

The Atomic Nucleus & Radiation

MODULE 6

Discovery of the Atom

Atoms are the smallest unit of elements; atoms combine to form molecules, the smallest unit of compounds.

The first direct observation of atoms was in Brownian motion.

Analysis of Brownian motion gave accurate sizes for atoms (10^{-10} m on average) and a precise value for Avogadro's number.

Discovery of electron and nuclei

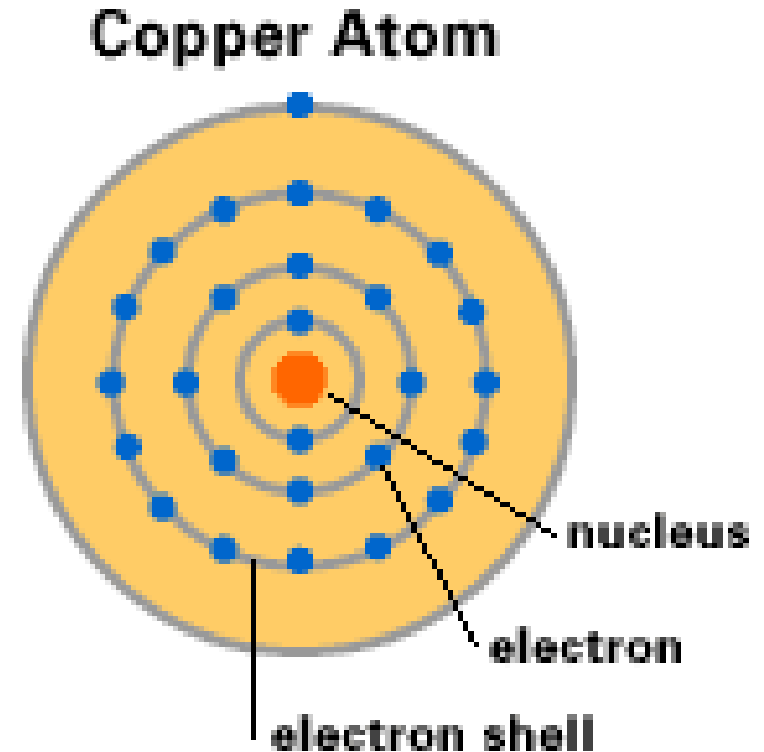
Atoms are composed of negatively charged electrons, first proved to exist in cathode-ray-tube experiments, and a positively charged nucleus.

All electrons are identical and have a charge-to-mass ratio.

The positive charge in the nuclei is carried by particles called protons

- Mass of electron= 9.11×10^{-31} kg.
- Mass of proton= 1.67×10^{-27} kg.

The planetary model of the atom pictures electrons orbiting the nucleus in the same way that planets orbit the sun.



Bohr's Theory

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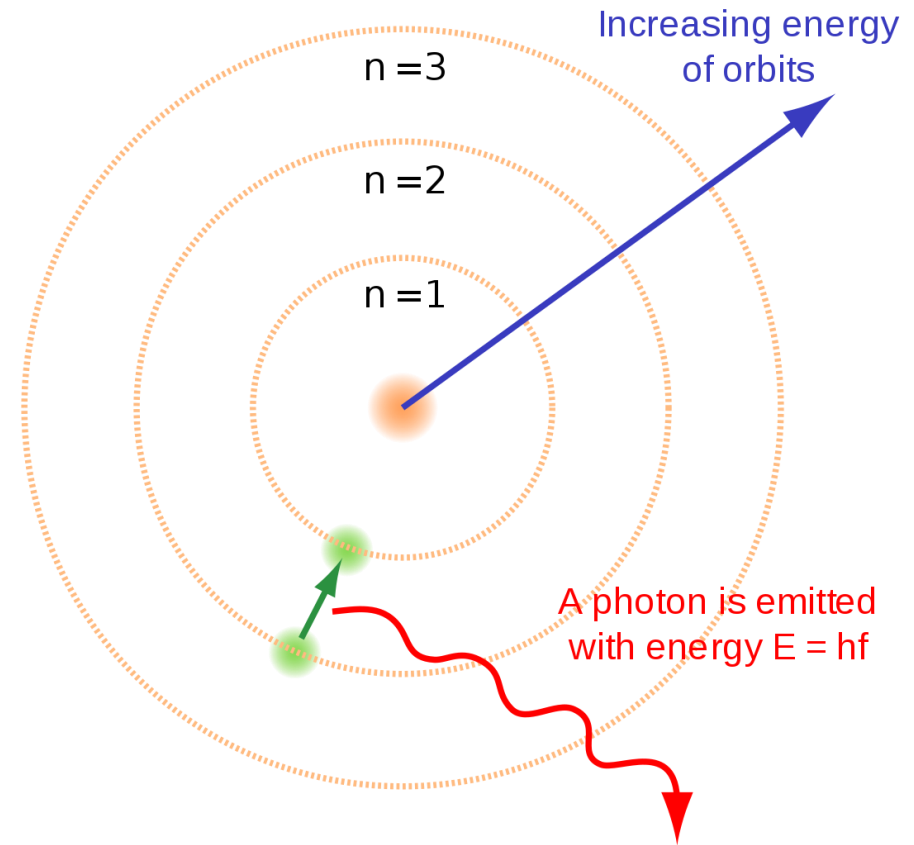
Bohr used the planetary model to develop the first reasonable theory of hydrogen, the simplest atom.

Atomic and molecular spectra are quantized.

Bohr correctly proposed that the energy and radii of the orbits of electrons in atoms are quantized, with energy for transitions between orbits given by $\Delta E = hf = E_i - E_f$

Bohr proposed that the allowed orbits are circular and must have quantized orbital angular momentum.

Furthermore, the energies of hydrogen-like atoms are given by $E_n = -13.6 \text{ eV} / n^2$ ($n=1, 2, 3 \dots$).



Nuclear Radioactivity

Some nuclei are radioactive—they spontaneously decay destroying some part of their mass and emitting energetic rays, a process called nuclear radioactivity.

Nuclear radiation, like x rays, is ionizing radiation, because energy sufficient to ionize matter is emitted in each decay.

- The range (or distance traveled in a material) of ionizing radiation is directly related to the charge of the emitted particle and its energy, with greater-charge and lower-energy particles having the shortest ranges.
- Radiation detectors are based directly or indirectly upon the ionization created by radiation, as are the effects of radiation on living and inert materials.

X-Rays are harmful : Atomic science was initially (early 1900's) seen as exciting and harmless but perceptions later changed.

Medical Imaging and Diagnostics

Radiopharmaceuticals are compounds that are used for medical imaging and therapeutics.

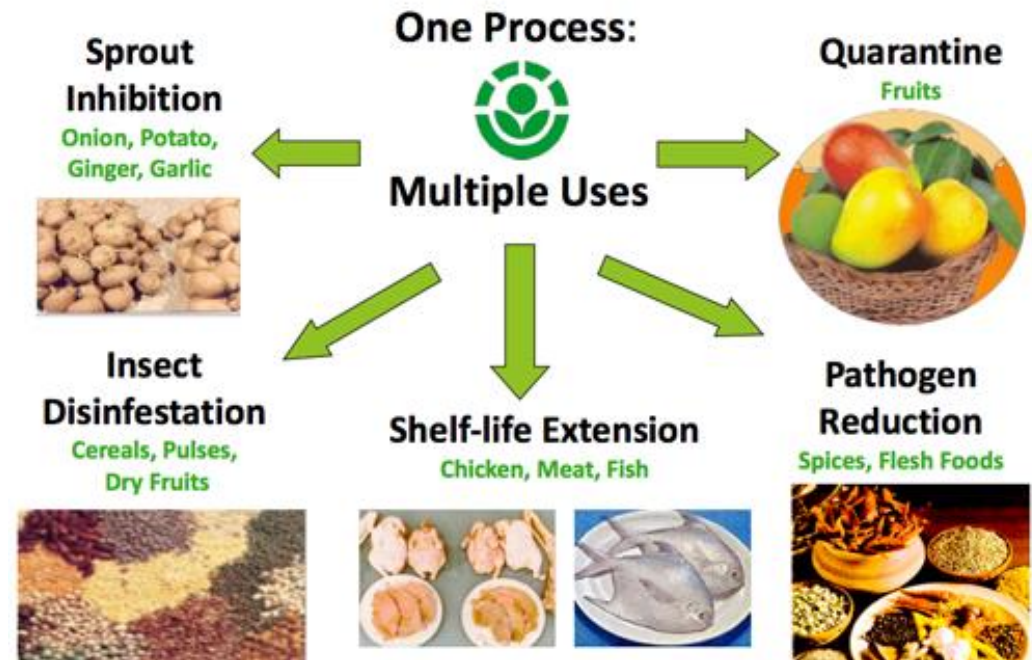
The process of attaching a radioactive substance is called tagging.

Radiogenic isotopes used to image different parts of the body are seen as very useful uses of nuclear radiation in medicine.

Food Irradiation

Food irradiation is the treatment of food with ionizing radiation. It is used to reduce pest infestation and to delay spoilage and prevent illness caused by microorganisms.

Food irradiation is controversial.



Food Irradiation-is it worth it?

Proponents see it as superior to pasteurization, preservatives, and insecticides, supplanting dangerous chemicals with a more effective process.

Opponents see its safety as unproven, perhaps leaving worse toxic residues as well as presenting an environmental hazard at treatment sites.

Radioactive Waste

Half-life: the time in which there is a 50% chance that a nucleus will decay.

- Plutonium-240: 6400 years
 - Over a long enough period of time a waste disposal site will become effectively an easy access mine for weapons grade plutonium
- Plutonium-239: 24000 years

Radioactive waste is often corrosive and there are risks it could contaminate the soil and groundwater near any disposal site.

People have concern about health hazards for high concentrations of a material that remains dangerous for a very long time.

The Limited Test Ban Treaty of 1963 prohibited all test detonations of nuclear weapons above ground, in space, or underwater.

- An effort to stop the effects of nuclear fallout from contaminating the planet's atmosphere

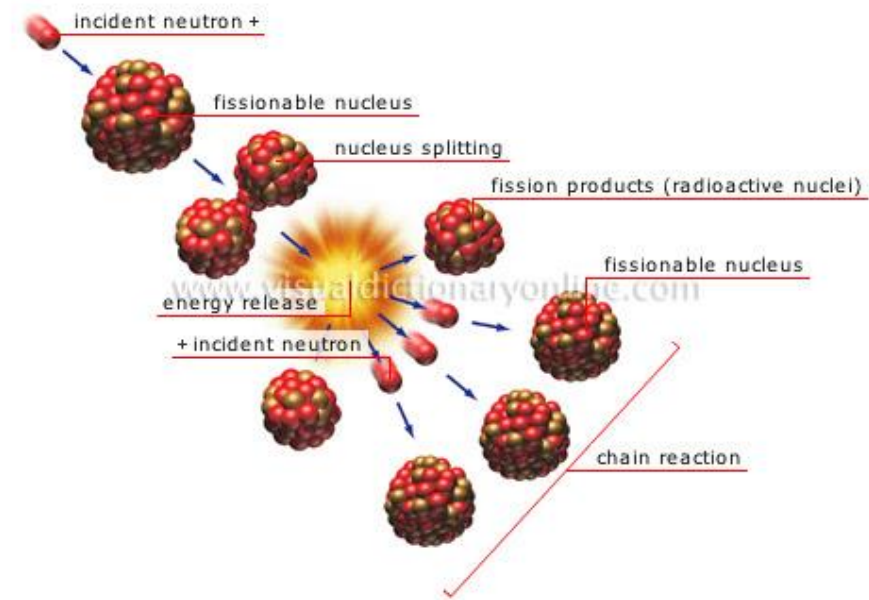
Nuclear Fission

Nuclear fission is a reaction in which a nucleus is split.

- Fission releases energy when heavy nuclei are split into medium-mass nuclei.
- Lots of power can be generated without taking up much space for fuel.
 - Ideal for aircraft carriers or submarines.

Nuclear Power plants: Controlled fission is practical and, at least in the short term, economical.

- Before the 2011 tsunami nuclear power was considered a means to energy independence but afterward is seen as too risky.
- Hydroelectric dams are seen as a viable clean and renewable alternative to the use of nuclear power to generate electricity



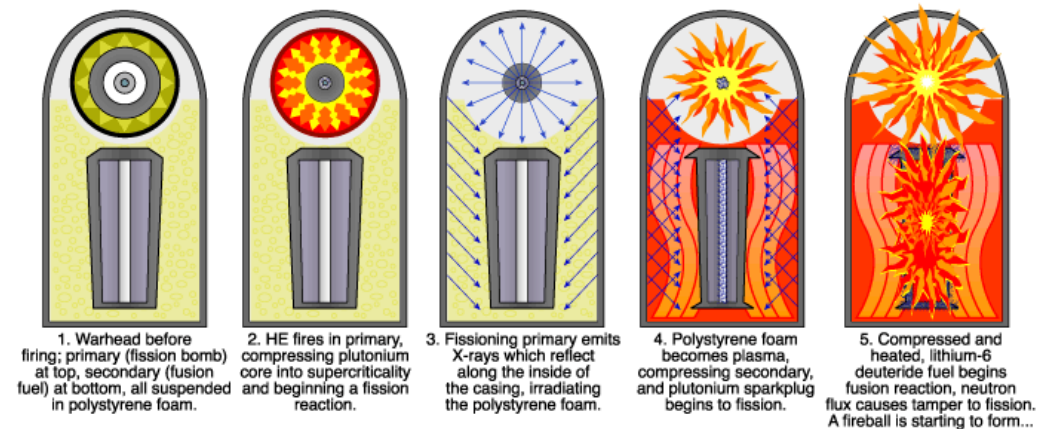
Nuclear Weapons

There are two types of nuclear weapons—fission bombs use fission alone, whereas thermonuclear bombs use fission to ignite fusion.

Both types of weapons produce huge numbers of nuclear reactions in a very short time.

Energy yields are measured in kilotons or megatons of equivalent conventional explosives and range from 0.1 kT to more than 20 MT.

Nuclear bombs are characterized by far more thermal output and nuclear radiation output than conventional explosives.



Nuclear Program Research

Nuclear program research-is it needed despite the high cost

- Much of the cost went into infrastructure to produce nuclear fuel and thus was of ongoing benefit for further nuclear technology development and research.

The top secret Manhattan Project (the program that researched and built the first atomic weapons in the United States) was a crash program aimed at beating the Germans.

- Carried out in remote locations, such as Los Alamos, New Mexico, whenever possible, and eventually came to cost billions of dollars and employ the efforts of more than 100,000 people

Code word

Oppenheimer