4.8: Radiation

Just prior to the turn of the twentieth century, additional observations were made which contradicted parts of Dalton's atomic theory. The French physicist Henri Becquerel (1852 to 1928) discovered by accident that compounds of uranium and thorium emitted *rays* which, like rays of sunlight, could darken photographic films. Seen in Figure $4.8.2$ is the photographic Becquerel used, darkened by the *rays* emitted by Uranium. Becquerel's rays differed from light in that they could even pass through the black paper wrappings in which his films were stored.

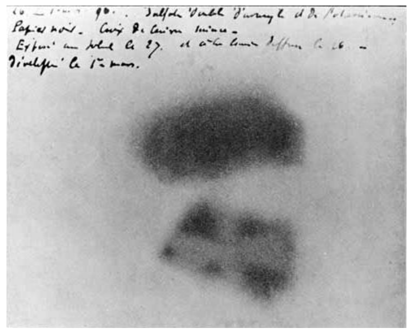

Figure $4.8.1$: Image of Becquerel's photographic plate which has been fogged by exposure to radiation from a uranium salt. The shadow of a metal Maltese Cross placed between the plate and the uranium salt is clearly visible (Public Domain).

Black and white picture of a photographic film with two areas of dark spots. One is rectangular in shape and the other has an imprint of a Maltese Cross.

Detecting Radiation

Although themselves invisible to the human eye, the rays could be detected easily because they produced visible light when they struck phosphors such as impure zinc sulfide. Such luminescence is similar to the glow of a psychedelic poster when invisible ultraviolet (black light) rays strike it. Further experimentation showed that if the rays were allowed to pass between the poles of a magnet, they could be separated into the three groups shown in Figure $4.8.2$.

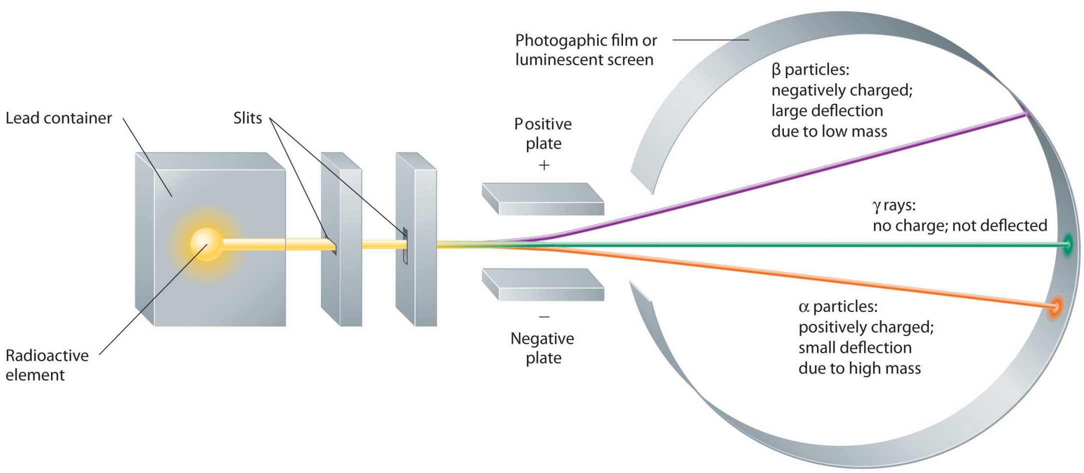

Figure $4.8.2$: Behavior of α particles, β particles, and γ rays upon passing through a magnetic field.

The experimental setup shows a lead container on the left containing a radioactive element inside it. The rays from this element first passes through a horizontal slit and then through a vertical slit. The ray then continues to pass between a positive plate at the top and a negative plate below. The rays are then allowed to hit a photographic film or a luminescent screen. The Beta particles's pathway is curved upwards. Gamma rays are not deflected and continues in a straight path. Alpha particles's pathway is curved downwards but to a less degree than the beta particle.

Properties of α, β and γ Particles

Because little or nothing was known about these rays, they were labeled with the first three letters of the Greek alphabet. Upon passing through the magnetic field, the alpha rays (α rays) were deflected slightly in one direction, beta rays (β rays) were deflected to a much greater extent in the opposite direction, and gamma rays (γ rays) were not deflected at all (Figure $4.8.2$). Deflection by a magnet is a characteristic of electrically charged *particles* (as opposed to rays of light). From the direction and extent of deflection it was concluded that the β particles had a negative charge and were much less massive than the positively charged α particles. The γ rays did not behave as electrically charged particles would, and so the name *rays* was retained for them. Taken together the α particles, β particles, and γ rays were referred to as **radioactivity**, and the compounds which emitted them as **radioactive**.

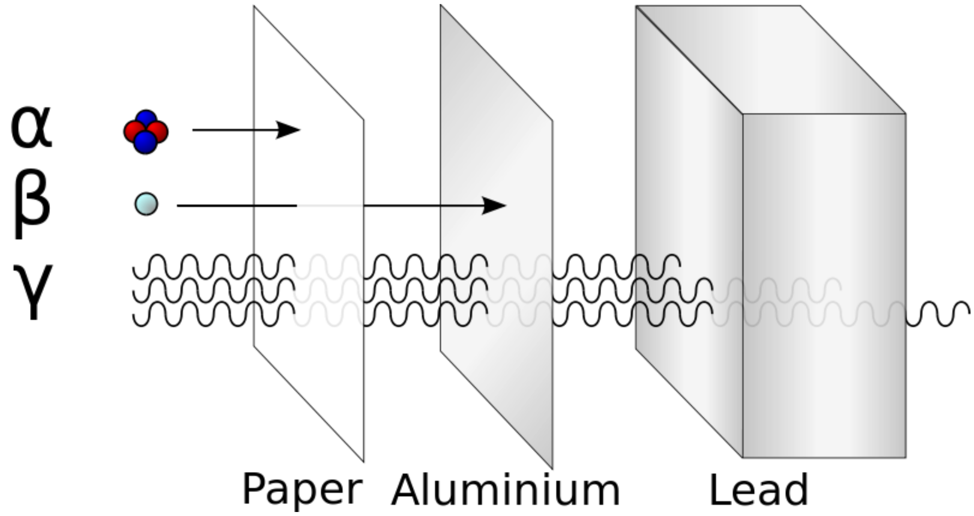

Figure $4.8.3$: This diagram demonstrates the ability to penetrate matter of different kinds of ionizing radiation. Alpha particles are stopped by a sheet of paper whilst beta particles halt to an aluminium plate. Gamma radiation is dampened when it penetrates matter. (CC BY-SA 2.5; Stannered).

Illustration of alpha particle, beta particle and gamma rays aligned on the left, starting at the same position. A piece of paper, aluminum, and lead is spaced apart and placed in that order. The alpha particle has an arrow that stops at the sheet of paper while the beta particles has arrows which pass through paper but stop at aluminum, and gamma rays are represented by multiple waves passing through paper, aluminum, and lead. However the number of rays is reduced as it exits the block of lead.

The three types of particle differ greatly in penetrating power Figure $4.8.3$. While γ particles may penetrate several millimeters of lead, β particles are may penetrate 1 mm of aluminum, but α particles do not penetrate thin paper, or a centimeter or two of air. The high penetrating power of γs does not make them more dangerous, because if they penetrate matter they do not cause changes in it. On the other hand, if an α source is a few inches away, it is not harmful at all; but if an α emitter like radon is inhaled, the α particles are very dangerous. Because they do not penetrate matter, their energy is absorbed in the alveoli of the lung where it causes molecular damage, sometimes leading to lung cancer.

Transmutation

Study of radioactive compounds by the French chemist Marie Curie (1867 to 1934) revealed the presence of several previously undiscovered elements (radium, polonium, actinium, and radon). These elements, and any compounds they formed, were intensely radioactive. When thorium and uranium compounds were purified to remove the newly discovered elements, the level of radioactivity decreased markedly. It increased again over a period of months or years, however. Even if the uranium or thorium compounds were carefully protected from contamination, it was possible to find small quantities of radium, polonium, actinium, or radon in them after such a time. To chemists, who had been trained to accept Dalton's indestructible atoms, these results were intellectually distasteful. The inescapable conclusion was that some of the uranium or thorium atoms were spontaneously changing their structures and becoming atoms of the newly discovered elements. A change in atomic structure which produces a different element is called transmutation.

Transmutation of uranium into the more radioactive elements could explain the increased emission of radiation by a carefully sealed sample of a uranium compound. During these experiments with radioactive compounds it was observed that minerals containing uranium or thorium always contained lead as well.

$$^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + \alpha$$

This lead apparently resulted from further transmutation of the highly radioactive elements radium, polonium, actinium, and radon. The lead found in uranium ores always had a significantly lower atomic weight than lead from most other sources (as low as 206.4 compared with 207.2, the accepted value). Lead associated with thorium always had an unusually high atomic weight. Nevertheless, all three forms of lead had the same chemical properties. Once mixed together, they could not be separated. Such results, as well as the reversed order of elements such as Ar and K in the periodic table, implied that atomic weight is not the fundamental determinant of chemical behavior.