CHEMISTRY

Production of Materials Assessment

Definitions

Word	Definition
Isotope	Isotopes are atoms of the same element (same atomic number) that has different forms, differentiated by having different numbers of neutrons, hence different mass numbers, but same number of protons.
Unstable Isotope	An isotope that spontaneously undergo radioactive decay, which is the disintegration of the nucleus that may have been caused by the capture of an electron. One or more different and lighter nuclei will be formed. Alpha and beta particles, and gamma rays are emitted. The rate of decay of radioactive substances is measured in terms of their half-life.
Radioactive Isotope	An atom that has a nucleus with excessive amount of energy to be imparted either to a newly created radiation particle within or to an atomic electron. This atom undergoes spontaneous breakdown in the unstable atomic nucleus and emits gamma rays or subatomic particles, which constitute ionizing radiation to stable its form.
Transuranic Element	Radioactive elements having an atomic number greater than 92 (uranium). All transuranium elements of the actinide series were discovered as synthetic radioactive isotopes, only neptium and plutonium occur in nature. (i.e. artificially manufactured). These elements are radioactive because of their large nuclei are unstable and super heavy elements have very short half-lives.
Radioisotope	A version of a chemical element that has an unstable nucleus and emits radioactive particles which usually result in the formation of another element. It is a radioactive isotope, either naturally or artificially produced.

Recent discoveries of elements

Elements	The history of their discovery
118	Element 118 (ununoctium) was discovered/created in 2002, a transactinide element with symbol Uuo, also known as eka-radon. It has the highest atomic number and atomic mass of all the elements discovered so far. Only tiny quantities have been made (only 3 atoms have been detected) as they are so unstable their existence is fleeting. Element 118 immediately decays into the product of element 116 but this also decays into other elements. It is a member of group 18, the zero-valence elements, having the most common chemical reactions as inert group. 1118 was produced via collisions of californium-249 atoms and calcium-48 ions. 118 has a half-life of 0.89 ms. "In 2011, the IUPAC has evaluated the 2006 results of the Dubna-Livermore collaboration and concluded that they did not meet the criteria for discovery." Hence, the most recent discoveries can only be theoretical as it needs further evidence. (all elements above 112 are still being investigated on)
115	In 2004, element 115 (Ununpentium - Uup) a synthetic superheavy element was made by the reaction 243 95Am + 48 20Ca → 2871115Uup + 410n. Its decay product is element 113. It belongs to group 15 (VA). It was first observed in 2003 and about 50 atoms of Uup have been synthesized. It has a half-life of 200 ms. It was created from bombarding americium-243 with calcium-48 ions. These atoms decayed by emission of alpha-particles to ununtrium in about 100 milliseconds.
93	It was found in 1940 at Berkeley in California; it was named neptunium (Np). 23892U + 10n →23992U + g → 23993 Np + 0-1e
94	Plutonium (Pu) was formed in 1941 by bombarding uranium with hydrogen nuclei using a cyclotron (a type of particle accelerator).
95 (americium) & 96 (curium)	Produced by bombarding plutonium

Production of transuranic elements

	Identify / describe	The process
Transuranic elements	Transuranic elements are artificially manufactured. They are the results of attempting to convert the largest naturally occurring element, uranium (U-235), into heavier elements by neutron bombardment in a nuclear reactor, resulting in nuclear fission. The nucleus split into two.	The isotope is placed in a nuclear reactor; it is bombarded by neutrons (released by the nuclear fission occurring in the reactor). A neutron will eventually strike the nucleus and cause the reaction. E.g. 23892U + 10n → 23992U →(beta decay) 23993Np uranium atom + neutron → neptunium atom
Elements with atomic number above 95	Only small numbers of new atoms can be made in a particle accelerator.	The process of the particle accelerator is when the nuclei of heavy elements are bombarded with the nuclei of other atoms. The atomic nuclei is accelerated up to very high speeds by powerful magnetic fields, and then collided so that 2 nuclei will fuse. E.g. 243 82Pb + 48 20Ca → 254102No lead nucleus + calcium nucleus → nobelium nucleus

Production commercial radioisotopes

	Identify / describe	The process
Commercial radioisotope	Neutron-rich radioisotopes are produced at the nuclear reactor.	Known as bombardment with neutrons. The production of radioactive materials is done by placing the appropriate 'target' atoms inside a nuclear reactor and allowing neutron bombardment to occur. There is a constant "flux" of neutrons, when one collides with the nucleus it may 'stick' and create a new isotope of that element. $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{236}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n$
Bombardment with charged particles	Neutron-deficient radioisotopes are produced in the cyclotron.	Protons are introduced to the nucleus, resulting in a deficiency of neutrons (proton-rich). The cyclotrons use high voltages and electric fields to accelerate hydrogen atoms through a vacuum chamber. When they collide with the target substance they produce radioactivity.

Instruments and processes that can be used to detect radiation

Instrument	How it works
Photographic film	Photographic film can be used to detect radiation. Radioactive emissions can be observed on photographic film, the longer it is exposed and the intensity of the radiation will increase the degree of darkening. For the people who work with radiation they can wear a badge containing photographic film which monitors their level of exposure to radiation.
Geiger-Counter	The ionisation counter: 'Geiger-Counter' or Geiger-Muller Tube is an electronic device which detects radiation because of the ionisation it causes, forming positive ions (cations) and free electrons. Radiation causes electrons to be knocked out of their orbits, so the atom becomes an ion. One alpha particle can ionize thousands of atoms, causing a tube of non-conducting gas (argon) to become momentarily conductive. The gaseous cations and electrons are attracted to electrodes, the electronic circuit detects the change and 'counts' the ionisation events occurring when radiation is present. A small window at one end allows radiation to pass into the tube, causing the argon atoms to ionise. The argon ions and free electrons produced allows a current to flow between the electrodes which causes bursts of current which are converted into audible clicks or digital readouts.
Scintillation Counter	A Scintillation Counter detects radiation by the flash of light which some chemicals (zinc sulfide) emit when struck by ionising radiation. The electrons in these substances are excited by the radiation and emit photons of light when the electrons return to lower energy states. Light sensitive detectors pick up each tiny flash of light and an electronic circuit counts and records the events.

Radioisotopes – in industry and medicine

Name	Use, chemical properties	Benefits, problems
Cobalt-60	Medical supplies such as bandages and dressings need to be totally sterile, which is achieved by irradiating the products with doses of gamma radiation high enough to destroy any bacteria or fungi spores which might be present. Hence the use of Cobolt-60 as it is very penetrating, and very destructive, which can kill the living cells of a tumor or bacteria. Airplane parts need to be welded in aircraft manufacturing. It is essential that the joints are welded are strong and free of defects. To 'see' inside the weld, gamma rays can be used. The energy of gamma rays emitted by Cobolt-60 is ideal for the imaging. They are beamed through the welded joint and an image is captured by a 'gamma-ray camera'. The analysis of these images allows engineers to be sure of the quality of the welding. Cobalt-60 has a half-life of 5.3 years, having a useful like of about 6-10 years before it needs to be replaced, which makes it convenient for industrial and medical uses.	The only way to check the quality of a welded joint, without breaking the joint open to inspect it visually is the use of gamma rays. X-rays can't penetrate the metal well enough, only the penetrating nature of the gamma rays makes it possible. This allows traveling on planes a safer experience. Gamma-rays emitted by Cobold-60 are cheaper, more effective and reliable than alternatives such as heat treatment and chemical antiseptics. The use of gamma ray therapy for certain cancers is sometimes the best option when surgery and chemotherapy are not appropriate. The main problem associated with the use of radioisotopes is the safety of the people who work with the radioactive materials. All radiations are dangerous to living cells, even low level exposure is known to increase the risk of genetic mutations and development of cancer. People who work with radioisotopes should wear 'tell-tale' detectors to warn them of radiation exposure, as sometimes radiation escapes from the packaging.
Technetium-99m (Tc-99m)	It is used in medical applications, such as pinpointing brain tumours. It can turn into a number of oxidation states, enabling the production of a range of biological active chemicals. (chemical properties in → box)	It has a very short half-life of 6 hours, hence it emits low energy gamma radiation that minimises damage to tissues but can still be detected in a person's body by a gamma ray sensitive camera. Technetium is reasonably reactive, so it is quickly eliminated from the body.

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