



# Classroom notes for: Radiation and Life

98.101.201

Professor: Thomas M. Regan

Pinanski 207 ext 3283



# Class 5: Radioactivity

1896- Antoine-Henri Becquerel (1852-1908) discovered natural radioactivity.

He posed the question: is it just electrical phenomena such as cathode tubes, or do other objects emit x-rays? This is the first step of the scientific method: **formulate a problem.**

He believed fluorescent materials would, so he tested some, including uranium salt. This represents steps two and three of the scientific method: **generate a hypothesis and test it by experimentation.**

In February 1896 he wrapped photographic film in black paper and put it in sunlight with a crystal of potassium uranyl sulfate-  $K_2UO_2(SO_4)_2$ - upon it. He reasoned that sunlight would make the crystal fluoresce, and any x-rays it produced would penetrate the black paper (as ordinary light would not) and fog the photographic plate. The plate did fog and Becquerel decided that fluorescence did produce x-rays. But then came a series of cloudy days and he could not continue his experiments. He had a fresh plate neatly wrapped in the drawer with a crystal resting upon it, but there was no sunlight to expose it (the crystal) to. Finally, unable to bear doing nothing, he developed the film anyway, just to make sure that nothing happened in the absence of sunlight. To his amazement, the film was strongly fogged. Whatever radiation was passing through the paper did not depend on either sunlight or fluorescence. (*Asimov's Chronology of Science and Discovery*, Asimov, pp. 459-460)



- ◆ As it happens, the radiation was not actually x-rays, but it was radiation nonetheless, and Becquerel's discovery was important.
- ◆ Two points can be made here about science.
  - With Becquerel, you see the role of hard labor. Scientific experimentation is often a laborious process; how many materials did Becquerel use before finally testing the uranium salt? Thomas Edison once said: “Genius is one percent inspiration, ninety-nine percent perspiration.” ([wysiwyg://35/http://www.houseofquotes.com/authors/thomas\\_edison.htm](http://www.houseofquotes.com/authors/thomas_edison.htm))
  - The element of chance also played a part in Becquerel's discovery.
- ◆ Interestingly, Becquerel's discovery had not aroused very much attention. When, just a day or so after his discovery, he informed the Monday meeting of l'Academie des Sciences, his colleagues listened politely, then went on to the next item on the agenda. It was Roentgen's discovery and the possibilities it provided that were the focus of the interest and enthusiasm of researchers. ([wysiwyg://114/http://www.nobel.se/physics/articles/curie](http://www.nobel.se/physics/articles/curie))
- ◆ However, Becquerel did receive a share of the 1903 Nobel Prize in physics for his discovery.



1897- J. J. Thomson (1856-1940) characterized the electron.

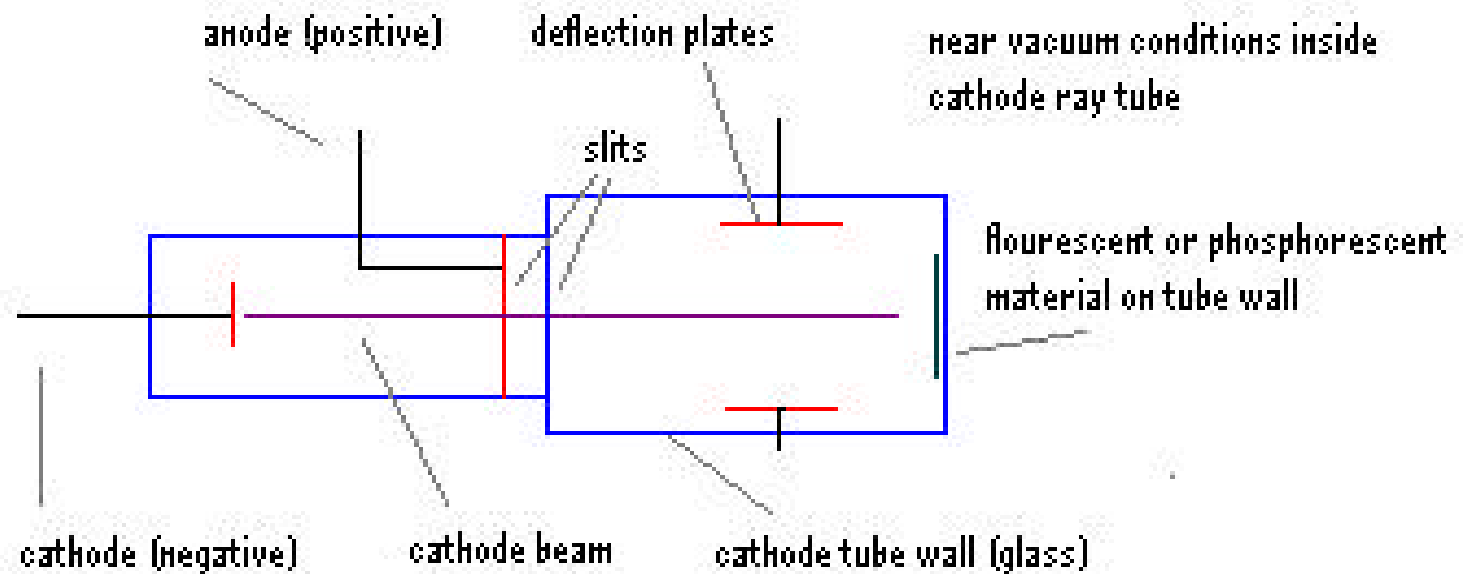
- ◆ It had already been determined by the French physicist Jean-Baptiste Perrin (1870-1942) that the electricity flowing through a cathode tube was composed of tiny particles with a negative charge. (*Asimov's Chronology of Science and Discovery*, Asimov, p. 460)
- ◆ Thomson showed that cathode rays could be deflected not only by a magnet but by an electric field. From the amount of the deflection, Thomson could work out the ratio of the electric charge of the cathode ray particle to its mass. This ratio turned out to be quite high, so that either the charge was high or the mass was low or both. Thomson supposed that the charge would be the unit charge worked out from Faraday's laws of electrolysis. If so, the mass of the cathode ray particle would be only a small fraction of the hydrogen atom's, the smallest atom known. (*Asimov's Chronology of Science and Discovery*, Asimov, p. 465)

# J. J. Thomson with a cathode-ray tube, 1897.

Image from the Cavendish Laboratory, University of Cambridge



# Cathode Ray Tube



Cathode Ray Tube (Rough Schematic)

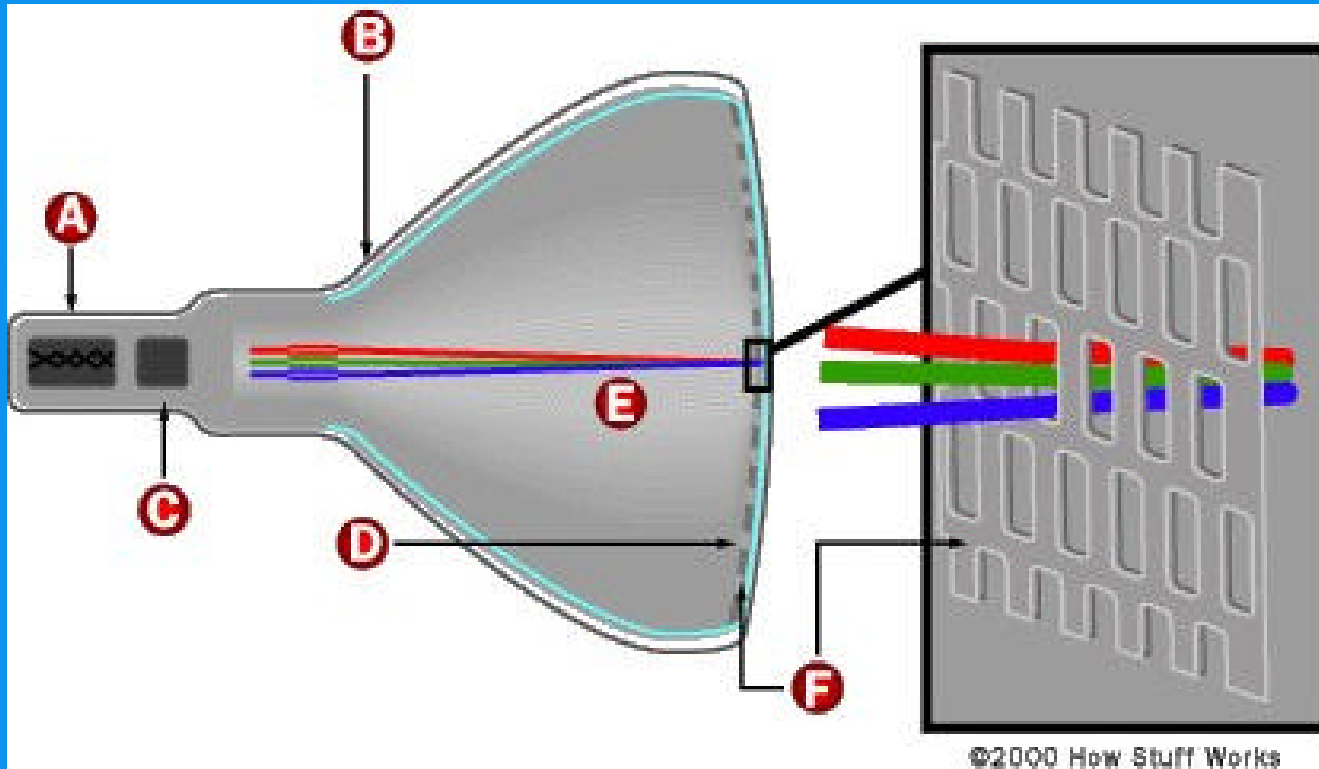


# Cathode Ray Continued

Cathode rays (electrons) are emitted from the cathode, which is at a negative potential relative to the anode (both slits are at a positive potential relative to the anode). An electric field between the cathode and the anode accelerates the electrons, and they pass through the two slits into a field-free region. The electrons then enter the electric field between the capacitor plates (labeled as deflection plates in the schematic). Because of the acceleration produced by this electric field, the velocity of the electrons has a vertical component when they leave the region between the plates. They strike the phosphorescent screen at the far right side of the tube at some deflection  $\Delta y$  from the point at which they strike when there is no field between the plates. The screen glows where the electrons strike it, indicating the location of the beam. (*Physics 3<sup>rd</sup> Ed.*, Tipler, p. 792)



# Color CRT (Computer Monitor)



- |                             |                                 |
|-----------------------------|---------------------------------|
| <b>A</b> Cathode            | <b>D</b> Phosphor-coated screen |
| <b>B</b> Conductive coating | <b>E</b> Electron beams         |
| <b>C</b> Anode              | <b>F</b> Shadow mask            |



# Thomson Cont'd

Thomson called the particle the electron, making use of Stoney's suggested name for the fundamental unit of electric charge, since he suspected that the particle carried that fundamental unit.

*(Asimov's Chronology of Science and Discovery, Asimov, p. 465)*

The electrons were the same no matter what substance emitted them, so all matter must have them. In 1904 *(Asimov's*

*Chronology of Science and Discovery, Asimov, pp. 486-487)*, Thomson proposed a model, in which he envisioned the atom to be a solid mass of positive charge embedded with the negatively charged electrons. This theory is sometimes known as the "plum-pudding" model, since the electrons are distributed throughout the atom like raisins in a plum pudding. *(Modern Physics, p. 150)* The positive charge was proposed to balance the negatively charged electrons, since matter was known to be electrically neutral (no charge).



# 1897 and 1898- Marie Sklodowska Curie (1867-1934) and her husband Pierre (1859-1906).

The Curies made several contributions to the fields of physics and chemistry.





# The Curies and Radioactivity

In 1897, she made use of her husband's discovery of piezoelectricity to measure the intensity of radiation given off by a variety of uranium compounds. She showed that the intensity was always in proportion to the quantity of uranium present. This demonstrated that the radiation did not come from the compound as a whole, but from the uranium atom specifically. It (radiation) was an atomic phenomenon and not a molecular one. (*Asimov's Chronology of Science and Discovery*, Asimov, p. 466) Many believe that from a conceptual point of view, this is her most important contribution to the development of physics.

(wysiwyg://114/<http://www.nobel.se/physics/articles/curie>)

In 1898, she demonstrated that thorium, a heavy metal, also produced radiation, and she coined the term radioactivity for the phenomenon. (*Asimov's Chronology of Science and Discovery*, Asimov, p. 468)



Curie investigated pitchblende (a dark, almost black ore containing about 75 percent  $U_3O_8$ ) for her doctoral thesis. (*Nuclear and Radiochemistry*, Friedlander, p. 2)

- She discovered levels of radiation in the minerals that were much higher than the levels produced by the uranium alone.
- Her hypothesis was that there were heretofore unknown elements that were much more radioactive than uranium.

The Curies extracted trace amounts polonium (July 1898) and radium (December 1898) from massive quantities of ore, confirming her hypothesis.

- From two tons of pitchblende, they had extracted about 100 mg total of radium chloride by 1902. (*Nuclear and Radiochemistry*, Friedlander, p. 2)
- Radium's chemical properties were identified by its spectrum (remember Kirchhoff?). (*Nuclear and Radiochemistry*, Friedlander, p. 2)



This was a tremendous effort carried out under extremely poor conditions. The lab in which the Curies worked was essentially an abandoned shed. The Curies would find the old shed suffocatingly hot and dusty in the summer, and bitterly cold and damp in the winter. Its humidity would pose serious problems for their delicate instruments. And its dust would interfere with their intricate crystallizations. Moreover, the shed lacked exhaust hoods to remove the toxic fumes produced by the numerous chemical separations the couple would undertake. (*Deadly Glow The Radium dial Worker Tragedy*, Mullner, p. 9)

Wilhelm Ostwald, the highly respected German chemist, who was one of the first to realize the importance of the Curies' research, traveled from Berlin to Paris to see how they worked. Neither Pierre nor Marie was at home. He wrote: "At my earnest request, I was shown the laboratory where radium had been discovered shortly before... It was a cross between a stable and a potato shed, and if I had not seen the worktable and items of chemical apparatus, I would have thought that I was been played a practical joke." (this is the wording used on the web page) ([wysiwyg://114/http://www.nobel.se/physics/articles/curie](http://www.nobel.se/physics/articles/curie))





# Polonium and radium properties.

The amount of polonium in their sample decreased by  $\frac{1}{2}$  over regular time intervals.

No chemical or physical treatment could alter the amount of radioactivity produced by a given amount of polonium or radium.

Radioactivity seemed to violate the principle of conservation of energy, because the radiation being emitted seemed to be spontaneously created.

Soon after its discovery, radium was found to have powerful physiological effects. In 1900, a German researcher reported that he developed skin burns a few days after handling tubes of radium. The researcher also indicated that he tested the effects of the new element by purposely exposing his arm to it. Pierre Curie also intentionally exposed himself, causing wounds. (*Deadly Glow The Radium dial Worker Tragedy*, Mullner, pp. 9-10)





In 1903, Marie finally finished her doctoral thesis. (*Deadly Glow The Radium dial Worker Tragedy*, Mullner, p. 11)

In 1903 the Curies shared the Nobel Prize for physics with Becquerel for their work regarding radioactivity. (*Asimov's Chronology of Science and Discovery*, Asimov, p. 468)

Marie Curie was thus the first woman to win the prestigious prize. (*Deadly Glow The Radium dial Worker Tragedy*, Mullner, p. 11)

In 1906, Pierre was killed by a horse-drawn carriage while crossing the street in Paris. (wysiwyg://114/<http://www.nobel.se/physics/articles/curie>)

In 1911, Marie Curie won the Nobel Prize in Chemistry for the discovery of polonium and radium. She is one of only four people to have won two Nobel Prizes, and the only woman to have done so.

*The other multiple prize recipients are as follows.*

*Linus Pauling- he won the Nobel Prize for chemistry in 1954 and the Nobel Peace Prize in 1962 for his work on ending the testing of nuclear weapons.*

*John Bardeen- Physics in 1956 and 1972*

*Frederick Sanger- Chemistry in 1958 and 1980*



# Curie's End

On July 4, 1934, at the age 66, she died from aplastic anemia, her bone marrow destroyed by her many years of exposure to radium. (*Deadly Glow The Radium dial Worker Tragedy*, Mullner, p. 13)

If today at the Bibliotheque Nationale you want to consult the three black notebooks in which their work from December 1897 and the three following years is recorded, you have to sign a certificate that you do so at your own risk. (wysiwyg://114/<http://www.nobel.se/physics/articles/curie>)



1897 and 1898- Ernest (Lord) Rutherford (1871-1937) classified alpha rays and beta rays.

In 1897, Rutherford observed that there were two types of radiation emitted by uranium. One kind was deflected only slightly in a magnetic field (remember Maxwell?) and in a direction that indicated it to be positively charged. The other kind deflected sharply in the opposite direction and was therefore negatively charged. He named the two types after the first two letters of the Greek alphabet. *(Asimov's Chronology of*

*Science and Discovery, Asimov, p. 466)*



In 1898, he performed an experiment to further characterize the two types of radiation.

- He spread a powdered compound containing uranium on the surface of one plate of a parallel-plate capacitor. The space between the plates contained a gas. When he applied a voltage between the plates, current ran between them, even though only gas filled the space. The radiation emitted by the uranium caused the gas to be able to conduct electricity. When Rutherford placed foils of different substances over the uranium, the current dropped, but didn't disappear; again demonstrating the existence of two types of radiation, one that was blocked by the foils (the alpha rays), and one that penetrated them and continued to cause the gas to conduct electricity (the beta rays).

(<http://www.xmission.com/~dparker/nucleus.html>)



Later (1900), Becquerel proposed that the beta rays were actually **beta particles**, and that **beta particles were electrons**. (*Asimov's Chronology of Science and Discovery*, Asimov, p. 474)

Later (1906), Rutherford (and Geiger) concluded that the alpha rays were actually **alpha particles**, and were simply **helium atoms** with a positive charge (positive *ions*); i.e., stripped of their electrons. (*Asimov's Chronology of Science and Discovery*, Asimov, p. 496)

Rutherford fired alpha particles at a double wall of glass with a vacuum between. The alpha particles had energy enough to penetrate the first partition but, in the process of penetration, lost so much energy that they were unable to penetrate the second. They therefore remained in the vacuum between, and after enough had accumulated, Rutherford found that the thin gas that appeared in the vacuum was indeed helium, judging from the spectrum. (*Asimov's Chronology of Science and Discovery*, Asimov, p. 496)





1900- Paul Ulrich Villard (1860-1934), a French physicist, discovered gamma rays.

- ◆ He noticed that in addition to the alpha and beta radiations emitted by uranium, there was also a radiation given off that was totally unaffected by magnets. It was similar to x-rays, but more penetrating; it came to be called gamma rays (after the third letter of the Greek alphabet).

*(Asimov's Chronology of Science and Discovery, Asimov, p. 474)*