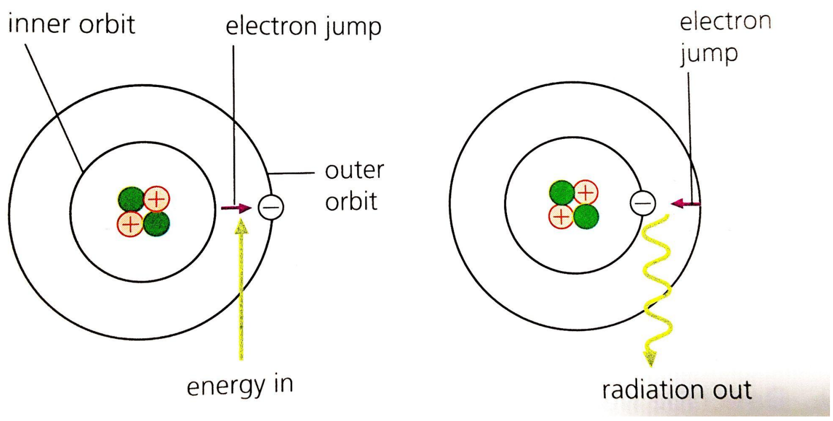
ATOMIC AND NUCLEAR PHYSICS

3.1 Atomic structure

Rutherford- Bohr model of the atom

Niels Bohr, a Danish scientist, created the nuclear model of the atom shortly after Rutherford presented it to explain how atoms emit light. He proposed that electrons circled the nucleus at great speeds, held in specific orbits by the nucleus' electrical attraction to them.
The electrons normally stay in their orbits unless the atom is given energy, for as by being heated.
Electrons have the potential to jump to the outer orbit. After that, the atom is said to be stimulated. Soon after, electrons return to an inner orbit, transferring energy via bursts of electromagnetic radiation (called photons), such as infrared light, ultraviolet light, or X-rays. The wavelength of the radiation released is determined by the electrons' jumping between two orbits. If an atom accumulates enough energy to allow one electron to escape completely, the atom becomes an ion, and the energy required to achieve this is referred to as the atom's ionization energy.



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Schrödinger model of the atom

The Rutherford-Bohr model was superseded by an enigmatic mathematical model created by Erwin Schrödinger, while it is still applicable in certain situations. The best explanation we can provide, devoid of complex mathematics, is that the atom in the Schrödinger model is made up of a nucleus encircled by an ill-defined cloud of electrons. Denser shading corresponds to areas of the atom where electron probability is predicted by mathematics.

Energy levels that are distinct for each element take the role of the concept of electrons traveling in predetermined orbits in this theory. An electromagnetic radiation photon with energy equal to the difference between the two levels is released when an electron "jumps" from one level. Therefore, the arrangement of energy levels determines the frequency (and wavelength) of radiation released by an atom.

The spectrum that is created, say, by a prism, for each atom that emits visible light is a collection of coloured lines specific to each element. Two adjacent yellow-orange lines are produced by sodium vapour in a gas discharge tube, like that of a yellow street light. Energy shifts in numerous distinct atoms produce light from the sun, and the resulting spectrum is continuous and contains every color.

3.2 Radioactivity

It was by accident that French physicist Henri Becquerel discovered radioactivity in 1896. He discovered that radiation from uranium compounds may (i) ionize a gas and (ii) damage a photographic plate, even if it was covered in black paper. Marie Curie discovered the radioactive element radium shortly afterward. We now understand that unstable nuclei, which can form naturally or in reactors, are the source of radiation. Research, industry, and medicine all make extensive use of radioactive materials.

(i) While the atmosphere largely absorbs cosmic rays, some of these high-energy particles from the Sun do make it to the surface of the planet.

(ii)The air contains radon gas.

(iii) Radioactive radon gas, which tends to accumulate in well-insulated rooms or basements with inadequate ventilation, is released by granite rocks, which are used in the construction of many residences, especially in Scotland.

(iv) Our bodies absorb potassium-40 radioactive material that is found in food.

(v) Several medical procedures involve the use of different radioisotopes.

(vi) Nuclear bomb testing releases fallout, which includes strontium isotopes with extended half-lives that are absorbed by bone. This is in addition to the emissions from nuclear power plants.

Radiation from alpha, beta, and gamma

Alpha (α-), beta (B-), and gamma (y-) radiation are the three types of radiation that radioactive substances release. These types of radiation are studied through experiments to examine their penetrating power, ionizing ability, and behavior in magnetic and electric fields. Radiation is released from a nucleus in a direction that is random and spontaneous.

ɑ-particles

Their range in air is limited to a few centimeters because they frequently collide with gas molecules, causing strong ionization in the gas. They are halted by a thick sheet of paper. Strong magnetic fields and electric fields cause them to deflect in a way and to an extent that suggests they are helium atoms stripped of their outermost electrons, or helium ions carrying a doubly positive charge. They are all released from a given material at the same speed, which is around one-twentieth the speed of light.

Smoke detectors employ Amerium (Am-241), a pure a-particle source.

B-particles

Some of these have a range of several meters in the air, and a few millimeters of aluminum stop them. In comparison to ɑ-particles, they have a far lower ionizing power. Magnetic fields more readily deflect them in addition to electric fields. According to measurements, ß-particles are streams of high-energy electrons that can shoot out at speeds up to the speed of light. Strontium (Sr-90) solely releases ß--particles.

y-emissions

These are the most invasive, with only several centimeters of lead standing between them. They are not repelled by magnetic and electric fields, and they ionize a gas even less than -particles. They are electromagnetic radiation that travels at the speed of light and produces diffraction and interference effects. Their wavelengths are similar to extremely brief X-rays; the only way they are different is that they originate in atomic nuclei, whereas X-rays are produced by energy fluctuations in electrons outside of the nucleus.

Aluminum can be used to cover cobalt (Co-60), which emits both y-radiation and B-particles, to produce pure y-radiation.

Radioactive decay

When an unstable nucleus emits an a- or ß-particle, radioactive decay takes place. One cannot predict when or in which way an individual atom will decay since radioactive decay is an unpredictable process. A new element is created when radioactive decay takes place.

If a nucleus is excessively massive or has too many neutrons, it becomes unstable. When a neutron splits into a proton and an electron, there are fewer neutrons, which increases stability in ß-decay. The emission of an a-particle makes heavy nuclei lighter and more stable. The changes that a nucleus experiences during radioactive decay can be represented using decay equations that employ nuclide notation.

Releasing an a- or B-particle from an unstable nucleus is known as radioactive decay. The nucleus transforms into that of another element, which can be unstable in and of itself, during a- or B-decay.
A stable element is created following a sequence of modifications. Whether the substance is pure or chemically mixed with another substance has no bearing on these alterations, which are random and uncontrollable.

Applications of radioactivity

These days, nuclear reactors produce radioisotopes, which are radioactive materials with a variety of applications.

Alarm for smoke

A smoke alarm is made up of two identical ionization chambers, one of which is open to the air and the other closed, as well as a battery, an alert device, and an alarm. Two electrodes with a potential difference across them from the battery are present in each chamber. Each chamber contains a tiny radioactive source (often americium-241) that releases o-particles that ionize the air molecules. As the ions migrate toward the electrodes, electricity flows. Every chamber produces the same tiny current since every chamber has the same circumstances. When ions stick to smoke particles, they become stationary when smoke enters the chamber that is exposed to the air. After the current drops and the alarm is set off by an electrical detection of the difference between the current and the unaltered current in the closed chamber. A lengthy half-life source is preferred to ensure a steady activity; a-particles are chosen because they do not offer a health danger due to their short airborne half-lives.

Sterilization

Medical equipment is sterilized using y-radiation, which destroys microorganisms. Additionally, some foods are irradiated with it to eliminate microorganisms and extend food preservation. Since there is no radioactive substance in the meal, using the radiation is harmless. Because y-radiation has a strong penetrating capability and can penetrate packaging, it is favored to have a long half-life source to sustain continuous activity.

Cancer diagnosis and treatment

To image and diagnose cancer, y-radiation is released by radioactive substances that are selectively absorbed by cancer cells. The selection of y-radiation is based on its strong penetration ability. Short half-life sources are favored for using radioisotopes inside the body to minimize exposure time. High-energy y-radiation beams are directed straight onto a tumor during radiotherapy treatment of cancer to destroy the malignant cells. To minimize harm to the surrounding tissue, the beams are spun around the body. A radioisotope with a long half-life will be employed for external use when a continuous dose is needed.

Tracers

With the use of a GM tube or another detector, the movement of a small quantity of a weak radioisotope introduced into a system can be monitored. The technique is applied in industry to measure fluid flow in pipes, in agriculture to examine how plants absorb fertilizers, and in medicine to identify brain tumours and internal hemorrhages.

It is best to use a tracer whose half-life corresponds with the amount of time required for the experiment; this way, once the source is consumed, its activity will be low and there won't be a continuing radiation risk.

Nuclear radiation risks

Small amounts of radiation exposure are unavoidable, but large doses can be harmful to our health. Nuclear radiation's ionizing impact damages bodily tissues and cells and has the potential to trigger gene mutations. Both cancer and cell death may result from this damage.

A-particle radiation poses little risk unless the source enters the body, but y- and M-radiation can result in radiation burns (skin redness and blisters) and long-term consequences like cancer and cataracts in the eyes. Radiation illness and death are possible outcomes of large exposures.

Safety measures

To lessen radiation exposure that ionizes:

(i) Reducing the amount of time spent exposed to radiation.
(ii) It's best to maintain the greatest possible distance between a source and a human.
(iii) Wearing radiation-absorbing shielding is a good way to safeguard individuals.