherford names the third kind of radioactivity, gamma rays.

1906 Rutherford improves previous measurements of the ratio of mass to charge in alpha particles, which leads him to think (correctly) that alpha particles are the nuclei of helium atoms. He does this by finding that the charge-to-mass ratio is actually twice that of a hydrogen ion. This might mean that the charge is the same as hydrogen and therfore the weight is twice that of hydrogen. However, there is no element with a weight of two. Rutherford reasons that the alpha particle could be a helium atom with a weight of 4 and a charge of +2. This would lead to the same charge-to-mass ratio as had been observed.

1907-1908 Rutherford and T.D. Royds collect enough alpha particles to show that they are helium nuclei.

1911 Soddy observes that whenever an atom emits an alpha particle, it changes to an element that is two places down in the list of atomic masses (an important precursor of the concept of atomic number).

1913 Soddy, K. Fajans, and A.S. Russell note that when an atom emits a beta particle, it changes into an atom one place up in a list of atoms by atomic mass. Soddy coins the term isotope on Feb 18 to describe atoms of the same element that have different atomic masses.Theodore William Richards finds that the element lead obtained from different minerals can have different atomic weights. This report supports the isotope theory. Richards wins the Nobel Prize the next year. Thomson uses improved canal ray tubes to observe that neon forms canal rays with two different charge-to-mass ratios. One is 20 times and one is 22 times the value for hydrogen. He concludes that two different isotopes of neon exist. Since both are non-radioactive, the occurrence of isotopes is shown to be independent of radioactivity. This is the first confirmation that isotopes, predicted by Soddy, are possible.

1914 Rutherford and E.N. da Costa Andrade succeed in measuring the wavelength of gamma rays, showing that they are even shorter than X-rays.

1917 Rutherford discovers artifical nuclear reactions. The reaction he discovers is:

$$^{14}_{7}N + ^{4}_{2}He \longrightarrow ^{17}_{8}O + ^{1}_{1}H$$

This also has the effect of demonstrating in a conclusive fashion that the proton (not so named for three more years) is a part of the nucleus.

1918 Francis W. Aston builds the first mass spectrograph, with which he discovers different isotopes of a variety of elements. He continues this work until 1930.

1919 Earnest Rutherford reports on his discovery of two years earlier that alpha particles striking nitrogen can knock out protons, the first form of artificial atomic fission; the experiment also proves that protons are constituents of the nucleus of the atom.

1920 Aston, discovers that all atomic masses, when isotopes are taken into account, are integral multiples of the same number (a number now taken to be one-twelvth the mass of carbon-12)