Isotopes and its uses

Hence Todd made the suggestion, which Soddy adopted, that a suitable name for such an entity would be the Greek term for " at the same place". Soddy's own studies were of radioactive (unstable) atoms. The first observation of different stable isotopes for an element was by J. J. Thomson in 1913. As part of his exploration into the composition of canal rays, Thomson channeled streams of neon ions through a magnetic and an electric field and measured their deflection by placing a photographic plate in their path. Each stream created a glowing patch on the plate at the point it struck.

Thomson observed two separate patches of light on the photographic plate (see image), which suggested two different parabolas of deflection. Thomson eventually concluded that some of the atoms in the neon gas were of higher mass than the rest. F. W. Aston subsequently discovered different stable isotopes for numerous elements using a mass spectrograph. Isotopes are different types of atoms (nuclides) of the same chemical element, each having a different number of neutrons. In a corresponding manner, isotopes differ in mass number (or number of nucleons) but never in atomic number. 1] The number of protons (the atomic number) is the same because that is what characterizes a chemical element. For example, carbon-12, carbon-13 and carbon-14 are three isotopes of the element carbon with mass numbers 12, 13 and 14, respectively. The atomic number of carbon is 6, so the neutron numbers in these isotopes of carbon are therefore 12? 6 = 6, 13? 6 = 7, and 14–6 = 8, respectively. A nuclide is an atomic nucleus with a specified composition of protons and neutrons. The nuclide concept emphasizes nuclear properties over chemical properties, while the isotope concept emphasizes chemical over nuclear.

The neutron number has drastic effects on nuclear properties, but negligible effects on chemical properties. Since isotope is the older term, it is better known, and is still sometimes used in contexts where nuclide might be more appropriate, such as nuclear technology. An isotope and/or nuclide is specified by the name of the particular element (this indicates the atomic number implicitly) followed by a hyphen and the mass number (e. g. helium-3, carbon-12, carbon-13, iodine-131 and uranium-238). When a chemical symbol is used, e. g. " C" for carbon, standard notation is to indicate the number of nucleons with a superscript at the upper left of the chemical symbol and to indicate the atomic number with a subscript at the lower left (e. g. 32He, 42He, 126C, 146C, 23592U, and 23992U). Some isotopes are radioactive and are therefore described as radioisotopes or radionuclides, while others have never been observed to undergo radioactive decay and are described as stable isotopes. For example, 14C is a radioactive form of carbon while 12C and 13C are stable isotopes.

There are about 339 naturally occurring nuclides on Earth[2], of which 288 are primordial nuclides. These include 31 nuclides with very long half lives (over 80 million years) and 257 which are formally considered as " stable"[2]. About 30 of these " stable" isotopes have actually been observed to decay, but with half lives too long to be estimated so far. This leaves 227 nuclides that have not been observed to decay at all. Numbers of isotopes per element Of the 80 elements with a stable isotope, the largest number of stable isotopes observed for any element is ten (for the element tin).

Xenon is the only element that has nine stable isotopes. Cadmium has eight stable isotopes. Five elements have seven stable isotopes, eight have six stable isotopes, ten have five stable isotopes, eight have four stable isotopes, nine have three stable isotopes, 16 have two stable isotopes (counting 180m73Ta as stable), and 26 elements have only a single stable isotope (of these, 19 are so-called mononuclidic elements, having a single primordial stable isotope that dominates and fixes the atomic weight of the natural element to high precision; 3 radioactive mononuclidic elements occur as well). 5] In total, there are 257 nuclides that have not been observed to decay. For the 80 elements that have one or more stable isotopes, the average number of stable isotopes is 257/80 = 3. 2 isotopes per element. Even/odd N| Mass| E| O| All| Stable| 145| 101| 246| Longlived| 20| 6| 26| Primordial| 165| 107| 272| Even and odd nucleons numbers The proton: neutron ratio is not the only factor affecting nuclear stability. Adding neutrons to isotopes can vary their nuclear spins and nuclear shapes, causing differences in neutron capture cross-sections and gamma spectroscopy and nuclear magnetic resonance properties.

Even mass number Beta decay of an even-even nucleus produces an odd-odd nucleus, and vice versa. An even number of protons or of neutrons are more stable (lower binding energy) because of pairing effects, so even-even nuclei are much more stable than odd-odd. One effect is that there are few stable odd-odd nuclei, but another effect is to prevent beta decay of many even-even nuclei into another even-even nucleus of the same mass number but lower energy, because decay proceeding one step at a time would have to pass through an odd-odd nucleus of higher energy.

This makes for a larger number of stable even-even nuclei, up to three for some mass numbers, and up to seven for some atomic (proton) numbers.

Double beta decay directly from even-even to even-even skipping over an odd-odd nuclide is only occasionally possible, and even then with a half-life greater than a billion times the age of the universe. Even-mass-number nuclides have integer spin and are bosons. Even proton-even neutron Even/odd Z, N| p, n| EE| OO| EO| OE| Stable| 140| 5| 53| 48| Longlived| 16| 4| 2| 4| Primordial| 156| 9| 55| 52|

For example, the extreme stability of helium-4 due to a double pairing of 2 protons and 2 neutrons prevents any nuclides containing five or eight nucleons from existing for long enough to serve as platforms for the buildup of heavier elements during fusion formation in stars (see triple alpha process). There are 141 stable even-even isotopes, forming 55% of the 257 stable isotopes. There are also 16 primordial longlived even-even isotopes. As a result, many of the 41 even-numbered elements from 2 to 82 have many primordial isotopes.

Half of these even-numbered elements have six or more stable isotopes. All even-even nuclides have spin 0 in their ground state. Odd proton-odd neutron Only five stable nuclides contain both an odd number of protons and an odd number of neutrons: the first four odd-odd nuclides 21H, 63Li, 105B, and 147N (where changing a proton to a neutron or vice versa would lead to a very lopsided proton-neutron ratio) and 180m73Ta, which has not yet been observed to decay despite experimental attempts[6].

Also, four long-lived radioactive odd-odd nuclides (4019K, 5023V, 13857La, 17671Lu) occur naturally. Of these 9 primordial odd-odd nuclides, only 147N is the most common isotope of a common element, because it is a part of the CNO cycle; 63Li and 105B are minority isotopes of elements that are rare compared to other light elements, while the other six isotopes make up only a tiny percentage of their elements. Few odd-odd nuclides (and none of the primordial ones) have spin 0 in the ground state. Odd mass number

There is only one beta-stable nuclide per odd mass number because there is no difference in binding energy between even-odd and odd-even comparable to that between even-even and odd-odd, and other nuclides of the same mass are free to beta decay towards the lowest-energy one. For mass numbers 5, 147, 151, and 209 and up, the one beta-stable isobar is able to alpha decay, so that there are no stable isotopes with these mass numbers. This gives a total of 101 stable isotopes with odd mass numbers.

Odd-mass-number nuclides have half-integer spin and are fermions. Odd proton-even neutron These form most of the stable isotopes of the odd-numbered elements, but there is only one stable odd-even isotope for each of the 41 odd-numbered elements from 1 to 81, except for technetium (43Tc) and promethium (61Pm) that have no stable isotopes, and chlorine (17Cl), potassium (19K), copper (29Cu), gallium (31Ga), bromine (35Br), silver (47Ag), antimony (51Sb), iridium (Ir), and thallium (81Tl), each of which has two, making a total of 8 stable odd-even isotopes. There are also four primordial long-lived odd-even isotopes, 8737Rb, 11549In, 15163Eu, and 18775Re. Even proton-odd neutron There are 54 stable isotopes that have an even number of protons and an odd number of neutrons. There are also four primordial long lived even-odd isotopes, 11348Cd (beta decay, half-life is 7. 7 ? 1015 years); 14762Sm (1. 06 ? 1011a); and 14962Sm (; 2 ?

1015a); and the fissile 23592U. The only even-odd isotopes that are the most common one for their element are 19578Pt and 94Be.

Beryllium-9 is the only stable beryllium isotope because the expected beryllium-8 has higher energy than two alpha particles and therefore decays to them. Odd neutron number Even/odd N| n| E| O| Stable| 188| 58| Longlived| 20| 6| Primordial| 208| 64| The only odd-neutron-number isotopes that are the most common isotope of their element are 19578Pt, 94Be and 147N. Actinides with odd neutron number are generally fissile, while those with even neutron number are generally not, though they are split when bombarded with fast neutrons.

Atomic mass of isotopes The atomic mass (mr) of an isotope is determined mainly by its mass number (i. e. number of nucleons in its nucleus). Small corrections are due to the binding energy of the nucleus (see mass defect), the slight difference in mass between proton and neutron, and the mass of the electrons associated with the atom, the latter because the electron: nucleon ratio differs among isotopes. The mass number is a dimensionless quantity.

The atomic mass, on the other hand, is measured using the atomic mass unit based on the mass of the carbon atom. It is denoted with symbols " u" (for unit) or " Da" (for Dalton). The atomic masses of naturally occurring isotopes of an element determine the atomic weight of the element. When the element contains N isotopes, the equation below is applied for the atomic weight M: M = m1x1 + m2x2 + ... + mNxN where m1, m2, ... , mN are the atomic masses of each individual isotope, and x1, ... , xN are the relative abundances of these isotopes.