APPENDIX C

NUCLIDES AND ISOTOPES

ACCOMPANYING THE CHART OF THE NUCLIDES
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INTRODUCTION

The earliest discussion of the atomic hypothesis is attributed to the ancient Greek philosophers who speculated about the mysteries of nature. In the fifth century B.C., Democritus believed that elementary substances (earth, water, fire, and air) were formed by minute individual particles called atoms. This vague philosophical speculation was given reality when John Dalton, between 1803 and 1808, showed how to determine the weights of different atoms relative to one another.

In 1816, William Prout believed (based on the few atomic weights known) that all atomic weights were whole numbers and integral multiples of the atomic weight of hydrogen. He thought that all elements might be built up from hydrogen. His concept lost favor when elements such as chlorine were definitely shown to have noninteger atomic weights.

PERIODIC PROPERTIES OF ELEMENTS

In 1869, Dmitri Mendeleev published a short note on the periodic regularity of chemical elements. He arranged the elements in rows according to the magnitude of their atomic weights, beginning with the smallest weight. Elements that appeared in the same vertical column showed a remarkable similarity in their chemical properties. Mendeleev hypothesized that deviations from the expected periodicity were due to chemists' failure to discover some elements in nature. He predicted the properties of gallium, scandium, and germanium, which were subsequently discovered. Pairs of elements (for example, nickel and cobalt) that did not fit the periodic properties of their columns were interchanged so that they would correspond. He argued that the atomic weight measurements for these elements must be in error. It is now known that the atomic number (see page 2), rather than the atomic weight, is the correct basis for the periodicity in the chemical properties of the elements. By coincidence, the list of elements ordered by atomic weight usually agrees with the list ordered by atomic number, except for the few cases observed by Mendeleev.

NEW PHENOMENA

Toward the end of the nineteenth century, the successes in chemistry, together with those of classical mechanics and electromagnetic theory, convinced some individuals that classical physics was a "closed book" and that workers in the field would henceforth merely advance existing knowledge to the next decimal place. This attitude changed in 1895 when Wilhelm Roentgen discovered X-rays and in 1896 when A. Henri Becquerel discovered natural radioactivity. Since such phenomena could not be explained by existing theories of matter, they created great interest.

In 1902, Ernest Rutherford and Frederick Soddy, in their theory of radioactive disintegration, proposed that radioactivity involves changes occurring within the atom. Their view met strong opposition because it was considered contrary to the established view on the permanency of the atom.

EARLY MODELS OF ATOMIC STRUCTURE

Early experiments in the investigation of atomic structure disclosed three different types of radioactivity, called alpha, beta, and gamma radiation. Alpha rays were found to be positively charged helium ions; beta rays were found to be negatively charged electrons; and gamma rays were high-energy electromagnetic waves. In a magnetic field, the alpha rays were deflected in one direction, the beta rays deflected in the opposite direction, and the gamma rays not deflected at all.

The discovery of radioactivity and Sir Joseph Thomson's proof of the independent existence of the electron were the starting points for theories of atomic structure. Thomson proposed one of the first models of the atom. His "plum pudding" model of internal structure depicted the atom as a homogeneous sphere of positive electric fluid (the pudding) in which were imbedded the negatively charged electrons (the plums). In this model the negatively charged electrons, which repel each other and which are attracted to the positive charge, assume certain stable positions inside the atom. If the electron distribution is disturbed by an external force, e.g., the violent collisions between atoms in a hot gas, the electrons vibrate about their equilibrium positions and emit electromagnetic radiation.

The homogeneous-atom concept was proved incorrect when Rutherford performed a series of experiments with a beam of high-speed alpha particles fired at a very thin metal foil. Most of the alpha particles passed straight through the foil or were scattered or deflected only slightly from their original paths. A small percentage of alpha particles were significantly deflected, however, with some alphas reversing their directions.

The Thomson model, in which the positive charge was uniformly distributed throughout the atom, would never permit a sufficiently large concentration of this charge in one region to affect the alpha particles significantly. Rutherford thought that "it (the experimental result) was about as credible as if you had fired a 15-inch shell at a piece of tissue paper and it came back and hit you."

To explain these results, Rutherford postulated that the atom does not consist of a uniform sphere of positive electrification, but that the positive charge is concentrated in a small region called the nucleus, at the center of the atom. In his dynamic planetary model, the nucleus plays the role of the sun and the electrons correspond to individual planets of the solar system revolving about the sun. This model, along with the classical physical laws of electricity and mechanics, provided an adequate explanation of the alpha particle's scattering. Subsequent experiments performed on seven different scattering materials and at different alpha energies verified Rutherford's theory.

Electromagnetic theory demands that an oscillating or revolving electric charge emit electromagnetic waves. Such emission results in the loss of energy by the emitting particle. Applied to Rutherford's electrons, this energy loss would cause a steady contraction of the system since the electrons would spiral into the central nucleus as their rotational energy was dissipated. This process would occur very rapidly and would directly contradict the permanent existence of atoms. Also, if the radiation pattern produced by the atom were related to the energy radiated by its moving electron, this radiant energy would be changing with the radius of curvature of the electron's path. The pattern would consist of a continuous range of wavelengths instead of the well-defined discrete wavelengths that are characteristic of each element.

BOHR ATOM

Since the known stability of atomic systems could not be reconciled with classical principles of mechanics and electrodynamics, Niels Bohr in 1913 reasoned that classical physics laws must be wrong when applied to the motion of the electron in the atom. Max Planck revealed an essential limitation in the theories of classical physics in 1901 when he introduced the concept of discrete amounts of energy (the energy quantum) in his quantum theory of heat radiation. Albert Einstein had applied this concept to light in 1905, when he described the photoelectric effect. The quantum theory states that electromagnetic radiation (of which light is one form) must be emitted or absorbed in integral multiples of these energy quanta. Bohr coupled Rutherford's atom with the quantum theory to produce his quantum theory of atomic structure.

Since a body that spins about its own axis or revolves in an orbit about a central point possesses angular momentum, Bohr assumed that the electron's angular momentum was restricted to certain values (he quantized the angular momentum). Each of the restricted values, which was described by a principal quantum number, n, would specify a particular circular orbit. An atomic system, whose electrons were in given orbits, would not emit electromagnetic radiation even though the particles were accelerating. The whole atom was said to be in a stationary state. Such an assumption is contrary to classical electrodynamics as mentioned earlier. Electromagnetic radiation would be emitted or absorbed only when an electron changed from one allowed orbit to another allowed orbit. The energy difference between the two states would be emitted or absorbed in the form of a single quantum of radiant energy, producing a radiation pattern of a definite frequency ν, related to the energy E by the relation E $h\nu$ already postulated by Planck and Einstein.

QUANTUM NUMBERS

The quantum theory was further refined in 1916 when Arnold Sommerfeld introduced an azimuthal quantum number, l, where l $n - 1$, which permitted discrete elliptical orbits for electrons, in addition to the circular orbits. This change permitted the Bohr model to account for detailed structure in the pattern of radiation emitted by hydrogen and other atoms. To account for the change in the emitted radiation pattern when an atom is exposed to a magnetic field, a magnetic quantum number m (with permitted integral values from $- l$ to l was added. This quantum number designates different projections of the possible circular or elliptical orbits along the magnetic field direction in space. Finally, a spin quantum number for the electron was postulated by Samuel Goudsmit and George Uhlenbeck to account for the close grouping of two or more spectral lines. An electron was considered to have an angular momentum about its own axis; in mechanical terms, this motion can be thought of as spin. In a magnetic field, the spin axis can have two directions relative to the field.

The orbits in which the electrons move can be described by specifying a set of these four quantum numbers. All electrons with principal quantum number n 1 are in the innermost orbit, called the K shell. All electrons with n 2 fall into a second group, called the L shell. The total number of electrons in a shell is limited by the various possible combinations of the other three quantum numbers. When an electron shell is filled, the atom is in a stable configuration (the noble gas configuration) and does not easily undergo chemical reactions. If only one or two electrons are in the last unfilled shell, it is relatively easy for the atom to lose these electrons to another atom whose last unfilled shell has one or two vacancies. The first of these two atoms becomes positively charged (because of the loss of electrons); the second becomes negatively charged (because of the gain of electrons). These atoms can now attract each other and form a compound (ionic bonding).

The periodicity or repetitive structure of the Mendeleev chart is now understood to be due to the number of electrons in the atom. In a neutral atom the number of electrons is balanced by the equal number of protons (hydrogen nuclei with a positive charge and a mass of about 1836 electron masses) in the nucleus of the atom. Note that the atomic number of an element is equal to the number of unit positive charges carried by the nucleus and is not the same as the atomic weight. In 1913,

Henry G. J. Moseley determined the magnitude of the nuclear charge by comparing the characteristic X-ray wavelengths of elements. Identification of the atomic number of an element from its high-frequency spectrum provided a rule for fitting newly discovered elements into vacant places on the Mendeleev chart.

In 1923, Louis DeBroglie postulated that, in analogy with light having both a wave and a particle nature, matter should have a wave as well as a particle nature. The wavelength that he predicted for a particle was inversely proportional to the particles' momentum. Clinton J. Davisson and Lester H. Germer experimented with the scattering of electrons from a crystal. They showed that electrons definitely had wave properties with a wavelength corresponding to the value predicted by DeBroglie.

The mechanical picture offered for the classification of stationary states of atoms by the Bohr theory, and its subsequent modification, was handicapped by its reliance on many ad hoc postulates and by an inability to explain the intensities of radiation patterns emitted by atoms. A new departure was provided in 1926 by Erwin Schrödinger's establishment of wave-mechanics,* in which stationary states are conceived as proper solutions of a fundamental wave equation. In advanced theories, the mechanical models are no longer used.

ISOTOPES

Experimental investigations in nuclear physics began to require specialized instruments. One of the first of these instruments was the mass spectrograph developed by Francis W. Aston to measure the relative mass of the atoms of an element. This device directed positive ions of an ionized (electrically charged) gas at a photographic plate. The ions were deflected by electric and magnetic fields, working at right angles, so that all particles having the same mass were brought to a focus at a fine line. Heavier ions, having more inertia, were deflected less than were the lighter ions.

With the use of the mass spectrograph, it was discovered that some chemical elements have two or more components, each with its own mass. Natural chlorine, whose atomic weight is fractional (about 35.5), produced two lines on the photographic plate corresponding to masses very close to 35 and 37. No particle was found with a fractional mass (within the experimental error). Components of the same chemical element with different mass numbers are called isotopes. Most elements in their natural state consist of two or more isotopes, although 20 elements have only one isotope: for example, aluminum, cobalt, and gold. Modifying Prout's hypothesis, Aston proposed the whole-number rule which states that all atomic masses are close to integers and that fractional atomic weights are due to the presence of two or more isotopes, each of which has an approximately integral value. On the carbon-12 scale now used, where the atomic weight of carbon-12 is exactly 12 units, all other isotopes have atomic weights close to integers.

With the problem of fractional atomic weights solved, physicists at first believed that nuclei consisted of electrons and protons. A nucleus with an atomic number Z and an atomic mass A would consist of A protons, to account for the total mass, and A minus Z electrons to balance the excess positive charge of the protons. This view of the structure of the nucleus was altered in 1932 when James Chadwick discovered the neutron. This particle has no electric charge and has approximately the same mass as the proton.

It is now believed that neutral atoms consist of N neutrons, Z protons, and Z orbital electrons, with $A = N + Z$. Isotopes are nuclides with the same Z but different N. For example, natural hydrogen consists almost entirely of atoms that contain one proton and one electron. However, a small amount (about 0.015 percent) of deuterium (heavy hydrogen) is present in nature; deuterium consists of one proton, one neutron, and one electron. In general, the situation becomes more complex as the heavier elements are encountered. Natural tin, which has atomic number 50, consists of 10 isotopes of masses 112, 114, 115, 116, 117, 118, 119, 120, 122, and 124. These isotopes differ from one another because, although each has 50 protons and 50 electrons, each contains a different number of neutrons (ranging from 62 to 74).

The nucleus is held together by attractive forces between the neutrons and protons. These attractive forces are not completely understood, but it is known that they must be strong enough to overcome the electrostatic repulsion between the protons. Because of this repulsion, however, the ratio of neutrons to protons increases for stable isotopes as the atomic number increases. Among light elements in nature, there is approximately one proton for every neutron. Among heavy stable isotopes, for every two protons there are approximately three neutrons.

As previously mentioned, Aston found that the atomic masses were approximately integers. More accurate measurements indicate that the total mass of a nucleus is always less than the sum of the proton and neutron masses of which the nucleus is composed. In 1905, Einstein had shown that mass, m, was another form of energy, E, expressed by his relationship $E = mc^2$, where c is the velocity of light. The mass deficiency of the nucleus is expressed as the nuclear binding energy. The binding energy represents the amount of energy required to break the nucleus into its constituent nucleons. The ratio of the binding energy to the number of particles in the nucleus varies among the stable elements. It is greater for elements with mass numbers between 30 and 120 than it is for very light or very heavy stable elements.

ARTIFICIAL RADIOACTIVITY

In 1919, Rutherford's discovery of artificial radioactivity achieved the feat vainly sought by the ancient alchemists, that is, changing one element into another. Rutherford bombarded nitrogen gas with a stream of alpha particles. Some of the alpha particles were absorbed by the nitrogen, protons were emitted, and a different element, oxygen, was formed. The physicist uses symbolic language

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* Wave-mechanics is equivalent to the matrix mechanics developed by Werner Heisenberg in 1925.

to represent the transformation as follows:

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H.$$
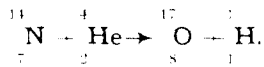
The superscripts denote the total number of nucleons (number of protons plus neutrons), and the subscripts denote the atomic number (number of protons) in each element. Note that the superscripts on one side of the arrow balance those on the other side. The same is true for the subscripts. The balance represents the conservation of the number of protons and neutrons separately.

This initial discovery has been followed by the construction of large machines designed to accelerate charged particles such as protons and alpha particles to higher energies so that they may be used to bombard nuclei. Among these machines are the Van de Graaff generator, the cyclotron, the betatron, the linear accelerator (linac), and others. Beams of high-energy neutrons can also be produced. Since the neutron is electrically neutral, however, there is no electrostatic repulsion between bombarding neutrons and the positively charged target nuclei. Even thermal neutrons could be used for nuclear reaction studies (thermal neutrons have energies that correspond to the most probable energy for a group of neutrons at $68°F$, that is, energies in the neighborhood of 0.025 eV).

NEUTRON FISSION

During the investigation of neutron-produced reactions in various target elements, Enrico Fermi and his associates discovered different beta activities (distinguished by half-life) when uranium was used as a target. They assumed that a transuranium element had been produced (that is, an element whose atomic number was greater than 92). In 1938, Otto Hahn and Fritz Strassman, repeating the experiments, discovered part of the activity to be due to barium (atomic number 56). Lise Meitner and Otto Frisch suggested that the uranium nucleus had split into two roughly equal parts, barium and krypton (the latter, atomic number 36), when the uranium captured the incident neutron. This reaction Frisch termed "fission," after the term used to describe the division of cells in a living organism. Since the mass defect (or binding energy) per particle is greater for the residual nuclei, barium and krypton, than for the uranium, neutron fission is accompanied by a large energy release.

For nuclear reactions other than fission, Fig. 1 illustrates the many combinations of incident (or bombarding) and emitted particles, and how each combination changes the original nucleus. This figure is copied from the lower right corner of the chart. A special type of shorthand is used on this diagram to identify the data represented. An example is (p,n) which denotes a reaction in which the nucleus absorbs a proton and emits a neutron. The symbols used are:

n	neutron	t	triton (hydrogen-3
d	deuteron		nucleus)
p	proton	α	alpha particle
^{3}He	helium-3 nucleus	γ	gamma ray

Using these reactions, nuclear physicists have produced far more artificially radioactive isotopes than the stable or radioactive isotopes that occur

in nature. The term "nuclide" was proposed by Truman P. Kohman for a species of atom characterized by the number of neutrons and protons that the atom contains. The term is used in this booklet in this general sense to encompass both stable and radioactive species. At present, there are 1675 nuclides known, of which 264 are stable forms of the natural elements. In addition, 65 of the unstable nuclides are found in nature, mainly among the heaviest elements. Active nuclear research, which is conducted in many laboratories throughout the world, causes additions and changes in the list of nuclides. Since the last edition of the chart was published (1966), 8 nuclides, which had been misassigned, have been removed, and 180 new nuclides have been added.

CHART OF THE NUCLIDES

(Data revised to December 1968;
occasional data to June 1969)

The general arrangement of the Chart is similar to that suggested by Emilio Segré and followed in previous editions. Because of its size, the Chart is presented in three overlapping sections. The numbers along the left-hand side, marking the horizontal rows, represent the atomic number Z (the number of protons in each nucleus of that row). Each horizontal row represents one element; the filled spaces indicate the known isotopes of that element. The numbers at the bottom of the vertical columns represent the number of neutrons in each nucleus of that column; the number is designated by N.

Heavy lines on the Chart occur for Z or N equal to 2, 8, 20, 28, 50, 82, and 126. These are the so-called "magic numbers", i.e., the numbers of neutrons (protons) present when a neutron (proton) shell is closed. In analogy with the electron shell model of the atom, a nuclear shell model has been developed for the neutrons and protons within a nucleus. Filled shells represent the most stable configurations. Nuclides having either a closed neutron shell, or a closed proton shell, or both, are most stable.

Spaces shaded in gray represent isotopes that occur in nature and that are generally considered stable. A black rectangular area at the top of a

α , 3n	α , 2n ^{3}He , n	α , n	
p , n	p , γ d , n ^{3}He , np	α , np t , n ^{3}He , p	
γ , n n , 2n	Original Nucleus	d , p n , γ t , np	t , p
γ , np	γ , p	n , p	
n , α	n , ^{3}He		
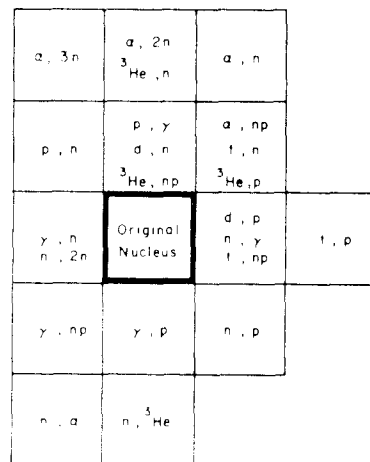
Fig. 1. Changes Produced by Various Nuclear Reactions

white square indicates a radioactive isotope that is found in nature. Examples of such isotopes are (1) an unstable nuclide having a lifetime sufficiently long to have prevented the loss by disintegration of all atoms of that particular nuclide that were available at the time the elements were formed, and (2) a short-lived nuclide that is a disintegration product of such a long-lived nuclide. Occasionally one nuclide has both the gray shading and the black top. This indicates an isotope found in nature, such as rubidium-87, that is radioactive with a very long half-life. Squares with smaller black rectangular areas near the top represent members of one of the naturally radioactive decay chains (see page 8). The old symbolic name is inserted in this smaller black area. White squares represent artificially produced radioactive nuclides.

The heavily bordered space at the left side of each horizontal row gives properties of the element as found in nature, including the chemical atomic weight (on a mass scale where the neutral atom of carbon-12 — 12.00000) and the thermal neutron absorption cross section (see page 6).

Each of the other occupied spaces carries the chemical symbol (a list of these symbols is given on page 7 along with the atomic weights) and the mass number of the nuclide indicated. The mass number, designated by A, is the sum of the number of neutrons and protons in the nucleus. The number of neutrons N is equal to the difference between the mass number and the atomic number, that is, A minus Z.

STABLE NUCLIDES

Classifying the 264 stable nuclides by the even- or oddness of Z and N gives four possible categories. The first category contains an even number of protons and an even number of neutrons (so called even-even nuclei). The other categories are even-odd, odd-even, and odd-odd. Table 1 shows the number of stable nuclides that fall in each category.

Table 1. Distribution of Stable Nuclides

A	Z	N	Number of Stable Nuclides
Even	Even	Even	157
Odd	Even	Odd	53
Odd	Odd	Even	50
Even	Odd	Odd	4
			264

Table 1 shows that for the odd A nuclides there are approximately as many nuclides with an even number of protons (even Z) as with an even number of neutrons (even N). This is evidence that the nuclear force between two nucleons is independent of whether the nucleons are protons or neutrons. Odd-odd stable nuclides are scarce, and they are found only among the lightest nuclides. Their scarcity is due to a "pairing energy" between particles in the same shell. The condition of being in the same shell increases the binding energy of these particles, making them more stable than particles in different shells. An odd-odd nuclide contains at least one unpaired proton and one unpaired neutron which are usually in different shells and hence contribute weakly to the binding. For the lightest nuclei, however, the unpaired neutron and proton are in the same shell.

Diagonals running from upper left to lower right connect nuclides of different elements, which have the same mass numbers. For example, one line could connect calcium-40, which has 20 protons and 20 neutrons, with argon-40, which has 18 protons and 22 neutrons. Nuclides of the same mass number are called isobars; nuclides with the same number of neutrons are called isotones.

DATA DISPLAY

The manner of displaying data is explained in the lower right corner of the chart. For stable nuclides, the first line contains the chemical symbol and mass number; the second line presents the atom percent of the natural element that this isotope represents (known as the absolute isotopic abundance); the third line contains the thermal neutron cross section (see page 6); and the fourth line presents the isotopic mass of the neutral atom (the mass of the nucleus and its surrounding electrons). This mass is given in atomic mass units where carbon-12 is assigned a mass of 12.00000.

For long-lived, naturally occurring radioactive nuclides, the first line contains the chemical symbol and mass number, the second line presents the absolute isotopic abundance, and the third line contains the half-life. The half-life is the period of time in which half of the nuclei initially present in a given sample disintegrate. Additional lines present the decay modes (or types) and energies of decay, and the isotopic mass of the nuclide. Energies are given in millions of electron volts (MeV). When more than one mode of decay occurs, the most prominent mode appears first (above, or to the left of, the other modes). When gamma radiation is emitted in more than one decay mode, or if several gamma rays are emitted in one mode, the gamma rays are separated and presented below (or to the right of) their associated decay mode(s).

For radioactive nuclides that are not of the long-lived, naturally occurring type, the same information is presented except that the isotopic abundance is omitted and the last line of the pertinent square contains the beta-decay energy instead of the isotopic mass. For the heavy elements, where the major mode of decay is alpha-particle emission, the isotopic mass is retained in the last line. In many squares, a small black triangle appears in the lower right corner to indicate that the nuclide has been formed as a product in the thermal-neutron fission of uranium-235.

METASTABLE STATES

Note that certain squares are divided, for example, the square for aluminum-26. Such divisions occur when a nuclide has one or more isomeric states, that is, when a nuclide has the same mass number and atomic number, but possesses different radioactive properties in different long-lived energy states. On the chart, a long-lived state is arbitrarily defined as a state whose half-life is one microsecond (one-millionth of a second) or longer. The lower energy state is generally referred to as the ground state, the higher state as the isomeric state. Frequently, the ground state is a stable nuclide. If one metastable state exists, it is shown on the left. If two exist, the higher energy state is shown on the

left, the lower below it or to the right of it, and the ground state to the right of both.

A mode of decay and the decay energy shown in parentheses indicate that the decay results from a short-lived daughter that accompanies its parent. (In a radioactive decay, the original nuclide is called the parent or precursor; the resultant nuclide is called the daughter.) For example, nitrogen-17, with a half-life of 4.14 seconds, decays by negative beta emission (symbol β^-) into an exceedingly short-lived state of oxygen-17, which in turn emits a neutron. Thus nitrogen-17 emits "delayed neutrons" with a half-life of 4.14 seconds.

Another example is 17-day palladium-103, which decays by K-electron capture mainly to the 57-minute rhodium-103 and, statistically less often, to stable rhodium-103. (K-electron capture occurs when the nucleus captures an electron from the K shell; the symbol is ε.) The 57-minute rhodium emits a gamma ray or an internal-conversion electron that corresponds to an isomeric transition of 0.040 MeV. (An internal-conversion process involves the direct transfer of energy from the nucleus to one of the orbital electrons, and the electron is ejected from the atom; the symbol used is e^-.) On the chart, the delayed gamma ray is assigned to the parent; inclusion of the energy in parentheses indicates that the gamma ray comes from the daughter, but continues to last as long as the disintegrating parent is still present.

A further example is provided by a standard laboratory radionuclide, 30.2-year cesium-137. This long-lived parent decays directly to a short-lived daughter, 2.551-minute barium-137, by negative beta emission. The 6.616-MeV gamma ray which is emitted by the barium is included in parentheses on the cesium square.

THERMAL NEUTRON CROSS SECTIONS

The Greek letter σ with various subscripts is used to identify the thermal neutron cross sections. The neutron cross section measures the probability of interaction of a neutron with matter. The cross section can be most easily visualized as a cross-sectional target area presented to the neutron by the nucleus. The cross section depends upon the type of interaction involved and the energy of the neutron. At thermal energies, a number of reaction types are possible. The thermal neutron absorption cross section (symbol σ_a) is the sum of the cross sections for all reactions except scattering of the neutron. Cross sections are usually measured in units of barns per atom. A barn is the area of a square a millionth of a millionth of a centimeter on each side (10^{-24} square centimeters). The most probable reaction (that is, the reaction with the largest cross section) is generally the neutron capture reaction (symbol σ_γ) in which the absorption of the neutron by the nucleus is accompanied by high-energy gamma-ray emission. Occasionally, a proton or an alpha particle may be emitted, or the nucleus may fission upon neutron absorption (symbols σ_p, σ_α, and σ_f). Examples of these cross sections are found on the squares of beryllium-7, boron-10, and thorium-227, respectively.

A given nuclide might undergo two or more interactions, and its square would then contain two or more of these cross section values. When neutron capture can lead to a metastable state as well as to the ground state, more than one value will appear beside the capture cross section for that nuclide. The cross-section value for metastable state formation is listed on the left and that for direct ground state formation on the right. For two metastable states, the higher of the two states is on the left. For example, indium-113 has an indicated capture cross section σ_c of (2.8 · 5.0 · 3), which means that the cross section for formation of 44-millisecond indium-114 is 2.8 barns, the cross section for the direct formation of 50.0-day indium-114 is 5.0 barns, and the cross section for formation of 71.9-second indium-114 is 3 barns.

The designation mb or μb following the cross-section value indicates that the units of the cross section are millibarns per atom (10^{-27}cm^2/atom) or microbarns per atom (10^{-30}cm^2/atom), respectively. When no mb or μb appears on the chart square, the units of the cross section are barns per atom.

SPINS AND PARITIES

In the upper right corner of the square for the ground state of a nuclide, and in the upper left corner of the isomeric state, are shown the spin and parity of the corresponding energy level. Each neutron and proton has an intrinsic angular momentum of $\frac{1}{2}$ (in units of h/2π, where h is Planck's constant), similar to that of the electron, which combines with their orbital angular momentum to produce a resultant angular momentum called the nuclear spin. Since the orbital angular momentum is always zero or an integral multiple of h/2π, the nuclear spin (in units of h/2π) is always integer or half-odd-integer, depending upon whether the nucleus has an even or an odd number of nucleons. The concept of parity was introduced by the mathematical formalism of quantum theory and has no classical analogue. A system in a given state may have even parity (symbol +) or odd parity (symbol −). For aluminum-27 the spin and parity are shown as 5 +, where the 2 in the denominator of 5/2 has been removed to improve the readability of the chart. The ground states of all even-even nuclides are known to have spin and parity 0 +; so 0 + has been omitted.

The arguments for the assignment of spin and parity to nuclear states can be divided into two classes: strong arguments such as measuring values directly, and weak arguments such as inferring values indirectly. On the chart, the absence of parentheses indicates spins and/or parities based on strong arguments; the presence of parentheses indicates spins and/or parities based on weak arguments. When the spins of both the ground state and an isomeric state are given for a particular nuclide, it is interesting to observe that these spins usually differ by two or more units of h/2π. The large angular momentum (spin) change is required for the gamma-ray transition between the states. Combining this spin change with the small energy differences (a few hundred keV) leads to a relatively long lifetime (metastable state).

RADIOACTIVE DECAY CHAINS

As nuclear processes occur, whether in natural radioactivity or under artificially induced conditions, the nuclides change in accordance with the scheme shown in Fig. 2. To understand the use of this scheme more fully, consider the uranium-238 decay chain (one of three such chains found in nature). On the chart we start with the parent uranium-238 which emits an alpha particle. The daughter nucleus is in the second space diagonally down to the left (see Fig. 2). This square represents the isotope thorium-234. (This nuclide is also identified by the old symbol uranium X_1, which is the historic name given it before it was identified as thorium.)

Thorium-234 in turn emits a negative electron; so the loss of mass is not appreciable. However, there is a loss of one negative charge, which means that the atomic number Z increases by one. In effect, one neutron has changed into a proton. The move one space up and one space to the left (see Fig. 2) leads to protactinium-234 which has isomeric states. Each of these states undergoes negative beta emission; so another move diagonally upward to the left leads to uranium-234.

Uranium-234 emits an alpha particle ending at thorium-230. Another alpha decay yields radium-226. Three further alpha decays result first in radon-222, then in polonium-218, and finally in lead-214. However, this isotope of lead is unstable and emits a negative electron producing bismuth-214. A beta decay to polonium-214 is followed by an alpha decay to lead-210. An alternate route from bismuth-214 to lead-210 is taken in a small fraction of the disintegrations since bismuth-214 can also emit an alpha particle and the resulting thallium-210 beta-decays to lead-210.

In either case, lead-210 beta-decays to bismuth-210. Another beta decay produces polonium-210 which alpha-decays to the stable isotope lead-206. At this point the chain ends. Incidentally, in many of the above steps, gamma rays and conversion electrons are also emitted.
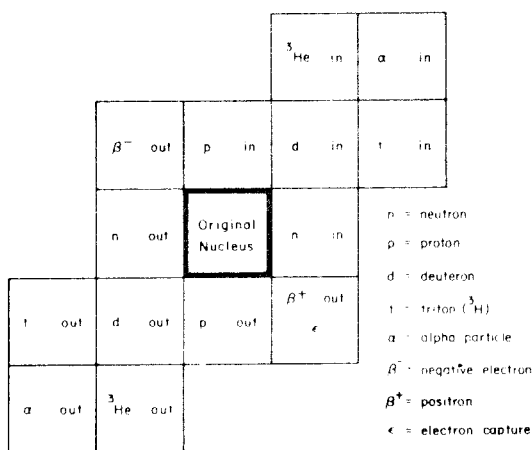
Similarly, the two other natural radioactive sequences may be traced. One is the actinium series which starts with uranium-235 and ends with lead-207. The other is the thorium series, which goes from thorium-232 to lead-208. A fourth, or neptunium, series is also known. However, the half-life of the parent, neptunium-237, is only about two million years. Since the age of the earth is five or ten billion years, most of the neptunium-237 present when the earth was younger has already decayed, and the series is not found in nature.

Since the naturally radioactive decay chains end at stable isotopes of lead, the isotopic composition of lead ore will be variable depending upon its source and its past history. Elements such as lithium and boron also have variable compositions that are affected by reactions that their samples have previously undergone. In a similar manner, scientists examining the isotopic compositions of samples recently brought back from the moon have already obtained an estimate of the age of the samples from the relative amounts of potassium and argon-40 present. A comparison of the isotopic composition of elements on the moon with those on earth might provide scientists with some solutions to the problem of the origin of the universe.

Errata
(Chart of the Nuclides, Tenth Edition)

The absorption cross sections for oxygen and sodium should read as follows:

Oxygen σ_a .27 mb

Sodium σ_a .534

The atomic weight for praseodymium should read 140.908.

ACKNOWLEDGMENTS

Fig. 2. Relative Locations of the Products of Various Nuclear Processes

LIST OF ELEMENTS

ATOMIC NUMBER	SYMBOL	NAME	ATOMIC WEIGHT	ATOMIC NUMBER	SYMBOL	NAME	ATOMIC WEIGHT
0	n	neutron	......	52	Te	tellurium	127.60
1	H	hydrogen	1.00797	53	I	iodine	126.9044
2	He	helium	4.0026	54	Xe	xenon	131.30
3	Li	lithium	6.940	55	Cs	cesium	132.905
4	Be	beryllium	9.0122	56	Ba	barium	137.34
5	B	boron	10.811	57	La	lanthanum	138.91
6	C	carbon	12.01115	58	Ce	cerium	140.12
7	N	nitrogen	14.0067	59	Pr	praseodymium	140.908
8	O	oxygen	15.9994	60	Nd	neodymium	144.24
9	F	fluorine	18.9984	61	Pm	promethium	......
10	Ne	neon	20.179	62	Sm	samarium	150.35
11	Na	sodium	22.9898	63	Eu	europium	151.96
12	Mg	magnesium	24.305	64	Gd	gadolinium	157.25
13	Al	aluminum	26.9815	65	Tb	terbium	158.924
14	Si	silicon	28.086	66	Dy	dysprosium	162.50
15	P	phosphorus	30.9738	67	Ho	holmium	164.930
16	S	sulfur	32.064	68	Er	erbium	167.26
17	Cl	chlorine	35.453	69	Tm	thulium	168.934
18	Ar	argon	39.948	70	Yb	ytterbium	173.04
19	K	potassium	39.102	71	Lu	lutetium	174.97
20	Ca	calcium	40.08	72	Hf	hafnium	178.49
21	Sc	scandium	44.956	73	Ta	tantalum	180.948
22	Ti	titanium	47.90	74	W	tungsten	183.85
23	V	vanadium	50.942	75	Re	rhenium	186.2
24	Cr	chromium	51.996	76	Os	osmium	190.2
25	Mn	manganese	54.9380	77	Ir	iridium	192.2
26	Fe	iron	55.847	78	Pt	platinum	195.09
27	Co	cobalt	58.9332	79	Au	gold	196.967
28	Ni	nickel	58.71	80	Hg	mercury	200.59
29	Cu	copper	63.546	81	Tl	thallium	204.37
30	Zn	zinc	65.37	82	Pb	lead	207.19
31	Ga	gallium	69.72	83	Bi	bismuth	208.980
32	Ge	germanium	72.59	84	Po	polonium	......
33	As	arsenic	74.9216	85	At	astatine	......
34	Se	selenium	78.96	86	Rn	radon	......
35	Br	bromine	79.904	87	Fr	francium	......
36	Kr	krypton	83.80	88	Ra	radium	......
37	Rb	rubidium	85.47	89	Ac	actinium	......
38	Sr	strontium	87.62	90	Th	thorium	232.038
39	Y	yttrium	88.905	91	Pa	protactinium	......
40	Zr	zirconium	91.22	92	U	uranium	238.03
41	Nb	niobium	92.906	93	Np	neptunium	......
42	Mo	molybdenum	95.94	94	Pu	plutonium	......
43	Tc	technetium.	......	95	Am	americium	......
44	Ru	ruthenium	101.07	96	Cm	curium	......
45	Rh	rhodium	102.905	97	Bk	berkelium	......
46	Pd	palladium	106.4	98	Cf	californium	......
47	Ag	silver	107.868	99	Es	einsteinium	......
48	Cd	cadmium	112.40	100	Fm	fermium	......
49	In	indium	114.82	101	Md	mendelevium	......
50	Sn	tin	118.69	102	No	nobelium	......
51	Sb	antimony	121.75	103	Lr	lawrencium	......

Relative Locations of the Products
of Various Nuclear Processes

			He³ in	α in
	β⁻ out	p in	d in	t in
	n out	**Original Nucleus**	n in	
t out	d out	p out	β⁺ out ε	
α out	He³ out			
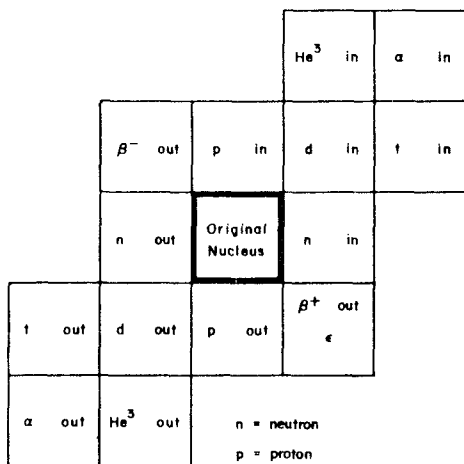
n = neutron
p = proton
d = deuteron
t = triton (H³)
α = alpha particle
β⁻ = negative electron
β⁺ = positron
ε = electron capture

Displacements Caused by Nuclear
Bombardment Reactions

α , 3n	α , 2n / He³ , n	α , n	
p , n	p , γ / d , n / He³ , np	α , np / t , n / He³ , p	
γ , n / n , 2n	**Original Nucleus**	d , p / n , γ / t , np	t , p
γ , np	γ , p	n , p	
n , α	n , He³		
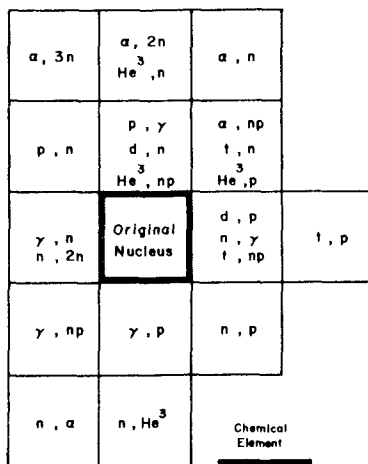
Chemical Element

H
1.00797
σ_a 0.332

— Symbol
— Atomic Weight (Carbon-12 Scale)
— Thermal Neutron Absorption Cross Section in Barns

Stable

Even Z, Even N Nuclides Have Spin and Parity 0+
— Symbol, Mass Number
— Thermal Neutron Activation Cross Section in Barns Leading to (Isomeric + Ground State)
— Fission Product, Slow Neutron Fission of U235

Percent Abundance ——
Mass (Carbon-12 Scale) ——

Artificially Radioactive

Mg 28
21.3h
β⁻.45 (2.85) γ.032,1.35,.40, .95,(1.78) E1.84

Modes of Decay, Radiation and Energy in Mev, ( ) Indicate Radiations from Short-Lived Daughter

— Symbol, Mass Number
— Half-Life
— Disintegration Energy in Mev

Naturally Occurring or Otherwise Available but Radioactive

Symbol, Mass Number ——
Percent Abundance ——
Half-Life ——
Thermal Neutron Capture Cross Section in Barns ——

— Spin and Parity
— Modes of Decay and Energy
— Mass

Member of Naturally Radioactive Decay Chain

Po 218
3.05m
α 6.000,5.179 β⁻0.020
218.0089

Symbol ——

— Symbol, Mass Number
— Half-Life
— Modes of Decay and Energy in Mev in Order of Intensity
— Mass

Two Isomeric States
One Stable

Sn 117
14d	7.61
IT.159 γ.161	

Half-Life ——
Modes of Decay, Radiations and Energies in Mev

— Spin and Parity of Ground State, 1/2 +
— Symbol, Mass Number
— Percent Abundance
— Mass
— Fission Product, Slow Neutron Fission of U235

Radioactive Upper Isomer   Stable Lower Isomer

Two Isomeric States
Both Radioactive

Mo 103
25.3h	66s
β⁻	β⁻
γ.54,1.26 γ.1,1.3,1.46	

— Symbol, Mass Number
— Half Lives, ? Indicates Uncertainty
— Modes of Decay and Energy in Mev in Order of Intensity; ·· Indicates Additional Low Intensity Transitions; — Indicates Several Energies Included

Radioactive Upper Isomer
Radioactive Lower Isomer

SYMBOLS

RADIATIONS AND DECAY

α   alpha particle
β⁻   negative electron
β⁺   positron
γ   gamma ray
n   neutron
p   proton
ε   electron capture
IT   isomeric transition
D   radiation delayed
SF   spontaneous fission
E   disintegration energy
e⁻   conversion electron

TIME

ms   milliseconds $(10^{-3} s)$
μs   microseconds $(10^{-6} s)$
s   seconds
m   minutes
h   hours
d   days
y   years

16

15

| | | | | | | | | **14** | Si 28.086 σ_a .16 | Al 23 |

13

| Al 26.9815 σ_a 234 mb |

12

| Mg 24.305 σ_a 63 mb | | | Mg 21 0.121s β+ (p)3.44,4.03, 4.81,6.45,... E 13 | Mg 22 3.99s β+ γ .074,.58 E 4.8 |

11

| Na 22.9898 σ_a .534mb | | ?Na 19 .03s (p) | Na 20 .40s β+11.3,5.6 γ 1.633 (α)2.15,4.44, 2.49,... E 14.0 | Na 21 3/+ 22.8s β+2.51,... γ .35 E 3.5 |

10

| Ne 20.179 σ_a .04 | Ne 17 105ms β+ (p)4.9,4.0,5.4,... 17.018 | Ne 18 1.5s β+3.42,2.38 γ1.043 E 4.45 | Ne 19 1/+ 17.5s β+2.22 E3.24 | Ne 20 90.51 σ_γ .04 19.99244 |

9

| F 18.9984 σ_a .01 | | F 16 ~10^-19 s p 81 16.0117 | F 17 (5/)+ 66s β+1.74 no γ E2.76 | F 18 1+ 109.8m β+.635, ε E1.65 | F 19 1/+ 100 σ_γ .01 18.99840 |

8

| O 15.9994 σ_a .27 | O 13 8.7ms β+ (p)6.40,6.97 13.0248 | O 14 71.0s β+1.81,4.1 γ2.313 E5.14 | O 15 1/- 122s β+1.74 no γ E2.76 | O 16 99.759 σ_γ .18mb 15.99491 | O 17 5/+ 0.037 σ_a .24 16.99913 | O 18 0.204 σ_γ .21mb 17.99916 |

7

| N 14.0067 σ_a 1.9 | N 12 1+ 11.0ms β+16.4,... γ4.43,... (3α) E17.4 | N 13 1/- 9.99m β+1.19 no γ E2.22 | N 14 1+ 99.63 σ_p 1.82 σ_γ .08 14.003074 | N 15 1/- 0.37 σ_γ .02mb 15.0001 | N 16 2- 7.13s β-4.3,10.4, γ6.130,7.119,... (α)1.7 E10.42 | N 17 4.14s β- γ 87,2.19 (n)1.21,40,1.81 E8.7 |

6

| C 12.01115 σ_a 3.4 mb | C 9 127ms β+ (p)9.3,12.3 9.0311 | C 10 19.4s β+1.87,... γ.72,1.03 E 3.6 | C 11 3/- 20.4m β+ .97 ε no γ E1.98 | C 12 98.89 σ_γ 3.4mb 12.00000 | C 13 1/- 1.11 σ_γ 0.9mb 13.00335 | C 14 5730y β-.156 no γ σ_γ <1μb E.156 | C 15 1/+ 2.3s β-4.5,9.77 γ5299, E9.77 | C 16 0.74s β- (n) E8.0 |

5

| B 10.811 σ_a 760 | B 8 (2+) 774ms β+14,... (2α)3 E18 | B 9 ≥3x10^-19 s p,(2α) | B 10 3+ 19.8 σ_a 3.84x10^3 σ 5 10.012939 | B 11 3/- 80.2 σ_γ 5mb 11.009305 | B 12 1+ 20.4ms β-13.4,9.0 γ4.440,... E13.4 | B 13 3/- 19ms β-13.4,9.7 γ3.68,... E13.4 | B 14 | B 15 |

4

| Be 9.0122 σ_a 9 mb | Be 6 ≥3x10^-21 s p,α,Li 6.0197 | Be 7 (3/-) 53.3d ε γ.4776 σ_a 5.4x10^4 E.862 | Be 8 ~1x10^-16 s 2α .092 8.005308 | Be 9 3/- 100 σ_γ 9mb 9.01219 | Be 10 2.7x10^6 y β-.556 no γ σ_γ<1mb E.555 | Be 11 13.7s β-11.5,9.3,... γ2.12,6.8,4.6,... E11.5 | Be 12 11.4ms β- (n) |

10

3

| Li 6.940 σ_a 71 | Li 5 3/- ~10^-21 s p,α 5.0125 | Li 6 1+ 7.56 σ_a 940 σ_γ.05 6.01512 | Li 7 3/- 92.44 σ_γ.036 7.01600 | Li 8 2+ 850ms β-13 (2α)3 E16.0 | Li 9 (3/-) 0.175s β-10,13.5 (n).7 (2α) E13.6 | Li 11 |

2

| He 4.0026 σ_a 7mb | He 3 1/+ 0.00013 σ_p 5.33x10^3 σ_γ<0.1mb 3.016030 | He 4 ~100 σ_γ 0 4.002603 | He 5 3/- 2x10^-21 s n,α 5.0123 | He 6 802ms β-3.51 no γ E3.5 | He 8 122ms β-10.5,... γ.98 (n) |

8

1

| H 1.00797 σ_a 0.332 | H 1 1/+ 99.985 σ_γ.332 1.007825 | H 2 0.015 σ_γ.52mb 2.014102 | H 3 1/+ 12.33y β-.0186 no γ σ_γ<6μb E.0186 |

6

0

| n 1 1/+ 11.0m β-.782 E.782 1.008665 |

Z ↑

N →

0   1   2   3   4

17

Cl — 35.453, σa 33.3

Cl 32	Cl 33	Cl 34	Cl 35	Cl 36	Cl 37	Cl 38	Cl 39	Cl 40
1+ 2.97ms β+9,4.7,4.7 r2.2,5.0,7.2,4.6 (a)(p) E12.8	3/+ 2.52s β+4.5 r2.93 E5.6	3/+ 0+ 32.2m 1.58s IT.46 β+4.5 β+2.5 r3 r2.13,3.30 1.18,64.4 E54.8	3/+ 75.77 σγ43 σp45,σa0.1mb 34.96885	2+ 3.07x10⁵y β⁻.709,ε,β'.12 no γ σγ~10	3/+ 24.23 σγ(.005+.43) 36.96590	2- 0.8s 37.2m IT.66 β⁻4.91 β⁻1.2,8 11.28 γ1.27,2.16 1.642 E4.92	3/+ 55.5m β⁻1.91,2.18,3.44 γ1.27,25,152 E3.44	(2-) 0.10s 1.42m β⁻3.2,~ 7.5 γ1.46,33, 5.9 E~8

24

S — 32.064, σa .52

S 29	S 30	S 31	S 32	S 33	S 34	S 35	S 36	S 37	S 38
0.19s β+ γ (p)559,386,360 E14	1.3s β+4,2.508 γ.677 E6.1	1/+ 2.64s β+4.4 γ1.27 E5.4	95.0 σa 4mb σγ.53 31.97207	3/+ 0.76 σp 2mb σγ.02 σa.16 32.97146	4.22 σγ.22 33.96786	3/+ 87.2d no γ E167	0.014 σγ.14 35.9671	(7/)- 5.06m β⁻1.64,4.75,1.04 γ3.11,3.71 E4.8	2.87h β⁻1.1,-(4.91,··) γ1.88(2.167, 1.642, ·) E3

22

P — 30.9738, σa .19

P 28	P 29	P 30	P 31	P 32	P 33	P 34
3+ 270ms β+11.5,·· γ1780.4,4.99 2.84-7.50 E14.3	4.23s β+3.95 γ1.28,2.43 E4.9	1+ 2.50m β+3.24 γ2.23 E4.2	1/+ 100 σγ.19 30.97376	1+ 14.31d β⁻1.709 no γ E1.71	(1/)+ 25.2d β⁻.248 no γ E.25	12.4s β⁻5.1,3.2,·· γ2.1,4.0 E.5

Si 25 0.22s β+ (p4.25,1.95,3.47, .82,5.90) E.5

Si 26	Si 27	Si 28	Si 29	Si 30	Si 31	Si 32
2.1s β+3.83 γ.829 E4.81	5/+ 4.20s β+3.8,·· γ2.21 E4.81	92.21 σγ.16 27.97693	1/+ 4.70 σγ.3 28.97650	3.09 σγ.10 29.97376	3/+ 2.62h β⁻1.48,·· γ1.27 σγ~.11 E1.48	~650y β⁻.21(1.71) no γ E.21

18   **20**

Al 24 4+ .129s 2.09s β+·· β+3,1.13, 8.76.8, 9.0 γ3.77,1,·· γ1.37,2.75,(4)~2 E4.4 E14.0

Al 25	Al 26	Al 27	Al 28	Al 29	Al 30
5/+ 7.23s β+3.24 γ1.6,·· E4.26	5+ .64s 7.4x10⁵y β+3.21 IT β+1.16 no γ ε γ1.81,112 E4.00	5/+ 100 σγ234mb 26.98154	2.27m β⁻2.85 γ1.779 E4.63	5/+ 6.52m β⁻2.5,1.4 γ1.28,2.43 E3.7	3.3s iT? β⁻5.05,·· γ2.24,2.24, 3.52, 3.52 E7

Mg 23	Mg 24	Mg 25	Mg 26	Mg 27	Mg 28
3/+ 12s β+3.1 γ.44 E4.06	78.99 σγ.05 23.98504	5/+ 10.00 σγ.2 24.98584	11.01 σγ.03 25.98259	1/+ 9.5m β⁻1.76,1.59 γ.844,1.015,1.75 σγ<.04 E2.61	21.3h β⁻.45,(2.85) γ.032,1.35,.40, .95,1.78 E1.84

Na 22	Na 23	Na 24	Na 25	Na 26	Na 27
3+ 2.602y β+.546, ε γ1.2745 σγ4x10⁻⁴ E2.84	3/+ 100 σγ(.40+.13) 22.98977	(1+) 4+ 199ms 15.00h IT.472 β⁻1.39 γ.275 γ.472 1.37 E5.51	5/+ 59s β⁻3.8,2.8 γ.98, 58, .40 1.61 E3.8	1.04s β⁻6.7 γ1.809 E9	

16

Ne 21	Ne 22	Ne 23	Ne 24
3/+ 0.266 20.99384	9.22 σγ.04 21.99138	(5/)+ 37.6s β⁻4.38,3.95 γ.44,1.64 E4.38	3.38m β⁻1.98,1.10 γ.472,0,.88 E2.5

F 20	F 21	F 22
2+ 11.2s β⁻5.4 γ1.633 E7.03	4.36s β⁻5.4,4.0 γ.35,1.38 E5.7	4.0s β⁻9.1,11.2 γ1.28,2.06 E12.5

14

O 19	O 20	O 21
5/+ 26.8s β⁻3.25,4.6 γ.20,1.36 E4.82	14s β⁻2.7 γ1.06 E3.8	

N 18	N 19
0.63s β⁻9.4 γ1.98,1.65,.82, 2.47 E13.9	

C 17

12

Top chart (Z rows 27–32, N columns 24–34):

| | Ge 72.59 σₐ 2.4 | | | | | | | | Ge 65 | Ge 66 |

32 — Ge 72.59, $\sigma_a\,2.4$

31 — Ga 69.72, $\sigma_a\,3.1$; Ga 63 (33s); Ga 64 (2.6m); Ga 65 (15.2m)

30 — Zn 65.37, $\sigma_a\,1.10$; Zn 60 (2.4m); Zn 61 (87s); Zn 62 (9.15h); Zn 63 (38.6m); Zn 64 (48.89), $\sigma_\gamma\,0.81$, 63.92914

29 — Cu 63.546, $\sigma_a\,3.8$; Cu 58 (3.21s); Cu 59 (81.5s); Cu 60 (23.0m); Cu 61 (3.41h); Cu 62 (9.80m); Cu 63 (69.17), $\sigma_\gamma\,4.7$, 62.92959

28 — Ni 58.71, $\sigma_1\,4.57$; Ni 56 (6.2d); Ni 57 (36.1h); Ni 58 (67.77); Ni 59 (8×10^4y); Ni 60 (26.16); Ni 61 (1.25), $\sigma_\gamma\,14$; Ni 62 (3.66), 61.92834

27 — Co 58.9332, $\sigma_a\,37.4$; Co 54 (14m,0.194s); Co 55 (18h); Co 56 (77.3d); Co 57 (271d); Co 58 (9h, 71.4d); Co 59 (100); Co 60 (10.47m,5.258y); Co 61 (1.65h)

N columns: **24 26 28 30 32 34**

Bottom chart (Z rows 17–27, N columns 14–26):

27 — Co 58.9332, $\sigma_a\,37.4$

26 — Fe 55.847, $\sigma_a\,2.55$; Fe 52 (8.5h)

25 — Mn 54.9380, $\sigma_a\,13.3$; Mn 50 (2m, 0.288s); Mn 51 (45.9m)

24 — Cr 51.996, $\sigma_a\,3.1$; Cr 46 (1.1s); Cr 48 (24h); Cr 49 (41.9m); Cr 50 (4.345), $\sigma_\gamma\,16$, 49.94605

23 — V 50.942, $\sigma_a\,5.03$; V 46 (1.0ms, 0.426s); V 47 (31.2m); V 48 (16.13d); V 49 (331d)

22 — Ti 47.90, $\sigma_a\,6.1$; Ti 41 (89ms); Ti 43 (49s); Ti 44 (47y); Ti 45 (3.078h); Ti 46 (7.93), $\sigma_\gamma\,0.6$, 45.95263; Ti 47 (7.28), $\sigma_\gamma\,1.7$, 46.95177; Ti 48 (73.94), $\sigma_\gamma\,7.9$, 47.94795

21 — Sc 44.956, $\sigma_a\,25$; Sc 40 (0.18s); Sc 41 (0.60s); Sc 42 (61s, 0.68s); Sc 43 (3.92h); Sc 44 (58.6h, 3.92h); Sc 45 (100), $\sigma_\gamma\,(12+13)$, 44.95592; Sc 46 (18.7s, 83.82d), $\sigma_\gamma\,7.7$; Sc 47 (3.347d)

20 — Ca 40.08, $\sigma_a\,0.43$; Ca 37 (173ms); Ca 38 (0.7s); Ca 39 (0.88s); Ca 40 (96.97), $\sigma_\gamma\,0.40$, 39.96259; Ca 41 (8×10^4y); Ca 42 (0.64), $\sigma_\gamma\,0.7$, 41.95863; Ca 43 (0.145), $\sigma_\gamma\,6$, 42.95878; Ca 44 (2.06), $\sigma_\gamma\,1.2$, 43.95549; Ca 45 (162.7d); Ca 46 (0.0033), $\sigma_\gamma\,0.7$, 45.9537

19 — K 39.102, $\sigma_a\,2.1$; K 36 (0.27s); K 37 (1.2s); K 38 (7.68m); K 39 (93.08), $\sigma_\gamma\,2.1$, 38.96371; K 40 (0.0118, 1.28×10^9y), $\sigma_\gamma\,4.4$, $\sigma_a\,39$; K 41 (6.91), $\sigma_\gamma\,1.5$, 40.96183; K 42 (12.42h); K 43 (22h); K 44 (22m); K 45 (.7m)

18 — Ar 39.948, $\sigma_a\,0.64$; Ar 33 (176ms); Ar 34 (0.9s); Ar 35 (1.82s); Ar 36 (0.337), $\sigma_a\,5.5$mb, 35.96754; Ar 37 (34.1d); Ar 38 (0.063), $\sigma_\gamma\,8$, 37.96273; Ar 39 (269y); Ar 40 (99.60), $\sigma_\gamma\,0.2$, 39.96238; Ar 41 (1.83h); Ar 42 (33y); Ar 43 (5.4m)

17 — Cl 35.453, $\sigma_a\,33.3$; Cl 32 (297ms); Cl 33 (2.52s); Cl 34 (32.2m, 1.58s); Cl 35 (75.77), $\sigma_\gamma\,43$, 34.96885; Cl 36 (24.23), $\sigma_\gamma\,(0.005+44)$, 36.96590; Cl 37 (24.23), 36.96590; Cl 38 (37.2m); Cl 39 (55.5m); Cl 40 (1.4m)

N columns: **14 16 18 20 22 24 26**

Chart of the Nuclides (upper section)

Ge 67	Ge 68	Ge 69	Ge 70	Ge 71	Ge 72	Ge 73	Ge 74	Ge 75	Ge 76	Ge 77	Ge 78	Ge 79
19.0m	287d	51μs | 39.2h	20.5	200ms | 11d	27.4	40μs | 7.8	36.5	49s | 82.8m	7.8	55s | 11.30h	1.45h	<1m
β⁺1.31,2.3,..,ε		γ085 | ε,β⁺(2)		IT.023 | ε		IT0.135		IT | β⁻120.92,		β⁻2.7,	β⁻70	β⁻
γ17,34⁻34	γ(1.077⁻)	63, γ1.07,574,872,	σγ(3+30)	γ.175 | no γ	σγ1.1	53s σγ16	σγ(15+31)	139 γ265,066,	σγ(10+05)	3.12, γ264,211,	γ278, 294	
		235⁻204				IT0.533		618		IT.159 42⁻2.79		
E4.4	E.95	E2.227	69.92425	E.235	71.92208	72.92346	73.92118	E1.20	73.92141	E2.95	E.98	

Ga 66	Ga 67	Ga 68	Ga 69	Ga 70	Ga 71	Ga 72	Ga 73	Ga 74	Ga 75	Ga 76	Ga 77	Ga 78
9.5h	78.2h	68.2m	60.16	21.1m	39.84	37ms | 14.1h	4.8h	7.9m	1.9m	32s	17s	~4s
β⁺4.153,..ε	ε	β⁺1.89,..		β⁻1.66		IT.100 | ε,β⁻	β⁻1.9,	β⁻2.6,4.3	β⁻3.3	β⁻~6	β⁻70	
γ1039,2,752,	γ093,185,3, | x1.077.1,578	γ1.077,1	σγ1.9	γ1.040,.173	σγ(.2+4.8)	γ.834,2,20,630,	γ296,325,742,	γ.596,2,45,38⁻	γ58, 56	γ56,112,		
β34 4.806	.093 888	2.34				290⁻3.34	(.0533,.0135)	36				
E5.175	E1.000	E2.920	68.92557	E.166,E⁺654	70.9247	E400	E1.55	E3.5	E3.3			

46

Zn 65	Zn 66	Zn 67	Zn 68	Zn 69	Zn 70	Zn 71	Zn 72
243.7d	27.81	9.3μs | 4.11	18.57	13.7h | 58m	0.62	3.97h | 2.4m	46.5h
ε,β⁺.325				IT.439 | β⁻.93		β⁻1.45,β⁻2.61,	β⁻30,..
γ1.115,	σγ1	γ.0933 | σγ6.7	σγ(0075+0.80)	no γ	σγ(8.2mb+86mb)	.388, 2.1,..	γ.145,191,016⁻
						988,.610,γ.512,	.112, (100)
						12⁻148,	e⁻
E1.349	65.92605	66.92714	67.92486	E.93	69.92534	E2.35 E2.61	E1.46

44

Cu 64	Cu 65	Cu 66	Cu 67	Cu 68	Cu 69
12.75h	30.83	5.10m	61.6h	31s	3.0m
ε β⁻,148		β⁻2.63,159,..	β⁻.40,.48,.58	β⁻3.50,2.26,..	β⁻2.66,..
β⁻.573,γ1.34,..	σγ1.9	γ1.039,834	γ.185,.090,.093,92,	γ.108,.81,.188,	γ1.007, .898,
β⁺.654		σγ160	.124,..	.124,..	.17⁻2.03
E.5733+1.677	64.92779	E2.63	E.58	E4.6	E2.66

Ni 63	Ni 64	Ni 65	Ni 66	Ni 67
92y	1.16	2.55h	54.6h	50s
β⁻.0659		β⁻2.14,.6.1.0	β⁻.20	β⁻.4.1,2,3.2
no γ	σγ1.7	γ1.481,1.115, .366,	no γ	γ.90, .90,1.26
		σγ20		
E.0659	63.92796	E.2.14	E.20	E.4.1

42

Co 62	Co 63	Co 64
1.6m | 13.9m	52s	28s | ~28s
β⁻ β⁻88	β⁻3.6,	β⁻~3.5
γ γ88	γ.088.2	γ.095
γ1.747,		
E.m.2.13,		
E5.32	E3.6	

36   **38**   **40**

Chart of the Nuclides (lower section)

Co 54	Co 55	Co 56	Co 57	Co 58	Co 59	Co 60	Co 61	Co 62	Co 63	Co 64
1.4m | 0.194s	18h	77.3d	271d	9.1h | 71.4d	100	10.47m | 5.258y	1.65h	1.6m | 13.9m	52s	28s | <28s
β⁺4.55,β⁺7.5	β⁺1.5,1.04,.ε	ε,β⁺1.46,..		IT.025,ε β⁺.48,		IT 0.586 | β⁻.318,	β⁻1.22	β⁻ | β⁻2.88,	β⁻3.6	β⁻~3.5
γ.41,	γ.93,1.408,.477,5	γ.847,1.238,.732,	γ.122,.014,.136,	γ.811,.863,1.67,4,	σγ(19+18)	γ1.333,	γ.070	γ .88,	γ.088.2	γ.095
x.04,	.09ε⁻3.17	⁻1.55		1.0μs γ⁻γ10⁻1.4		γ1.333,1.173,		γ117,147,		
				11.0.56.12.490				174,2.03,..		
E8.252	E3.46	E4.57	E.857	E2.30	58.9331	σγ.58 E2.819	E1.29	E5.32	E3.6	

Fe 53	Fe 54	Fe 55	Fe 56	Fe 57	Fe 58	Fe 59	Fe 60	Fe 61
2.53m | 8.53m	5.82	2.7y	91.66	2.19	0.33	45d	~10⁵y	6.06m
γ.702, β⁺2.8,		ε				β⁻.46,1.273,1.57,3	β⁻.135,.37,..	β⁻2.6,2.5,2.8,
IT0.11, | 2.4,.6,	σγ2.3	no γ	σγ2.6	σγ2.5	σγ1.2	γ1.099,1.292,192,	γ.0586,0,.0272	γ.120,.102, .30,
1.329, | γ.38,						γ.1.191,	(1.332,1.173,..	12⁻2.7
2.340	E.398	E.232	55.93494	56.93540	57.9333	E1.573	E.19	E3.8

Mn 52	Mn 53	Mn 54	Mn 55	Mn 56	Mn 57	Mn 58
21.4m | 5.6.2d	2 x 10⁶y	313d	100	2.582h	1.7m	1.1m
β⁺2.65,ε β⁺.575,ε	ε	ε		β⁻2.85,1.04,.75,	β⁻2.6,5.1	β⁻
γ1.58,γ.434,.7	no γ	γ.8348	σγ13.3	γ.846,1.811,2.113,..	γ.122,.014,.136,	γ.36⁻2.8
γ.44 γ.936,744	γ⁻.8 x 10⁻²	σγ<10			.12⁻.71	
E4.7	E.598	E1.379	54.93805	E3.702	E.7	

Cr 51	Cr 52	Cr 53	Cr 54	Cr 55	Cr 56
27.8d	83.79	9.50	2.365	3.53m	5.9m
ε				β⁻2.8	β⁻1.5
γ.320,	σγ0.8	σγ18	σγ0.38	γ1.52,2.24	γ.083,1.026
E.753	51.94051	52.94065	53.93888	E2.59	E1.6

V 50	V 51	V 52	V 53	V 54
0.24	99.76	3.75m	2.0m	55s
~4 x 10¹⁵y		β⁻2.5,	β⁻2.5	β⁻3.3
ε,β⁻1.56, E1.038	σγ4.9	γ1.434,..	γ1.00	γ.835,.99,2.21
γ.78 E⁺2.218				
σγ60				
49.94716	50.94396	E3.97	E3.4	E3.4

Ti 49	Ti 50	Ti 51	Ti 52
5.51	5.34	5.76m	1.7m | 49m
		β⁻2.14,1.5	β⁻1.8 β⁻
σγ1.9	σγ<0.2	γ.320,.93,.61	γ.125,γ(1.43)
			.017,
48.94787	49.94479	E2.46	E1.97

Sc 48	Sc 49	Sc 50	Sc 51
1.82d	57.5m	0.4s | 1.73m	12s
β⁻.65,.48	β⁻2.0,..	IT.258 | β⁻3.6	β⁻~5,..
γ1.31,.983,1.037,	γ1.78	γ1.2,1.56,	γ1.44,2.16
.175⁻1.212		.52	
E3.98	E2.008	E6.8	E6.52

Ca 47	Ca 48	Ca 49	Ca 50
4.53d	0.18	8.70m	11s
β⁻.68,1.98,..	σγ1.1	β⁻2.1,..	β⁻
γ1.297, .489		γ3.08,4.07,..	γ.072,(.26)
.808			
E1.98	47.9525	E5.26	E5.4

K 46	K 47
115s	17.5s
β⁻6.3,..	β⁻4.1,~6,
γ1.35,3.70,..	γ2.0,2.6
E7.72	E6.65

28   **30**   **32**   **34**   **36**   **38**   **40**

Top section

Column heads (neutron number): 34, 36, 38, 40, 42, 44, 46

Z	Element						
40	Zr 91.22 σ_a.182	Zr 81 ~10m	Zr 82 ~10m	Zr 83 ~7m	Zr 84 16m	Zr 85 15m 1.4h	Zr 86 16.5h $\epsilon(\beta^+1.2,)$ γ.24,.03.6/11.08, .16.1
39	Y 88.905 σ_a1.28			Y 82 12m β^+	Y 83 7.5m	Y 84 41m β^+2.5,3.5, γ.80,.98,1.04	Y 85 (9/+) 2.7h 5.0h β^+5, β^+2.2, ϵ 2.1, γ.50, ϵ γ.23-2.6
38	Sr 87.62 σ_a1.4		Sr 80 1.7h γ.58	Sr 81 29m β^+	Sr 82 25d ϵ(β+3.15) γ.76	Sr 83 32.4h ε,β+1.27.8 γ.76,.382(.042)	Sr 84 0.56 σ_γ(.58+.31) 83.91343
37	Rb 85.47 σ_a0.4	Rb 77	Rb 78 6m ϵ .465,1.64	Rb 79 23m β^+ γ.688-.83	Rb 80 34s β^+4.1 γ.6	Rb 81 3/- 32m 4.7h β+3.4, IT.085 γ.190,.44	Rb 82 1+ 64h 1.25m ε,β+ β+3.15 γ.77,.41	Rb 83 5/- 8ms 83d .0423
36	Kr 83.80 σ_a23.9	Kr 74 16m β^+3.1 no γ E4.1	Kr 75 ~5m γ.14 E5	Kr 76 14.8h ε γ.267,.316,.03-.45 E~	Kr 77 1.2h β+1.85,1.6,ε γ.130,.146,1.08 E3.0	Kr 78 0.354 σ_γ(1.2+4.5) 7792040	Kr 79 7/+ 50s 34.9h IT.127,ε,β+.60,.32 γ.26,.60 E.3	Kr 80 2.27 σ_γ(4.6+3.4) 79.91638	Kr 81 7/+ 13s 2.1x10^5y no γ 81.91348	Kr 82 11.56 σ_γ(20+10)
35	Br 79.904 σ_a6.8	Br 70? 23s (p)2.5		Br 74 4m 36m γ.55,β+ E5.7	Br 75 3/+ 97m β+1.72 γ.65 E3.0	Br 76 16h β+3.58,ε γ.56,.65,1.21,.29-4.5 E4.6	Br 77 3/- 4.3m 56h IT.108,ε,β+.36 γ.094-1.4 E.37	Br 78 1+ 6.4m IT β+2.5, γ.61 E2.0	Br 79 3/- 50.69 σ_γ(2.8+.97) 78.91833	Br 80 1+ 4.84s 17.6m IT.048,β+2.0,2.1,4 γ.666,.617 β-1.97 E1.87,E-2.02	Br 81 3/- 49.31 γ.27 σ_γ(2.8+.3) .28 80.91629
34	Se 78.96 σ_a11.8	Se 70 39m β^+ γ.427	Se 71 4.5m β+3.4 γ.15 E4.4	Se 72 8.5d ε(β+2.50,3.34,) γ.046(.835,.630) E~.6	Se 73 9/+ 42m 7.1h β+1.83,ε(β+1.29) γ.076,.05,.361(γ.360,.06) E2.74	Se 74 0.87 σ_γ58 73.92248	Se 75 5/+ 120.4d ε γ.265,.136,.280,.024-.619 E.865	Se 76 9.02 σ_γ(20+65) 75.91921	Se 77 1/- 17.7s 7.58 IT.162 σ_γ.42 76.91991	Se 78 23.52 σ_γ(.33+.07) 77.91731	Se 79 7/+ 3.9m <6.5x10^4y IT.096 β-.15 e- E.154	Se 80 49.82 σ_γ(.08+.53) 79.91653

Bottom section

Column heads (neutron number): 28, 30, 32, 34, 36, 38, 40

Z	Element						
34	Se 78.96 σ_a11.8			Se 70 39m β+3.4 γ.427 E4.4	Se 71 4.5m β+3.4 γ.15 E~.6	Se 72 8.5d ε(β+2.50,3.34,) γ.046(.835,.630) E2.74	Se 73 9/+ 42m 7.1h 73.92248	Se 74 0.87 σ_γ58 E.865	Se 75 5/+ 120.4d ε γ.265,.136,.280,.024-.619
33	As 74.9216 σ_a4.3		As 68? ~7m β^+	As 69 15m β+2.9 γ.23 E3.9	As 70 52.5m β+2.1,4,ε γ.040,668,.114,.745,.175-.443 E6.2	As 71 64h β+.81 γ.175,.023 E2.0	As 72 2- 26h β+2.50,3.34,ε γ.835,.630,69-37 E4.36	As 73 IV- 76d ε γ.053,.053(.0135) E.34	As 74 2- 8.0s 17.7d IT.28,β+.9,1.5 γ.596,.609 β-1.36,-2.5 γ.635 E.35
32	Ge 72.59 σ_a2.4		Ge 65 1.5m β+5.5 γ.6,1.2 E6.5	Ge 66 2.4h ε γ.183,.044,.368.7 E3.0	Ge 67 19m ε γ.17,.34-3.4 E4.4	Ge 68 287d ε γ.1-.7 E.25	Ge 69 39.2h β+1.21 γ.085,.87,.57-3.4 .235-2.34 E2.22	Ge 70 20.5 σ_γ(3+3.0) 69.92425	Ge 71 200ms 11d IT.023 no γ E.235	Ge 72 27.4 σ_γ1 71.92208	Ge 73 9/+ 40μs 7.8 IT.035 .535 σ_γ16 .53 72.92346

Top chart

Zr (Z=40)

Zr 87	Zr 88	Zr 89	Zr 90	Zr 91	Zr 92	Zr 93	Zr 94	Zr 95	Zr 96	Zr 97	Zr 98	Zr 99	Zr 100	Zr 101
1.6h	85d	4.20m 78.4h	0.80s 5146	11.23	17.11	9.5 x 10⁵y	17.40	65.5d	2.80	16.8h	31s	2.4s	~1s	~3.3s
β⁺2.10, γ.38) E3.50	γ390	IT 588 ε,β⁺.90 ε,β⁺.9 γ.15 E2.83	IT 2.319, σᵧ.07 γ2.18 899.0470	σᵧ0.9 90.90564	σᵧ0.18 91.90503	β⁻.063,.034 (γ.030) σᵧ<4 E.09	σᵧ.05 93.90631	β⁻.40,36,89, (160) γ756,723,(1.23,.765) E1.121 95.90829	σᵧ0.2	β⁻191(.,(1.27)) γ.11-185(.743) E2.67	β⁻ E~1.5	β⁻ E4.5		β⁻ E~6.5

Y (Z=39)

Y 86	Y 87	Y 88	Y 89	Y 90	Y 91	Y 92	Y 93	Y 94	Y 95	Y 96	Y 97		Y 99
48m 14.6h	13h 80h	0.30ms 106.6d	15.7s 100	3.19h 64.0h	50.5m 58.8d	3.53h	10.2h	20.3h	10.5m	2.3m	1.11s		~0.8s
β⁺2.10, γ.208, γ.08,1.16	IT 38 ε,β⁺.8 γ.484,.39	IT 39 ε,β⁺.75 IT 25, γ.45	IT.909 σ(1mb+ 1.28)	IT 48 β⁻2.27 γ.20, σᵧ<ε β⁻.62 σᵧ<ε γ2.3 E2.27	IT.55 β⁻1.54 σᵧ4 E1.54	β⁻3.63,1.32, 1.59-2.71 γ93,.47,1.4, .07-2.4 E363	β⁻2.89, γ.27,.94,.49-2.4	β⁻5.0, γ.92,.55,1.14,1.67 3.5 E5.0	β⁻4.3,.76,1.17 γ.95,2.18,1.32, .43-4.07 E4.3	β⁻3.5 γ.7,1.0, E7	β⁻		

Sr (Z=38)

Sr 85	Sr 86	Sr 87	Sr 88	Sr 89	Sr 90	Sr 91	Sr 92	Sr 93	Sr 94	Sr 95	Sr 96	Sr 97
70m 64.7d	9.87	2.83h 7.04	82.53	50.8d	28.9y	9.67h	2.69h	7.5m	129m	26s	4.0s	~0.4s
IT.006, ε γ.23, γ.514	σᵧ(.84+?)	IT.39 ε	σᵧ.6 mb 87.90564	β⁻1.46, σᵧ.15 E1.463	β⁻.546,(.12,.27) no γ σᵧ0.9 E.546	β⁻1.09,1.36, 2.67, γ(.55)1.65-1.65 E2.67	β⁻.55,1.5 γ1.37,.44,.23 E1.9	β⁻2.9,2.6,2.2 γ.60,.80,.3-2.1 E4.8	β⁻2.1 γ1.42 E3.5	β⁻	β⁻	

Rb (Z=37)

Rb 84	Rb 85	Rb 86	Rb 87	Rb 88	Rb 89	Rb 90	Rb 91	Rb 92	Rb 93	Rb 94	Rb 95	Rb 96	Rb 97
20m 33.0d	72.15	1.00m 18.66d	27.85 5.0x10¹⁰y	17.7m	15.2m	4.28m 2.7m	57.9s	4.48s	5.87s	2.67s	0.36s	0.23s	.14s
	σᵧ(.06+.40) 84.91180	IT.56 γ1.08,	β⁻.27 no γ σᵧ.12 E.274	β⁻5.2,3.3,2. γ1.84,899,2.6H, 2.20,(.55)-3.5	β⁻1.26,2.21,4.49, γ1.03,1.25,.66,	β⁻1.66, .58,2.2, γ.094,.35 E6.6		β⁻ (n)	β⁻	β⁻ (n)	β⁻ (n)	β⁻ (n)	(n)

Kr (Z=36)

Kr 83	Kr 84	Kr 85	Kr 86	Kr 87	Kr 88	Kr 89	Kr 90	Kr 91	Kr 92	Kr 93	Kr 94	Kr 95	
1.86h 11.55	56.90	4.4h 10.74	17.37	76m	2.79h	3.18m	32.3s	8.6s	1.84s	1.29s	1s	Short	60
γ.032 σᵧ.173 γ.009	σᵧ(.09+.042) 83.91150	IT.83 β⁻.67, γ.150 γ.514 IT 3(n) E.67	σᵧ.06 85.91062	β⁻3.8,1.3,3.3 γ.403,2.56,.85 E3.8Y	β⁻.52,2.7, γ.08-2.2 E2.9	β⁻4.9,4.6,3.8, γ.22,.59,.086-4.7 E5	β⁻2.8, γ1.215,.540,1.12, 1.538,.11-3.6 E4.6	β⁻3.6, γ.51,1.1 E5.7	β⁻ (n)	β⁻ (n)	β⁻	β⁻	

Br (Z=35)

Br 82	Br 83	Br 84	Br 85	Br 86	Br 87	Br 88	Br 89	Br 90	
6.1m 35.4h	2.40h	6.0m 31.8m	3.0m	54s	55.6s	16s	4.5s	1.6s	58
IT.046 β⁻.44 γ.777,554, E.53,E3.09	β⁻.93 γ.52	β⁻.88 γ.881.9 γ.032,.00H) E4.7	β⁻ γ.81,1.92 E2.8	β⁻3.5,74, γ16,1.4,2.8, E7.6	β⁻2.6, γ.14,2.6,3.0-5.0 (n).3 E6	β⁻ (n) 5	β⁻ γ.79,	β⁻ (n)	

Se (Z=34)

Se 81	Se 82	Se 83	Se 84	Se 85	Se 86	Se 87	
57m 18m	9.19	69s 23m	3.2m	39s	≥16s	5.8s	56
IT.103 β⁻1.58, γ.103, .275,.290 E(3.4)	σᵧ(.04+.006) 81.91671	β⁻3.5, β⁻.93,05, 1.5,2.4, γ1.01,(2.0,).356, .65,.35, .47,.226	β⁻	β⁻	β⁻	β⁻	

Magic numbers (columns): 48   50   52   54

Bottom chart

Se (Z=34)

Se 76	Se 77	Se 78	Se 79	Se 80	Se 81	Se 82	Se 83	Se 84	Se 85	Se 86	Se 87
9.02	17.7s 7.58	23.52	3.9m 56.5x10⁴y	49.82	57m 18m	9.19	69s 23m	3.2m	39s	≥16s	5.8s
σᵧ(20+65) 75.91921	IT 162 σᵧ.42 78.91994	σᵧ(.31+.07) 77.97173	IT.096 β⁻.15 no γ E.154	σᵧ(.05+.53) 79.91653	IT.103 β⁻1.58, γ.275,.290 E(3.4)	σᵧ(.04+.006) 81.91671	β⁻3.5, β⁻.93,05, 1.5,2.4, γ1.01,(2.0),.356, .65,.35, .47,.226	β⁻1.4 γ.408	β⁻	β⁻	β⁻

As (Z=33)

As 75	As 76	As 77	As 78	As 79	As 80	As 81	As 82	As 83	As 84	As 85	As 86	As 87
16.4ms 100	19µs 26.4h	16µs 38.8h	1.52h	9.0m	15s	32s	15s	14s	5.8s	2.1s		<1.5s
IT.024, σᵧ4.3 γ.28 74.92160	IT 2, β⁻6, γ.559,	IT.2, β⁻.7 γ.239 E.68	β⁻4.1 γ.614,1.45,.31 E4	β⁻2.1 γ.365, E	β⁻6.0,5.33,0-4.5 γ.666,.78,2.35 E6.0	β⁻3.8 no γ E38	β⁻ γ.655,.817	β⁻ (n)	β⁻ (n)	β⁻ (n)	(n)	(n)

Ge (Z=32)

Ge 74	Ge 75	Ge 76	Ge 77	Ge 78	Ge 79				
36.5	46s 82.8m	7.8	55s 11.30h	19.82	<1m	48	50	52	54
σᵧ(.15+31) 73.92118	IT β⁻1.1 γ.139 σᵧ.265+.65 E	σᵧ(.10+.05) 75.92141	β⁻2.9 β⁻2.2 γ.21,.42-2.2, γ.59,1.2-2.54 E2.95 E2.70	β⁻.79 E.38	<1m				

Magic numbers (columns): 42   44   46   48   50   52   54

Top chart

			48	Cd 112.40 σ_a 2460	Cd 101 1.2 m β^+	Cd 102 5.5 m β^+	Cd 103 7.3 m β^+	Cd 104 55 m	Cd 105 57 m	Cd 106 1.22 σ_γ 1 105.90646	Cd 107 6.5h	Cd 108 0.88 σ_γ 1.1 107.90419
		47	Ag 107.868 σ_a 63.6		Ag 99 1.8m	Ag 100 8m	Ag 101 10.8m	Ag 102 8m 14m	Ag 103 5.8s 1.10h	Ag 104 29m 67m	Ag 105 41.0d	Ag 106 8.4d 24.1m IT 093	Ag 107 44s 51.82 106.90509
	46	Pd 106.4 σ_a 8			Pd 98 17.5m ϵ E 3.8	Pd 99 23m	Pd 100 3.7d	Pd 101 8.3h	Pd 102 0.96 σ_γ 5 101.9056	Pd 103 17d ϵ E.56	Pd 104 10.97 103.9040	Pd 105 22.23 104.905	Pd 106 27.33 105.90348
45	Rh 102.905 σ_a 148			Rh 95 4.8m β^+	Rh 96 ~1.5m?~9m	Rh 97 33m	Rh 98 ~3m 8.7m	Rh 99 4.7h 15.0d	Rh 100 21h	Rh 101 4.47d 3y	Rh 102 2.1y 207d	Rh 103 55m 100 IT 040 102.9055	Rh 104 38s 35.5h IT 129
	48		50		52		54		56		58		60

Bottom chart

			45	Rh 102.905 σ_a 148		Rh 95 4.8m β^+	Rh 96 ~1.5m?~9m	Rh 97 33m	Rh 98 ~3m 8.7m IT
		44	Ru 101.07 σ_a 2.6		Ru 93 ~52s β^+	Ru 94 52m	Ru 95 1.65h	Ru 96 5.51 σ_γ 21 95.90760	Ru 97 1.8ms 2.89d
	43	Tc			Tc 92 4.4m	Tc 93 43m 2.73h	Tc 94 52m 4.8h	Tc 95 61d 20.0h	Tc 96 52m 4.3d IT 034
42	Mo 95.94 σ_a 2.68			Mo 88? 27m	Mo 89? 7m	Mo 90 5.7h	Mo 91 65s 15.49m	Mo 92 15.84 91.9068	Mo 93 6.9h ~3x10³y	Mo 94 9.04 93.90509	Mo 95 15.72 σ_a 14.4 94.90584
41	Nb 92.906 σ_a 1.15				Nb 88 14m	Nb 89 68m 1.9h	Nb 90 14.59m	Nb 91 62d long	Nb 92 10.13d >350y	Nb 93 13.6y 100 92.90634	Nb 94 6.26m 2.0x10⁴y
40	Zr 91.22 σ_a 182	Zr 81 ~10m	Zr 82 ~10m	Zr 83 ~7m	Zr 84 16 m	Zr 85 15m 1.4h	Zr 86 16.5h	Zr 87 1.6h	Zr 88 85d	Zr 89 4.20m 78.4h	Zr 90 0.80s 51.46 89.90470	Zr 91 11.23 σ_γ 0.9 90.90564	Zr 92 17.11 σ_a 0.18 91.90503	Zr 93 9.5 x 10⁵ y
40		42		44		46		48		50		52	

Top block — Cd, Ag, Pd, Rh isotopes

Cd 109 12μs 453d	Cd 110 12.39	Cd 111 48.6m 12.75	Cd 112 24.07	Cd 113 156y 12.26	Cd 114 28.86	Cd 115 44.1d 53.5h	Cd 116 7.58	Cd 117 3.2h 2.5h	Cd 118 49m	Cd 119 2.7m 10m		Cd 121 13s
Ag 108 2.42m	Ag 109 39.8s 48.18	Ag 110 24.6s	Ag 111 74s 7.4Bd	Ag 112 3.12h	Ag 113 1.2m 5.3h	Ag 114 4.6s	Ag 115 54s 21m	Ag 116 2.5m	Ag 117 1.1m	Ag 118 5s	Ag 119 Short	**74**
Pd 107 22s ~7×10⁶	Pd 108 26.71	Pd 109 4.7m 13.46h	Pd 110 11.81	Pd 111 5.5h 22m	Pd 112 21h	Pd 113 1.5m	Pd 114 2.4m	Pd 115 39s		Pd 117 5s	Pd 118 3.1s	
Rh 106 30.0s	Rh 107 22.4m	Rh 108	Rh 109 ~30s	Rh 110 5s								

68   70   72

62   64   66

Bottom block — Rh, Ru, Tc, Mo, Nb, Zr isotopes

Rh 99 4.7h 15.0d	Rh 100 21h	Rh 101 4.4?y 3y	Rh 102 2.1y 207d	Rh 103 55m 100	Rh 104 4.36m 42s	Rh 105 38s 35.5h	Rh 106 2.18h 30.0s	Rh 107 22.4m	Rh 108 17s	Rh 109 ~50s ~30s	Rh 110 5s
Ru 98 1.87	Ru 99 12.72	Ru 100 12.62	Ru 101 17.07	Ru 102 31.61	Ru 103 39.8d	Ru 104 18.58	Ru 105 4.44h	Ru 106 368d	Ru 107 4.2m	Ru 108 4.5m	Ru 109 35s
Tc 97 90d 2.6×10⁶y	Tc 98 ~1.5×10⁶y	Tc 99 6.00?m 2.13×10⁵y	Tc 100 15.9s	Tc 101 14.2m	Tc 102 5.3s 4.3m	Tc 103 50s	Tc 104 18.0m	Tc 105 7.8m	Tc 106 37s	Tc 107 29s	Tc 108 <10s
Mo 96 16.53	Mo 97 9.46	Mo 98 23.78	Mo 99 66.6h	Mo 100 9.63	Mo 101 14.6m	Mo 102 11.1m	Mo 103 5.3h? 66s	Mo 104 1.3m	Mo 105 41s	Mo 106 9.5s	
Nb 95 87h 35.1d	Nb 96 23.4h	Nb 97 58s 73.6m	Nb 98 2.8s 51m	Nb 99 14s 2.4m	Nb 100 6.6s 2.9m	Nb 101 7.0s					
Zr 94 17.40	Zr 95 65.5d	Zr 96 2.80	Zr 97 16.8h	Zr 98 31s	Zr 99 2.4s	Zr 100 ~1s	Zr 101 ~3.3s				

66

64

62

54   56   58   60

55	**Cs** 132.905 σ₀29.9	Cs120						
54	**Xe** 131.30 σ₀25	Xe115 19s ε	Xe116 .55s ε,β+ γ104	Xe117 .65s ε,β+ γ059,117,222,	Xe118 6m ε,β+ γ053,117,	Xe119 6m ε,β+ γ098,231,		
53	**I** 126.9044 σ₀6.2		I115 1.3m β+	I116 <5m β+ γ104	I117 2.4m β+ γ16,33,72,	I118 9m 14.2m β+6 ε γ60,6 γ55,605 E~7		
52	**Te** 127.60 σ₀4.7	Te107 2.2s β+ α3.28	Te108 5.3s β+ α3.08 (p)3.4,3.7,2.6	Te109? 4.2s (p)	Te111? 19.3s (p)	Te114 17m β+(40,2.7) γ(89,130)	Te115 0.10s 6m IT.28 β+2.8.2 γ2,128, 38,96 E4.5	Te116 2.5h ε,β+(2.3,) γ094,1129, 93,97,222 E1.6	Te117 64m ε,β+ γ720,172,09, 57-230 E350
51	**Sb** 121.75 σ₀5				Sb112 0.9m β+,ε γ1.27	Sb113 6.7m β+2.42,1.85 γ3-5,1079 E6.3	Sb114 3.4m β+40,27 γ89,130 E6.3	Sb115 31.9m ε,β+1.5 γ499,114-222 E3.03	Sb116 60.4m 16m ε,β+ γ293, E4.6
50	**Sn** 118.69 σ₀.63		Sn108 9m γ28,42	Sn109 .15m .18m β+ ε γ34,112, 891,66 E2.52	Sn110 4.0h γ283,166	Sn111 35.1m ε,β+,ε γ115,076,191 373-232 E2.52	Sn112 0.96 σγ(3+8) 111.9048	Sn113 20m 115d IT.079 ε γ255 392 E1.02	Sn114 0.66 113.9028	Sn115 159μs 0.35 σγ.45 σγ5 3μs 114.9033
49	**In** 114.82 σ₀194		In106 5.1m β+31,49 γ165,185 E6.54	In107 32m β+25, γ22,28-25 E3.5	In108 40m 5.7m β+35 ε,β+3 γ24,15 γ63,84 E4.5	In109 .21s 4.2h 1.68 ε,β+90 71.43,γ20,63, 48-105 V13m E2.02	In110 49h 67m ε ε,β+2.25 γ12,66,ε,γ66, (1-94) no1T E3.93	In111 8m 2.82d IT.54 ε γ247, 173, E1.1	In112 208m 14.4m IT.56 β.66 ε,β+157 γ62,69-1.5 E.66 E*2.59
48	**Cd** 112.40 σ₀2460	Cd101 1.2m β+	Cd102 5.5m β+ γ118,481,104,	Cd103 7.3m β+ γ108,145,146	Cd104 55m ε(β+2.7) γ084,067 (556)e⁻ E~12	Cd105 57m ε,β+169 γ08,35,168, 131, E~2.8	Cd106 1.22 σγ1 105.90646	Cd107 6.5h ε,β+30 γ(093),033 1.22 E1.417	Cd108 0.88 σγ11 107.90419

Additional right-hand cells:

In113 1.66h 4.28 IT392 σγ12,8+ (0+3) 112.90409	In114 44ms 71.9s IT.19 ε,β+ β+40 γ72,56 E*.43

Cd109 12μs 453d IT060 ε γ700 E160	Cd110 12.39 σγ(.1+11) 109.90301	Cd111 48.6m 12.75 IT.151 247D σγ24 110.90419	Cd112 24.07 σγ(.03+2.2) 111.90276	Cd113 13.6y 12.26 β-58 IT.27 σγ2x10⁴ 112.90441

Bottom axis labels: **52   54   56   58   60   62   64**

Upper chart section

Cs 134 2.90h 2.06y	Cs 135 53m 2.3×10⁶y	Cs 136 13d	Cs 137 30.2y	Cs 138 32.2m	Cs 139 9.3m	Cs 140 63.8s	Cs 141 24.7s	Cs 142 1.7s	Cs 143 1.7s	Cs 144 1.1s		
Xe 133	Xe 134	Xe 135	Xe 136	Xe 137	Xe 138	Xe 139 13.6s	Xe 140	Xe 141 1.72s	Xe 142 1.22s	Xe 143 0.96s	Xe 144 9s	
I 132 2.284h	I 133 20.8h	I 134 52.3m	I 135 6.7h	I 136 85s	I 137 22.3s	I 138 6.0s	I 139 2.0s	I 140 1.5s				**90**
Te 131 30h 25.0m	Te 132 78h	Te 133 53m 12.5m	Te 134 43m	Te 135 11s	Te 136 ~33s					**88**		
Sb 130 8m 37m	Sb 131 23.0m	Sb 132 4.5s 2.1m	Sb 133 2.7m	Sb 134 11.3s	Sb 135 1.70s			**86**				
Sn 129 ~2m 2.5m	Sn 130 2.6m	Sn 131 1.3m	Sn 132 1.0m	Sn 133 ~55s								

80   82   84

Lower chart section

Cs 121 2m	Cs 122 0.5s	Cs 123 5.9m	Cs 124	Cs 125 45s	Cs 126 3.8m	Cs 127	Cs 128	Cs 129 32.3h	Cs 130 30m	Cs 131 9.69d	Cs 132 6.58d	Cs 133 100
Xe 120 4.0m	Xe 121 39m	Xe 122 20h	Xe 123	Xe 124 0.096	Xe 125	Xe 126 0.090	Xe 127 36.41d	Xe 128 1.92	Xe 129 26.44	Xe 130 4.08	Xe 131 21.18	Xe 132 26.89
I 119	I 120 53m 1.35h	I 121 2.12h	I 122 3.5m	I 123	I 124 4.9 d	I 125 13.0d	I 126 13.04	I 127 100	I 128 25.01m	I 129 1.6×10⁷y	I 130 12.4h	I 131 8.065d
Te 118 6.00d	Te 119 4.7d 16h	Te 120 0.089	Te 121	Te 122 2.46	Te 123 0.87	Te 124 4.61	Te 125 6.99	Te 126 18.71	Te 127 9.3h	Te 128 31.79	Te 129 69m	Te 130 34.48
Sb 117 2.80h	Sb 118 3.5m	Sb 119 38.1h	Sb 120 5.76d 16.0m	Sb 121 57.25	Sb 122	Sb 123 42.75	Sb 124 20.3m 60.2d	Sb 125 2.73y	Sb 126 19.0m 12.4d	Sb 127 3.80d	Sb 128 10.4m 9.0h	Sb 129 4.34h
Sn 116 14.30	Sn 117 14d 7.61	Sn 118 24.03	Sn 119 9.58d	Sn 120 32.85	Sn 121	Sn 122 4.72	Sn 123 40.3m 129d	Sn 124 5.94	Sn 125 9.6m ~10⁵y	Sn 126 ~10⁵y	Sn 127 4.2m 2.12h	Sn 128 59.0m
In 115 4.50n 95./22.3s	In 116 142s	In 117 44m	In 118 4.5m	In 119	In 120	In 121	In 122 8s	In 123 36s 6s	In 124 ~4s	In 125 18s 2.5s		**78**
Cd 114 28.86	Cd 115 44.1d 53.5h	Cd 116 7.58	Cd 117	Cd 118 4.9m	Cd 119 7m		Cd 121 13s			**76**		

66   68   70   72   74

	61	Pm

| | | 60 | Nd 144.24 σ_0 50 | | | Nd135 12m β^+ γ 21, 44 | Nd136 55m ϵ | Nd137 38m ϵ, β^+ |

| | 59 | Pr 140.909 σ_0 12 | | | | Pr 134 17m β^+, ϵ γ 41, 64, 22-96 | Pr 135 22m β^+ 2.5, ϵ γ 22, 08, 30 | Pr 136 13.5m ϵ, β^+ E 5.07 |

| 58 | Ce 140.12 σ_0 0.6 | | | Ce129 ~13m γ 08, 32, 75 | Ce 130 27m ϵ, β^+ γ 129 | Ce 131 5m 9.5m ϵ, β^+ γ 21, 72.14, 43 | Ce 132 4.2h ϵ, β^+ γ 182, 155, 217 E ~1.2 | Ce 133 97m 6.3h ϵ, β^+ 1.3 (0.2) γ 1.8, 1.8 E ~2.8 | Ce134 72h ϵ γ 55, 56, 57 E ~1.4 | Ce135 17.7n ϵ, β^+ γ 265, 300, 606, 0345-180 E ~2.1 |

| 57 | La 138.91 σ_0 9.1 | | ?La125 <1m β^+, ϵ γ 26, | La 126 1.0m | La 127 3.6m | La 128 0.6s 4.6m γ 068, β^+ 3.2, ϵ 28, 48, 64, | La 129 9m β^+, ϵ E ~4 | La 130 3+ 8.7m β^+, ϵ γ 357, E ~5.6 | La 131 (9/+) 158μs 59m IT 1.7 ϵ, β^+ 1.42 γ 194, 108,418,365,285 080-196 E2.96 | La 132 2 4.6h β^+ 3.7, ϵ γ 464,568,103, 664, 19-363 E 5.3 | La 133 4h ϵ, β^+ 1.2 γ 8 E2.2 | La134 1+ 6.7m β^+ 2.62.0,14, 2, γ 605, 56, 563, 664-270 E49 |

| 56 | Ba 137.34 σ_0 1.3 | Ba122 12m | Ba 123 2m | Ba 124 2.5m | Ba 125 βm 30m 65m β^+ 5.5 β^+ 4.6 γ 076, 084, 14, | Ba 126 97m $\epsilon, (\beta^+$ 3.8, γ 27, 70 (386) E ~3 | Ba 127 18m 12m β^+ 4.3 β^+ 4.5 γ 11, 07 | Ba 128 2.42d $\epsilon, (\beta^+$ 2.9), γ 28, 11.3, 443 E ~7 | Ba 129 2.1h 2.2h β^+ 1.43, γ 182, 125, 1.0 145, 21, 22, E2.45 | Ba 130 0.101 $\sigma_\gamma (2.5+8)$ 129.9062 | Ba 131 14.6m 11.7d IT 0.78 ϵ γ 1.07 γ 50, 240, 216, 055- 105 E1.16 | Ba 132 0.097 β^+ (?+8) 131.905 | Ba 133 38.9h 10.7y IT 275 IE γ 0123 γ 356,08 303,053 -384 E49 |

| 55 | Cs 132.905 σ_0 29.9 | Cs120 | Cs121 2m | Cs122? 0.5s | Cs 123 5.6m β^+, ϵ γ 01 E ~3.6 | Cs124 | Cs 125 45m ϵ, β^+ 2.05 γ 112 E 3.0? | Cs 126 1+ 1.6m β^+ 3.8, ϵ γ 386 E4.8 | Cs 127 1/+ 6.2h $\epsilon, (\beta^+$ 67, 1.07, γ 411, 125, 462, 20-198 E2.10 | Cs 128 1+ 3.8m β^+ 2.9 2.46, ϵ γ 443, 526 2.86 E 3.93 | Cs 129 1/+ 32.3h ϵ γ 37, 41, 55, E ~1.1 | Cs 130 1+ 30m ϵ, β^+ 1.97 γ 536, 586, 894, e^- E-442 E+299 | Cs 131 5/+ 9.69d no γ E.36 | Cs 132 2+ 6.58d ϵ, β^+ 4, γ 668,363-1985 β^- γ 465,567,1031 E-2.08 E-1.2 |

| 64 | | 66 | | 68 | | 70 | | 72 | | 74 | | 76 | |

Pm 149ᵐ 53.1h	Pm 150 2.68m	Pm 151⁵/⁺ 28.4h	Pm 152 4.2m	Pm 153 5.5m	Pm 154 2.5m				
Nd 148 5.73	Nd 149ᵐ 1.73h	Nd 150 5.62	Nd 151 12.4m	Nd 152 11.7m			**96**		
Pr 147 12m	Pr 148 2.0m	Pr 149 2.3m			**94**				
Ce 146 14.2m	Ce 147 70s	Ce 148 ~43s		**92**					
Ba 144 11.9s									
Cs 143 1.7s	Cs 144 1.1s								

88   90

Pm139? ~6m	Pm140 5.8m	Pm141 20.9m	Pm142 36s	Pm143 265d	Pm144 363d	Pm145 18y	Pm146 5.53y	Pm147 2.6234y	Pm148 41.5d / 5.4d
Nd138 5.2h	Nd139 5.5h / 30m	Nd140 6??	Nd141 2.44h / 62s	Nd142 27.11	Nd143 12.17	Nd144 2.1×10¹⁵	Nd145 8.30	Nd146 17.22	Nd147 11.06d
Pr137 77m	Pr138 2.10h / 1.5m	Pr139 4.41h	Pr140 3.39m	Pr141 100	Pr142 19.2h	Pr143 13.58d	Pr144 17.3m / 7.2m	Pr145 5.98h	Pr146 24.2m
Ce136 0.193	Ce137 34h / 9.0h	Ce138 0.250	Ce139 137.5d / 56s	Ce140 88.48	Ce141 32.5d	Ce142 11.07	Ce143 33.0h	Ce144 284.4d	Ce145 2.9m
La135 19.5h	La136 11s	La137 6×10⁴y	La138 0.089	La139 99.91	La140 40.23h	La141 3.87h	La142 92.4m	La143 14m	La144 41s
Ba134 2.42	Ba135 6.59	Ba136 7.81	Ba137 11.32	Ba138 71.66	Ba139 83.2m	Ba140 12.8d	Ba141 18.3m	Ba142 10.7m	Ba143 12s
Cs133 100	Cs134 2.90h / 2.06y	Cs135 2.3×10⁶y	Cs136 13d	Cs137 30y	Cs138 32.2m	Cs139 9.3m	Cs140 63.8s	Cs141 24.7s	Cs142 1.7s

78   80   82   84   86

Top chart section

	82	84	86	88	90	92	94
69 Tm 168.934 σ_a 113	Tm 153 1.58s α 5.11	Tm 154 2.98s 5s α 5.04 α 4.96					Tm 161 30m γ 046-373 E 3.5	Tm 162 79m 22m γ 102, 24 β+ 2.3, 3.8,9 γ 102, E 4.9	Tm 163 1.8h ε, β+, 4 γ 104, 242, 022, .80 E 2.27	Tm 164 1.9m β+ 2.94, ε γ 091, 21-2 38 E 3.96
68 Er 167.26 σ_a 1.6 x 10²		Er 152 11s α 4.60 β+	Er 153 36s α 4.67 β+	Er 154 5m α 4.15	Er 155 5.3m < 4m	Er 156 < 4m β+	Er 157 24m β+ γ 117-2.00	Er 158 2.4h ε γ 0.07), 072, 98 2 60 e-	Er 159 36m ε γ 729, 966, 087-2 8 e-	Er 160 29h ε, (β+ 57 e-	Er 161 3.1h ε, β+ 2.8, γ 210, 806, 067 e-	Er 162 0.136 σ_γ 160 161.9287	Er 163 75m ε γ 43, 301, E 1.2
67 Ho 164.930 σ_a 65	Ho 150 20s	Ho 151 42s 36s α 4.60 α 4.51	Ho 152 52s 2.5m α 4.45 α 4.38	Ho 153 6.5m 9.3m α 4.00 ε α 3.95	Ho 154 3.25m 11.8m β+, ε α 3.91 γ 335,412, 477, 158- 1.25 E 6.4	Ho 155 55m ε γ 138, 266, 566, 100, 141	Ho 156 15m	Ho 157 15m	Ho 158 24m 11.3m ε, β+,α 289 γ 099, 1.07 E ~ 8	Ho 159 8.2s 33m IT 206 e- E ~ 8	Ho 160 4.7h 25m IT 60 e β+ γ 729, 966, 087-2 8 E 3.5	Ho 161 6.8s 2.5h e- γ 026, 10, 078, 044- 76 E ~ 8	Ho 162 67m 13m IT- or ε β+, 108, 13 γ 058, γ 081 γ 038, 2.16 γ 081 132

Bottom chart section

	78	80	82	84	86	88	90
67 Ho 164.930 σ_a 65			Ho 150 20s	Ho 151 42s 36s α 4.60 α 4.51	Ho 152 52s 2.5m α 4.45 α 4.38	Ho 153 6.5m 9.3m α 4.00	Ho 154 3.25m 11.8m β+,ε α 3.91 γ 335,412, 477,150- 1.25 E 6.4	Ho 155 55m ε γ 138, 266, 566, 100,141	Ho 156 55m ε,β+,18,2.0,1.3 γ 067-1.20	Ho 157 15m
66 Dy 162.50 σ_a 930				Dy 149 ~15m ε	Dy 150 7.2m β+,ε α 4.2 γ 39 E 1.7	Dy 151 18m β+,ε α 4.06 γ 256 E ~ 2.9	Dy 152 2.38h γ 256 54 152.926	Dy 153 5h β+,ε α 3.55 γ 081, 400, 082 154 152.926	Dy 154 13h ~10⁶ y α 2.85 153.924	Dy 155 10.2h β+, ε α ~ 3 155.924	Dy 156 0.052 2 x 10⁻⁴ α ~ 3 155.924
65 Tb 158.924 σ_a 27				Tb 147 100m 24m ε	Tb 148 70m ε,β+ 4.6, γ 78,112 E 5.6	Tb 149 4.15m 4.13h ε,α 3.95 γ 64,93 E 3.8	Tb 150 17m 3.1h ε,β+ α γ 64,93 E 4.2	Tb 151 17.9h ε α 4.42 γ 108, 1b-13 150.923	Tb 152 4m 17.6h ε,β+2,8,1,9, α 4.42 γ 344,587, 36 E 4.2	Tb 153 0.19ms 2.4s IT 08 γ 098, 212, 0,2,016	Tb 154 8h 18h ε γ 123, E 4.2	Tb 155 5.4d ε γ 0.86, 1-53, 213, 6- e-
64 Gd 157.25 σ_a 4.6 x 10⁴		Gd 144 45m β+ E 5.4	Gd 145 22.9m ε,β+25 γ 176,188, 33- 1.8- E 5.1	Gd 146 9h 5d ε γ 22, 115 E 5.3	Gd 147 38h ε,β+ γ 229, 396, 924, 1.76 E 2.22	Gd 148 93y α 3.18 147.918	Gd 149 9.5d ε,β+ 185-1.08 α 3.3 148.919	Gd 150 1.8 x 10⁶ y α 2.73 149.9186	Gd 151 120d ε γ 022(1), 054, 175, 3- α 2.14 α 2.6- E 1.4 151.9198	Gd 152 0.20 α 2.14 151.9198	Gd 153 76μs 242d IT ε γ 103, 097, 243 E 0.24	Gd 154 2.15 153.9209
63 Eu 151.96 σ_a 4.2 x 10³	Eu 142 1.1m β+,ε	Eu 143 2.6m β+,ε E 5.0	Eu 144 10s β+,ε γ 744,155,24- E 6.8	Eu 145 5.96d ε,β+ 172,74 γ 894,165,11- 651 E 2.72	Eu 146 4.6d ε,β+1,478,2,1 γ 634,633,666, 705,145,216 E 3.87	Eu 147 24.3d ε,β+ 25,62,55 γ 197,121, 1.07- 198 α 2.90 E 1.77	Eu 148 54.5d ε,β+ γ 550, 630, 925, 1.53, 1.02- 6-5	Eu 149 24m 93d ε,β+ γ 114, 277- 98 154	Eu 150 12.6h ε γ 334 64- 703-	Eu 151 60μs 47.82 IT ε γ 21 E 0.5	Eu 152 52.18	Eu 153 52.18
62 Sm 150.35 σ_a 5860	Sm 140 14m ε	Sm 141 23m ε,β+~2.6 (β+~2.6) E 2.1	Sm 142 72.5m ε IT 750 β+247 γ 571 E 3.49	Sm 143 63s 8.83m IT 50 γ 1056, 1.96,173, 273-217 143.9120	Sm 144 3.09 σ_γ ~ 7 143.9120	Sm 145 340d ε γ 061d, 49, <10 145.9130	Sm 146 1.0 x 10⁸ y α 2.50	Sm 147 1.07 x 10¹¹ y α 2.23 σ_γ 65 46.9149	Sm 148 >3 x 10¹⁴ y α 1.84? 47.9148	Sm 149 13.83 >1 x 10¹⁵ y σ_γ 41,800 σ_a 05 148.9172	Sm 150 7.44 σ_γ 102 149.9173	Sm 151 93y σ_γ 10	Sm 152 26.72 σ_γ 208 151.9198
61 Pm	Pm 139? ~6m β+ no γ	Pm 140 5.8m ? β+, ε γ 1.03, 43,78) E 3.6	Pm 141 20.9m ε β+ γ 72, 89,195- 2 37 E 4.8	Pm 142 36s β+ 3.8, ε γ 1.57 E 1.08	Pm 143 265d ε γ 742 E 2.37	Pm 144 363d ε γ 618,697,477, 302, 151 E 14	Pm 145 18y ε γ 072, 0670 α 2.24	Pm 146 553y ε,β- γ 454, 736, 79,7, 747 σ_γ 8400 E 154 E+149	Pm 147 2.6234y β- .225 γ 120 σ_γ 151-1021 E 225	Pm 148 41.5d 5.4d β- 2.47, 68),686, 915,115 γ 551, 550 IT 137 E 2.46	Pm 149 53.1h β- 1.07 γ 286- 85 σ_γ 1350 E 1.07	Pm 150 2.68h β- 2.3, 18, 4.3 γ 334, 026, 96 E 3.4	Pm 151 28.4h β- γ 340, 026, 96 175, 41- 3 E γ < 70

Tm 165 [1/4]	Tm 166 [2+]	Tm 167 [1/4]	Tm 168 [3+]	Tm 169 [1/4]	Tm 170 [1]	Tm 171 [1/4]	Tm 172 [2-]	Tm 173 [1/4]	Tm 174	Tm 175 [1/4]	Tm 176		
9 μs 30h	7.7 h	9.3 d	93.1 d	100	4 μs 129d	2.5μs 1.92y	63.6 h	8.2 h	5.5 m	1.6 m	1.4 m		
ε,β⁺ 30 080,03 ε,β⁺ 9.3,7.2	ε,β⁺ 9.4,7.2	γ 208, .057	γ98,816,448, 184,0798-149		γ 144, β⁻ 967,.88	γ 308, β⁻ 098,	β⁻ 1.8,1.88, γ1.094,1.387,	β⁻ 12,.7 γ.400, 47,	β⁻ 9,15,1.9, γ 3670, 9920,	β⁻ 9,15,1.9, γ 36, 94, 042,	β⁻ 2.0,1.15,3.05 γ.19,105,87,1.8,		
80μs γ.054, 245 1.069	.08, .184, .07 2.68	2.5-, .532			058, γ 0843 ε,⁺γ 95	112, ~.01 .005, γ.0667	1.530,1.466, 0790-1.622		.2730,	1.51	(.096~.389)		
β⁺17				σγ(10+103)		ε γ 4.5 E.098							
E2.1 E1.57	E3.04	E1.16	E1.72	168.9342	E.967 E*5		E1.88	E1.32	E3.0		E4.1		

Er 164	Er 165 [5/2]	Er 166	Er 167 [7/2]	Er 168	Er 169 [1/4]	Er 170	Er 171 [5/2]	Er 172	Er 173		**108**
1.56	10.36 h	33.41	2.3s 22.94	27.07	9.3 d	14.88	7.5 h	49 h	12.0 m		
σγ 13	ε	σγ(12+171)	IT 208 σγ 6.5×10³	σγ 1.91	β⁻.34,.33 .0084	σγ 5.7	β⁻.106, 58-149 116, 012-140	β⁻2.3,1.8 γ.05,41,61,	β⁻2.3,1.8 γ.20,.40,18, 037-0.52		
					e⁻						
163.9293	E.11	165.9303	166.932	167.9324	E.340	169.9356	E1.490	E.89			

[7] Ho 163 [7/2]	Ho 164	Ho 165 [7/2]	Ho 166 [0]	Ho 167 [7/2]	Ho 168	Ho 169 [7/2]	Ho 170			**106**
1.7s 4.3y	56m 29m	100	1.2×10³ 26.8h	3.1 h	3.0 m	4.7 m	44 s			
ε	ε 94 β⁻	σγ(3.2+62)	β⁻.06, 1.76, .0806, 184,811,0806, 712, 1.380, .184-1.183	β⁻ 346, 321, .079, 2080, 074- .92	β⁻ 2.0	β⁻ 2.0 γ.78, .85, .06 .92	β⁻ 3.3, γ 43			
E 5.07	E1.03 E*1.11	164.9304	2.1ms E1.85	E.097			E 4.2			

<div align="center">96   98   100   102   104</div>

Ho 158 [5+]	Ho 159	Ho 160 [5+]	Ho 161 [7/2]	Ho 162 [1+]	Ho 163 [7/2]	Ho 164	Ho 165 [7/2]	Ho 166 [0]	Ho 167 [7/2]	Ho 168	Ho 169 [7/2]	Ho 170		
24m 11.3m	8.2s 33m	4.7h .25m	6.8s 2.5h	67m 13m	.07s 4.33y	56m 29m	100	1.2×10³ 26.8h	3.1 h	3.0 m	4.7 m	44 s		
β⁺,ε,β⁺ .20,195,		γ 206	γ 271.4	γ 026, 10, 076,044,	γ.058, γ.081		σγ (3.2+62)	β⁻.06, 1.76, .0806, 184,811,0806, 712, .184-1.183	γ 346, 321, 079, 2080, 074- 745	β⁻ 2.0 γ.85,	β⁻1.20,195, γ.78, 85, 06- .92	β⁻3.3, γ 43		
E4.22	E~1.8	E~1.8	E1.8	E~1.6	E.009		164.9304		E.097		E2.1	E4.2		

Dy 157 [3/2]	Dy 158	Dy 159 [3/2]	Dy 160	Dy 161 [5/2]	Dy 162	Dy 163 [5/2]	Dy 164	Dy 165 [7/2]	Dy 166	Dy 167		**104**
8.1 h	0.090	0.122ms 144 d	2.29	18.88	25.53	24.97	28.18	32s 2.35h	81.5 h	4.4 m		
γ.326, 82, 1.43,	σγ 100	IT.109	σγ 1.29	σγ 590	σγ 200	σγ 140	σγ(1820+780)	σγ(1820+780)	β⁻.40, 48, γ 082, 028-43	β⁻ γ.19-.57		
157.9244			159.9269		161.9268	162.9288	163.9292		E.48			

Tb 156 [3-]	Tb 157 [3/2]	Tb 158	Tb 159 [3/2]	Tb 160 [3]	Tb 161 [3/2]	Tb 162	Tb 163 [3/4]	Tb 164			**102**
5h 5.3 d	150 y		100	72.4 d	7.0 d	2.24h 7.47m	19.5m 6.5h	3.04 m			
γ.534, 535, 199, .334, 127, 089	ε~.54		σγ 27	β⁻.86, 58, 36, γ.879,299,966, 0868-1.311	β⁻.57, .49, γ.026, 0499, 0746	β⁻26,89, γ.89,081, 1.27	β⁻ γ 35,19, 49, 07- 84	β⁻1.20,195, γ.756, 611, 215, 169, 06-1.44			
E2.4	E.07		158.9254	E~2.8	E1.83		E1.7				

Gd 155 [3/2]	Gd 156	Gd 157 [3/2]	Gd 158	Gd 159 [3/2]	Gd 160	Gd 161 [5/2]	Gd 162			**100**
14.73	20.47	15.68	24.87	.46ms 18.2h	21.90	3.7m	10.4 m			
σγ 61×10³	σγ 8	σγ 2.50×10⁴	σγ 2.4	IT~.70 β⁻ 95, 89, 59, γ.363,0580 .0795, 85	σγ .77	β⁻1.56, γ.361,.315,102, .056~.5	β⁻ γ.41, .43			
154.9227	155.9222	156.9240	157.9242	E.95	159.9271	E 2.0				

Eu 154	Eu 155 [5/2]	Eu 156	Eu 157	Eu 158	Eu 159	Eu 160			**98**
7.8 y	5.0 y	15.2 d	15.2 h	45.9 m	18.1 m	~2.5 m			
β⁻.24,1.26,.82,1.86, 123,.274,.723, γ,1450	β⁻.086, γ.105, .04	β⁻ 48,2.45, 30, γ.090,199-2.19	β⁻1.28,1.45, γ.41,0650, 16 .97	β⁻ 5,19,01, γ.080, 95, 89, 187	β⁻ 2.57,(*)010- 175 γ.084, 67, 092, 04-1.5	β⁻ 3.6			
E1.98	E.245	E1.45	E1.35	E3.5	E 2.97	E 3.6			

Sm 153 [3/2]	Sm 154	Sm 155 [3/2]	Sm 156	Sm 157					
46.8 h	22.71	22.3 m	9.4 h	0.5 m					
β⁻.70,.63, 80, γ.103,.0697, 083~.636	σγ 5	β⁻1.54, γ.1044, 246, 141, 026~.430	β⁻.43, 72, γ.087, 20, 04- 29	β⁻ γ.57					
E.801	153.9223	E.165	E.72						

Pm 152 [1+]	Pm 153	Pm 154						**98**
4.2 m	5.5 m	2.5 m						
β⁻2.2,3.4 γ.122, 245,	β⁻~1.65 γ.125, 18	β⁻~2.5						
E~3.5	E1.8							

<div align="center">92   94   96</div>

		84	86	88	90	92	94	96
76						Os 190.2 σ_a 15			
75						Re 186.2 σ_a 87			
74						W 183.85 σ_a 18			
73						Ta 180.948 σ_a 22			
72	Hf 178.49 σ_a 106	Hf 157 0.12s a 5.68	Hf 158 3s a 5.27						Hf 168 22m β^+ 2 γ 13, 37
71	Lu 174.97 σ_a 74	Lu 155 0.07s a 5.61	Lu 156 0.23s ~0.5s a 5.54 a 5.43						Lu 167 55m ϵ, β^+ 15, γ 030, 239, 056-40 E3.0
70	Yb 173.04 σ_a 37	Yb 154 0.39s a 5.33	Yb 155 1.6s a 5.21			Yb 162 ~23m ϵ γ 041	Yb 163 11m	Yb 164 77m ϵ β^+ 29	Yb 165 10m β^+ 158, γ 080, 069, 1.09 E 2.7	Yb 166 57h ϵ γ 082 e^- E 3
69	Tm 168.934 σ_a 115	Tm 153 1.58s a 5.1	Tm 154 2.98s 5s a 5.04 a 4.96			Tm 161 30m ϵ γ 046-373 E 3.5	Tm 162 79m 22m ϵ, β^+ γ 102, 24 γ 102, E 4.9	Tm 163 1.8h ϵ, β^+ 1, 4 3.8,9 γ 104, 242, 022 180 E2.27	Tm 164 1.9m β^+ 2.94, γ 091, 21- 2 38 E 3.96	Tm 165 9μs 30h γ 080, 031 ϵ, β^+ 30 80μs γ 054, 243 IT 069 016-143 β^+ ? E2.7 E1.57

Os 187	Os 188	Os 189	Os 190	Os 191	Os 192	Os 193	Os 194	Os 195		
1.64	13.3	16.1	26.4	15.5d	41.0	31 h	6.0 y	6.5 m		
186.9558	187.9561	188.9583	189.9586		191.9615			E 2.0		

Re 186	Re 187	Re 188	Re 189	Re 190	Re 191	Re 192				**122**
	62.93			2.8h 3m	10m	65				
186.9558	186.9558									

W 185	W 186	W 187	W 188	W 189			**118**	**120**	
	28.41	23.9h	69d	11.5m					
	185.9544		E.349	E 2.5					

Ta 184	Ta 185	Ta 186		
8.7h	49m	10.6m		

Hf 183			

112 **114** **116**

				Os 179	Os 180	Os 181	Os 182	Os 183	Os 184	Os 185	Os 186
					24s	2.8m 105m	21.5h	9.9h 14h	0.018	94d	1.59
									183.9527	E 98	185.9539

			Re 178	Re 179	Re 180	Re 181	Re 182	Re 183	Re 184	Re 185
				20m	2.45m	19 h	12.7h 64h	10ms 70d	165d 38d	37.07
										184.9531

W 173	W 174		W 176	W 177	W 178	W 179	W 180	W 181	W 182	W 183	W 184
16m	29m		2.5h	2.2h	21.5d	38m 5.4ms	0.14	130d	26.41	5.2s 14.4	30.64
									181.9483	182.9503	183.9510

Ta 172	Ta 173		Ta 175	Ta 176	Ta 177	Ta 178	Ta 179	Ta 180	Ta 181	Ta 182	Ta 183
44m					8.1h	9.1m 2.2h	1.8h 600d	8.13h 0.0123	99.988	15.9m 115d	5.0d
									180.9480		

Hf 169	Hf 170	Hf 171	Hf 172	Hf 173	Hf 174	Hf 175	Hf 176	Hf 177	Hf 178	Hf 179	Hf 180	Hf 181	Hf 182
1.5h	12h	4h			0.17		5.20	18.5	13.75	5.5h 35.24	42.4d	9×10⁶y
									178.9460				

Lu 168	Lu 169			Lu 173	Lu 174	Lu 175	Lu 176	Lu 177	Lu 178	Lu 179	Lu 180
7m 2.0m	2.7m			1300d	97.41	2.59	161.0d 67d	20m 30m	4.6h	2.5m
				174.9406					E.135	E3.3	

Yb 167	Yb 168	Yb 169	Yb 170	Yb 171	Yb 172	Yb 173	Yb 174	Yb 175	Yb 176	Yb 177
5m	0.135	46s	14.31	21.82	31.84	16.13	12.73			6.41s 1.9h
	167.934					173.9387			175.9427	

Tm 166	Tm 167	Tm 168	Tm 169	Tm 170	Tm 171	Tm 172	Tm 173	Tm 174	Tm 175	Tm 176		**110**
7.7h	9.3d		100			8.2h	5.5m	16m	1.4m			

98 **100** **102** **104** **106** **108**

Z / Element	N=94	95	96	97	98	99	100	101	102	103	104	105	106
81 Tl 204.37 σ_a 3.7													
80 Hg 200.59 σ_a 3.7×10²						Hg179 3.5s α6.08	Hg180 6s α5.96	Hg181 3.6s α6.00,5.91	Hg182 10s β+,ε α5.85	Hg183 9s β+,ε α5.91,5.83	Hg184 32s β+,ε γ.157,.257 α5.54	Hg185 52s β+,ε α5.65,5.57	Hg186 1.4m β+ γ..25 α5.5
79 Au 196.967 σ_a 98.8					Au177 1.3s α6.12	Au178 3s α5.92	Au179 7.5s α5.85		Au181 11s α5.62,5.48		Au183 49s α5.34	Au184 1.0m β+ γ163,273,357 α5.07	Au185 4.3m α5.07
78 Pt 195.09 σ_a 10		Pt173 Short α6.19	Pt174 0.7s α6.93	Pt175 2.1s α5.95	Pt176 6.6s α5.73	Pt177 6.9s α5.52	Pt178 21s α5.44	Pt179 33s α5.15	Pt180 52s α5.14	Pt181 51s α5.02	Pt182 2.9m ε α4.84	Pt183 7m ε α4.73	Pt184 10ms 42m 18m α4.68
77 Ir 192.2 σ_a 426	Ir171 1.0s	Ir172 2s	Ir173 3s α5.67	Ir174 4s α5.48	Ir175 5s α5.39	Ir176 8s α5.12	Ir177 21s α5.11				Ir181 Short	Ir182 15m β+ γ13,28	Ir183 58m γ24
76 Os 190.2 σ_a 15							Os176 3.6m γ276,129,857		Os178 5m	Os179 8m	Os180 24m	Os181 2.8m,105m	Os182 <1m 21.5h

Column markers (bottom): 94   96   98   100   102   104   106

Top section

Tl 201	Tl 202	Tl 203	Tl 204	Tl 205	Tl 206	Tl 207	Tl 208	Tl 209	Tl 210
1.9ms / 73h	0.54ms / 12.2d	29.50	62µs / 3.80y	70.50	RaE" 4.21m	AcC" 4.77m	ThC" 3.06m	2.2m	RaC" 1.3m
IT 22, 58 γ 167, 331, 135,166	IT 460 ε 490 γ 44, 22	σ 11.0 202.97235	β⁻ .763 γ 761 204,97444	σ .7	β⁻ 1.52 noγ E1.524	β⁻ 1.44 γ 90 E 4.995	β⁻ 1.80, 64-2.38 γ 2.615, 583, 511, .04 109 E 3.93	β⁻ 1.8 γ 120, 45, 1.56	β⁻ 1.9, 1.3, 2.3 γ 79, 30, 0.1-2.43 E 5.47

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Hg 200	Hg 201	Hg 202	Hg 203	Hg 204	Hg 205	Hg 206
23.13	94µs / 13.22	29.80	2.1µs / 46.6d	6.85	5.5m	8.2m
σ <60 199.96833	IT 1.55, 27 σ <80 200.97038	σ 4.8 201.97064	γ 58 β⁻ 2.2 γ 279 203.97350	σ .4	β⁻ 1.4 γ 205 E 1.7	β⁻ γ 305, 65

128   130

Au 199	Au 200	Au 201	Au 202	Au 203	Au 204
4.4ms / 3.15d	19h / 48.4m	26m	29s	55s	4s
γ .055,.094 β⁻ .30, γ 1583, 2082, .49%	β⁻ 2.2, γ 368, 580, 256	γ 63	β⁻ .55	β⁻ γ 44, 52	β⁻ 4.5 γ 69

Pt 198	Pt 199	Pt 200	Pt 201
7.21	14.1s / 31m	12h	2.5m
σ γ (27mb + 4.0) 197.9679	γ .392 β⁻ 1.7 γ 543, 1.9	β⁻ .66	β⁻ γ 1.76

124   126

Ir 197
7m
β⁻ 2.0, 1.5 γ .50 E 2.0

120   122

Bottom section

Tl 191	Tl 192	Tl 193	Tl 194	Tl 195	Tl 196	Tl 197	Tl 198	Tl 199	Tl 200
10m	11m / 10m	2.1m / 23m	32.8m / 34m	3.6s / 1.17h	1.4h / 1.8h	0.54s / 2.83h	1.87h / 5h	28.7m / 7.4h	34ms / 26.1h
ε	ε	ε γ 365	ε γ 426	γ 383 γ .037	γ 152 ε β⁻ E 4.6	IT 222 γ 385	IT 261	IT 0.21	IT 0.21 β⁻

Hg 187	Hg 188	Hg 189	Hg 190	Hg 191	Hg 192	Hg 193	Hg 194	Hg 195	Hg 196	Hg 197	Hg 198	Hg 199
3m	3.7m	8.7m	20m	56m		11h / 4h	520y / 4h	0.40s / ~13y	0.146	23.8h / 64.1h	10.02	43m / 16.84
β⁺ γ 40 α 5.14.2	β⁺ α 5.14	γ 0.14, 19, 195				γ 380	γ .048, 184	40h / 9.5h	σ (120+3.0×10⁴)	ε γ .077D	σ (18mb+?)	IT 0.21

Au 186	Au 187	Au 188	Au 189	Au 190	Au 191	Au 192	Au 193	Au 194	Au 195	Au 196	Au 197	Au 198
12m	0.14s / 8m	8m	4.6m / 30m	42m	3.2h	4.7h	3.9s / 17.6h	9.7h / 176d	30.5s / 184d	9.7h / 6.18d	75s / 100	2.696d
ε β⁺ γ 16, 22, 30, 41	ε β⁺	γ 22, 34, 61	β⁺	β⁺ γ 301	ε β⁺ 239, 210	γ 290	IT 0.32	ε β⁺ 1.49 γ 258	IT 1.057 γ .261	IT 1.175 γ .144, 188	IT 1.30 γ 279	β⁻ .96, .29, 1.37 σ 2.6×10⁴

Pt 185	Pt 186	Pt 187	Pt 188	Pt 189	**Pt 190**	Pt 191	Pt 192	Pt 193	Pt 194	Pt 195	Pt 196	Pt 197
1.1h	2.3h	2.5h	10.2d	11h	**45µs / 0.0127**	107µs / 3.0d	0.78	<3d / <500y	32.9	4.1d / 33.8	25.3	80m / 20.0h
γ .035, 63, 156	α 4.23 γ 065, 14, 19, 68, 140	β⁺ γ 110, 106, 180, 122	γ 195, 188, 423		7×10¹¹y α 3.18 σ ~90 189.9600	IT 0.91 γ 539 σ (2+<1) 191.9612		IT 1.30 γ .013 noγ E .05	σ (.09+1.1) 193.9627	IT 0.099 σ 27 194.9648	σ (.05+.9) 195.9650	IT 0.347 γ .099, .031, 279

Ir 184	Ir 185	Ir 186	Ir 187	Ir 188	Ir 189	Ir 190	Ir 191	Ir 192	Ir 193	Ir 194	Ir 195	Ir 196
3.2h	14h	1.7h / 15h	2.4ms / 11.2h	41.4h	12ms / 13.3d	3.1h / 12d	4.9s / 37.3	~650y / 74.3d	12d / 62.7	31ms / 17.8h	4.1h / 2.8h	53s / 1.40h
ε β⁺ γ 264, 120, 391	γ .024, 667	β⁺ 1.93 γ 137, 434, 071	γ 137	β⁺ 1.66 γ 155, 633, .478	γ 110, 167, 245	IT 1.042 γ 187, 558, 187	IT 0.171 γ 047, 082	IT 0.058 γ 205, 489	IT 0.080	σ 11×10²	IT 1.00 γ 33, 29, 59-211	β⁻ .394 γ 355, 779, 333, 521

Os 183	Os 184	Os 185	Os 186	Os 187	Os 188	Os 189	Os 190	Os 191	Os 192	Os 193	Os 194	Os 195
9.9h / 14h	0.018	94d	1.59	2.34µs / 1.64	13.3	5.9h / 16.1	9.9m / 26.4	13.0h / 15.5d	41.0	31h	6.0y	6.5m
IT 1.71 γ 382, 115, 145, 067	σ 3.0×10³	γ 65, 88, 87, .072-.72 E 98		IT 0.1		IT 0.030 σ (10+3)	σ .074 γ 138, 187, 1294	σ 2.0		β⁻ 1.13, 1.06 γ 461, 139, 559, 281, 073-874	β⁻ .097, .054 γ .043	β⁻.2

108   110   112   114   116   118

	86	**Rn** (box)			Rn200? 3s α6.77	Rn201 3s α6.72	Rn202 11s α6.64	Rn203 28s|45s α6.55|α6.50	Rn 204 75s α6.42 203.99
	85	**At** (box)	At194 Short	At195 Short	At196 0.3s α7.06	At197 0.4s ε α6.96	At 198 1.5s|5s ε α6.85|α6.75	At199 7s α6.64	At200 4.3s|42s α6.54|α6.41 n.46	At 201 1.5m α6.34	At 202 2.6m?|3.0m α6.13	At 203 7.4m ε α6.09
	84	**Po** (box)	Po192 0.5s α6.58	Po 193 Short α6.98	Po 194 0.6s α6.85	Po 195 2.0s|5s α6.70|α6.61	Po 196 ~5.5s α6.52	Po 197 26s|56s α6.58|α6.28	Po 198 1.75m α6.18	Po 199 4.2m|5.2m α6.06|α5.95	Po 200 11.5m α5.80	Po201 9.0m|15.4m α5.78|α5.64	Po 202 44m α5.58
	83	**Bi** 208.980 σ_a 34mb	Bi190 ? α6.5	Bi191 ?|14s α6.9|α6.31	Bi192 ~40s α6.05	Bi193 3.2s|~70s α6.5|α5.89	Bi194 85s α5.6	Bi195 ~60s|2.5m α6.10|α5.4	Bi196? 7.8m γ5.8?	Bi197? 1.7m α6.2	Bi198 11.9m	Bi199 24.7m α5.50	Bi200 35m	Bi201 53m|11m α5.25|γ629
	82	**Pb** 207.19 σ_a 18					Pb 194 11m γ204	Pb 195 17m γ0990,385	Pb 196 37m γ192,240,253	Pb197 42m ? γ.184	Pb 198 2.4h γ173,240,.031,865	Pb199 12.3m	5h	Pb 200 21h γ148,142,235,268,033,45
	81	**Tl** 204.37 σ_a 3.7				Tl 191 10m ε	Tl 192 11m|10m ε γ11,42	Tl193 2.1m|23m|32.8m|34m IT<.025 γ365 γ24,25,26,27~33 γ097 γ43	Tl 194 3.6s|1.17h IT.099 ε,β⁺~1.8 γ383 γ037 226 88	Tl195 14h|18h ε γ084 IT.120 γ034,241,275	Tl196 0.54s|2.83h IT 222 γ152 .018 101	Tl197 1.87h|5h ε,γ.048 γ283	Tl198 28.7ms|7.4h IT 383 .029 γ455 367 35 γ412 195 γ72 247 158 ε,γ 035 49

106   108   110   112   114   116   118

Rn 217 5ms	Rn 218 35ms	Rn 219 AcEm 3.96s	Rn 220 Tn 55.6s	Rn 221 25m	Rn 222 Rn 3.824d	Rn 223 .7h	Rn 224 1.9h	Rn 225 4.5m	Rn 226 6m		
α 7.74 217.0039	α 7.1 2.8.0056		α 6.288,5.747 γ .62 220.0114	β⁻ α	α5.486, γ .51 ν~.72 222.0175	β⁻ α	β⁻	β⁻	β⁻	**140**	**142**
At 216 35ms	At 217 32ms	At 218 2s	At 219 0.9m						**138**		
α 7.80 216.0	α 7.07 γ 217.0046	α 6.69 218.0086	α 6.27 β 219.0113			**136**					
Po 215 AcA 1.78ms	Po 216 ThA .15s	Po 217 <10s	Po 218 RaA 3.05m								
α 7.38 γ .44 214.9994	α 6.78 216.0019	α 6.54	α 6.00,5.179 β 218.0089								
Bi 214 RaC 19.8m	Bi 215 7.4m				**134**						
α 5.44,5.51,5.45 β γ 214.	β 215.2										
Pb 213 10.2m	Pb 214 RaB 26.8m										
β γ 295.055	β γ 214.										

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Rn 205 2.8m	Rn 206 6.3m	Rn 207 11m	Rn 208 22m	Rn 209 30m	Rn 210 2.4h	Rn 211 15h	Rn 212 25m	Rn 213 19ms	Rn 214 Short	Rn 215 ~1µs	Rn 216 .05ms
α 6.26 204.93	α 6.27 205.94	α 6.13 ε=4.8	ε α 6.15	ε α 6.04	α 5.54 206.9907	β⁻ α 210.9907	α 6.27 210.9907	α 8.09 212.9939	α 9.04 214.00	α 8.67 214.999	α 8.05 no γ 216.0003
At 204 9.1m	At 205 26m	At 206 2.8h 31m	At 207 1.79h	At 208 6.2h	At 209 5.5h	At 210 8.3h	At 211 7.2h	At 212 0.12s 0.22s	At 213 Short	At 214 ~2µs	At 215 .10ms
ε α 5.95 E~7.1	ε α E~4.9		ε α 5.76			ε α 5.45	ε α 5.86 211.990	α 7.82 7.88 .06 212.993	α 9.07 213.9963	α 8.78 214.9987	α 8.00,7.60 γ~.40
Po 203 30m	Po 204 3.5h	Po 205 64ms 1.8h	Po 206 10d	Po 207 5.7h	Po 208 2.896y	Po 209 103y	Po 210 RaF 138.40d	Po 211 AcC' 45s 25s	Po 212 ThC' 0.304µs	Po 213 4µs	Po 214 RaC' 164µs
ε α 5.58 E~4.5	α 5.38 γ .88 E~2.5	α 5.22	α 5.22 207.98	α 5.12 206.9828	α 4.88	α 4.88	α 5.305 γ .80 209.9828	α 7.44, γ .06 .57 211.98887	α 8.785, .89 212.9928	α 8.38,7.62 .79 213.99520	α 7.688,6.89 γ .79
Bi 202 95m	Bi 203 11.8h	Bi 204 11.3h	Bi 205 15.31d	Bi 206 6.24d	Bi 207 30y	Bi 208 2.57ms 3.68x10⁵y	Bi 209 100	Bi 210 RaE 5.01d	Bi 211 AcC 2.14m	Bi 212 ThC 60.60m	Bi 213 46m
ε β⁺ γ 422,.96 α 4.85	ε β⁺ γ .35,.74		ε γ .79		ε γ 1.92	γ 1.05	>2x10¹⁸y	β 1.16 β 60 210.9873	α 6.622,6.278, γ .351 β .60	α 6.05,6.09, γ .727,.785 .180	β 1.42,1.02 α 5.87,5.55 E 1.42
Pb 201 61s 9.4h	Pb 202 3.6h ~3x10⁵y	Pb 203 6.2s 52.1h	Pb 204 66.9m 1.48	Pb 205 3x10⁷y	Pb 206 23.6	Pb 207 0.80s 22.6	Pb 208 52.3	Pb 209 3.31h	Pb 210 RaD 22y	Pb 211 AcB 36.1m	Pb 212 ThB 10.64h
γ 350 E 1.4	γ .44 .49 E .82	γ .279 E 1.0	IT .90 α 2.6 203.97304	γ 2.6 .048		γ 1.06 .57 206.97590		β .64	β .015,.061 γ .0465	β 1.37,.55, γ .405,.832,427 065-.270	β 34,.58, γ .239,.300,.115 E .58
Tl 200 34ms 26.1h	Tl 201 19ms 73h	Tl 202 0.58ms 12.2d	Tl 203 29.50	Tl 204 3.80y	Tl 205 70.50	Tl 206 4.21m	Tl 207 AcC" 4.77m	Tl 208 ThC" 3.06m	Tl 209 2.2m	Tl 210 RaC" 1.3m	
ε β⁺ γ 1.22, .331 .135 E 1.44	IT 1.22, γ 167, .135	IT .460 γ .490	IT α 1.0 202.97235	γ 204.97444	σ₇	β 1.53 204.9	β 1.44 γ .90	β 1.80,.64 γ 2.615,.58, .04 .09	β 1.8 γ 120,45,1.56	β 1.9,1.3,2.3 γ 79,.30,.01-2.43 E 5.47	

| 120 | 122 | 124 | 126 | 128 | 130 |

Z	112	113	114	115	116	117	118	119	120	121	122	123	124	125
90											Th 232.038 σ₀ 7.4	Th213 .15s α7.69	Th214 .13s α7.68	Th215 1.2s α7.39,7.52, 7.33
89							Ac		Ac209 0.1s α7.58	Ac210 ~0.35s α7.46	Ac211 ~0.25s α7.48	Ac212 ~0.93s α7.38	Ac213 0.8s α7.36 213.01	Ac214 8.2s α7.21,7.08, 7.00 214.01
88					Ra		Ra206 0.4s α7.27	Ra207 1.3s α7.13	Ra208 1.2s α7.13	Ra209 4.7s α7.01	Ra210 3.8s α7.02	Ra211 15s α6.91 211.001	Ra212 13s α6.87 212.000	Ra213 2.7m α6.62,6.73, ε52 213.000
87			Fr		Fr203 0.7s α7.13	Fr204 2.2s / 3.3s α7.03/6.97	Fr205 3.7s α6.92	Fr206 15.7s α6.79 206.00	Fr207 15s α6.77 207.00	Fr208 38s α6.65 208.00	Fr209 54s α6.65 209.00	Fr210 3.0m α6.57 210.00	Fr211 3.08m α6.53	Fr212 19m α6.26,6.38,6.41, 6.34 ε~5.2
86	Rn		Rn200? 3s α6.77	Rn201 3s α6.77	Rn202 11s α6.64	Rn203 28s / 45s α6.5?/6.50	Rn204 75s α6.42 203.99	Rn205 2.8m α6.26 204.99	Rn206 6.3m ε α6.26 205.99	Rn207 11m ε α6.13 ε~4.8	Rn208 22m ε α6.15 ε~5.0	Rn209 30m ε α6.04 ε~4.0	Rn210 2.4h ε α6.04 209.9895	Rn211 15h γ.032÷1.80 α.578,.585,5.62 γ.069,.17,.23 ε2.89

Bottom axis (neutron number): **112 114 116 118 120 122 124**

Pa230 17.7d	Pa231 3/2- Pa 3.24×10⁴	Pa232 1.32d	Pa233 27.0d	Pa234 UX₂ UZ 1.17m 6.66h	Pa235 24m	Pa236 12m β⁻3.3	Pa237 39m		
Th229 7340y	Th230 Io 7.8×10⁴y	Th231 UY 25.52h	Th232 Th 100	Th233 22.2m	Th234 UX₁ 24.10d	Th235 <3m			**150**
Ac228 MsTh₂ 6.13h	Ac229 1.1h	Ac230 <1m	Ac231 15m					**148**	
Ra227 41.2m	Ra228 MsTh₁ 5.75y	Ra229 <5m	Ra230 ≤1h						
Fr226 1.4m					**144**		**146**		
Rn225 4.5m	Rn226 6m								
140		**142**							

91	Pa	Pa224 0.6s	Pa225 ~1s	Pa226 1.8m	Pa227 (5/-) 38.3m	Pa228 (3+) 26h	Pa229 (5/-) 1.4d

Th216 25ms	Th217 <5ms			Th220	Th221 1.7ms	Th222 ~2.8ms	Th223 0.6s	Th224 1.1s	Th225 8m	Th226 31m	Th227 RdAc 18.72d	Th228 RdTh 1.913y
Ac215 0.17s	Ac216 0.38ms–0.38ms		Ac218 Short	Ac219 Short	Ac220 24ms	Ac221 0.05s	Ac222 5s	Ac223 2.2m	Ac224 2.9h	Ac225 10.0d	Ac226 29h	Ac227 Ac 21.772y
Ra214 2.6s	Ra215 1.56ms	Ra216 <1ms	Ra217 <0.3ms	Ra218 Short	Ra219 10ms	Ra220 ~23ms	Ra221 29s	Ra222 38s	Ra223 AcX 11.43d	Ra224 ThX 3.64d	Ra225 14.8d	Ra226 Ra 1602y
Fr213 34.7s	Fr214 3.4ms 50ms	Fr215 <<1ms	Fr216 Short	Fr217 Short	Fr218 ~5ms	Fr219 21ms	Fr220 28s	Fr221 4.8m	Fr222 15m	Fr223 AcK 22m	Fr224 2.7m	Fr225 3.9m
Rn212 25m	Rn213 19ms	Rn214 Short	Rn215 ~1µs	Rn216 0.5ms	Rn217 5ms	Rn218 45ms	Rn219 An 3.96s	Rn220 Tn 55.6s	Rn221 25m	Rn222 Rn 3.824d	Rn223 .7h	Rn224 1.9h

126	**128**	**130**	**132**	**134**	**136**	**138**

100

Fm | Fm244
~3.3ms
SF

99

Es

98

Cf | Cf241
?
a 7.31 | Cf 242
3.4m
a 7 36

97

Bk

96

Cm | Cm 238
2.5h
ε
a 6 51
238.0530 | Cm239
2.9h
ε
γ 188
E ~ 17 | Cm240
26.8d
a 6 29,
SF
240.0555

95

Am | Am232
1.4 m
SF ?
ε ? | Am234
2.6m ?
SF | Am 237
~1.3h
ε
a 6.02
E 1.4 | Am238
1.6ms 1.9h
SF
γ 98, 58, 36,
95, 1.35
E ~ 2.3 | Am239 (5/-)
12.1h
ε
γ 278, 228,
.045-.227
a 5.78
γ 048 E 81

94

Pu | Pu 232
36m
ε
a 6.58
232.0412 | Pu 233
20m
ε
a 6.3
233 0430 | Pu 234
9h
ε
a 6 20, 6 15,
γ .05
E ~ 43
234.0433 | Pu 235
26m
ε
a 5.86
E 13 | Pu236
2.85y
γ 145, ε
a .047, 2
SF
236.0461 | Pu237 7/+
0.18s 45.6d
IT 145, ε 34,.998
a .54,546,..
SF
237.0483 | Pu 238
87.4 y
a5.50,5.46,
γ.044,.100-8r
SF
238.0495

93

Np | Np 227
or 228
1.0m
SF | Np 229
40m
a 6 89 | Np230
4.6m
a 6 66
ε ?
230.04 | Np 231
~50m
ε
a 6 29
231.0583 | Np 232
~13m
ε
γ
ε ~2.5 | Np 233
35m
ε
a 5.54
t ~.7
233.0407 | Np234
4.4d
ε
γ .043-.61
E 1.8 | Np235 5/+
>5×10³y 22h
a 452-4.87
γ .045
E .13 | Np 236
>5×10³y
ε, β⁻
γ .160-.643
.045, ε
.57
1.92 236.0466 | Np237 5/+
2.14 ×10⁶y
a 452-4.87,
γ.029-.2-
σ₁169, σ_f.018
237.0481

92

U | U
238.03
σ₀ 7.6
σ_f 4.18 | U227
a 6 87
227.0309 | U 228
9.1 m
a 6.68,6.59,
γ.25,.19, .15,
ε .56
228.0314 | U 229
58m
ε
a 6.36,6.33,6.30,
ε 1.56
229.035 | U230
20.8d
a 5.89,5.82,
γ .05
231.0339 | U231
4.3d
ε
γ
a 5.45
231.0359 | U232
72y
a 5.32,5.26,5.14,
γ .058
SF
232.0372 | U 233
1.59 ×10⁵y
a 4.82,4.79,
γ .042
σ_f 527
233.0395 | U234
UII 0.0057
σ₀ 99.6 2.47×10⁵
a 4.77,4.72,
γ.053,.121
SF 234.0409 | V+U235 7/-
26.1m AcU
7.1×10⁸y SF
a 4.39,4.58, γ.19,
σ .98 σ_f 580
235.0439 | U236
2.42 ×10⁷y
a 4.49,
γ .05
SF
236.0456

91

Pa | Pc224
0.6s
a | Pa 225
~1s
a 7.25
225.03 | Pa 226
1.8m
a 6.86,6.82,
ε
E 2.78
226.028 | Pa 227 (5/-)
38.3m
a 6.47,6.42,
γ.065,
ε
E 1.00
227.0288 | Pa 228 (3+)
26h
γ .058, .189
a 6.08,5.71,6.14
ε 32
E 2.10
228.0310 | Pa 229 (5/-)
1.4 d
γ .0424
a 5.58,5.67,
γ .32, 5.74
ε
γ .026-.074
E .35 | Pa 230
17.7d
ε
γ .055
β⁻?
a 4.76 5.5
γ 1500 ε 1, .951.462 | Pa 231 5-
Pa 3.24×10⁴y
a5.01,4.50-5.05,
γ .019-.38,
σ_f .201,σ 01
231.0359 | Pa 232
1.32 d
β⁻ 32,
γ .0476,.040-.371,
σ_f .760 σ .700
E 1.35 | Pa 233 3/-
27.0d
β 26, 15, 57,
.312, γ.0172-.416,
σ .100-191,σ_f <1
E .569 | Pa 234
UX₂ UZ
1.17m 6.66h
β 2.29,..β .51,
.043,..γ .043, 94,
IT.07, 970,
γ .9 < 500 234.0433 E 4.

132   134   136   138   140   142   144

105 — 260? >10ms α9.7 | 261? 0.1–3s α9.4

104 — 257 ~4.5s α9.00,8.95,8.78, 8.70 / SF | 258? 11ms SF | 259 ~3s α8.77,8.86 | 260? 0.3s SF | 261? ~1m α8.2–8.3

103 (Lr) — Lr 256 ~35s α8.4 | Lr 257 ? α8.5–8.6 | Lr 258 or 259 8s 257.10

102 (No) — No 251 0.8s α8.60,8.68 | No 252 2.4s α8.41 SF | No 253 1.6m α8.01 253.091 | No 254 56s α8.1 SF 254.091 | No 255 3.0m α8.08 255.09 | No 256 3.2s α8.43 SF | No 257 23s α8.23,8.27

101 (Md) — Md 252 8m ε | Md 255 28m ε α7.34 Eα.85 255.0906 | Md 256 1.3h ε α7.18 | Md 257 ~5h ε α7.08 SF | Md 258 5.4d α6.73,6.78

Fm (100) — Fm 245 4s α8.5 | Fm 246 1.3s α8.24 SF | Fm 247 9s|35s α8.18|7.93 SF | Fm 248 .61m α7.87,7.83 SF 248.0771 | Fm 249 ~26m α7.53 249.079 | Fm 250 30m α7.43 250.0795 | Fm 251 7h α6.9 γ.41 Eα1.2 | Fm 252 23h α7.04,7.00 SF 252.0826 | Fm 253 2.6d α6.95,6.68, γ.145,.272 E.19 | Fm 254 3.24h α7.20,7.16,7.06 γ.041,.098,.15 SF 254.0868 | Fm 255 20.1h α7.02,6.97,6.41,7.13 γ.081,.059, SF σγ26 255.09 | Fm 256 2.63h SF α6.9 | Fm 257(9/+) 80d α6.52,6.70,6.44, γ.062,.18,.24, SF | Fm 258 <0.2s SF

Es (99) — Es 245 1.3m ε α7.70 Eν2.9 | Es 246 7.7m ε α7.33 Eν3.4 | Es 247 5.0m ε α7.33 Eν2.3 | Es 248 25m ε α6.88 Eν2.8 | Es 249 2h ε α6.77 E1.41 249.0763 | Es 250 8h F ε α6.48 Eν6 251.0799 | Es 251 1.5d ε α6.77 Eν2.1 | Es 252(7+) ~140d α6.64,5.9– 6.6 γ.40,.07–.57 252.0828 | Es 253 20.5d α6.64,5.73–6.63 γ.041,.0088–.90 SF σ.(180+141) 253.0847 | Es 254 39.3h|276d α6.48,113– α6.44 γ.648,.044 SF σγ~40 254.087 | Es 255 39d β⁻.19 α6.31,6.27,6.22 SF σγ~40 | Es 256 22m β⁻ | Es 257 <20h β⁻

Cf (98) — Cf 243 11m ε α7.06,7.17 | Cf 244 20m α7.21 | Cf 245 44m ε α7.14 E1.52 | Cf 246 36h α6.76,6.72, γ.042,.096,.146 SF 246.0688 | Cf 247 2.5h ε α5.95,42,46 Eν.9 | Cf 248 350d α6.27, SF 248.0723 | Cf 249(9/–) 352y α5.81,5.90,5.93, 6.20, γ.388,.333,.253, 49.0747 | Cf 250 13.1y α6.03,5.84,6.01, γ.043 σ.1~3000 250.0764 | Cf 251(1/+) 900y α6.12,6.08, γ18,.22 σγ~1500 251.08 | Cf 252 2.65y α6.12,6.08, γ.043,.100, SF σγ20 252.08 | Cf 253 17.6d β⁻ α5.98,5.92 σγ~165 E.27 | Cf 254 60d SF α5.83,5.79 σγ<2

Bk (97) — Bk 243 4.6h ε α6.57,6.54,6.18 6.76, γ187,.04,.55 E1.49 | Bk 244 4.4h ε α6.67,6.62 Eν2.2 | Bk 245(3/–) 4.98d ε α6.35 γ.253,.381,.385 γ.207,.47,.166 E.84 245.0663 | Bk 246 ? 1.8d ε | Bk 247 1.4×10³y α5.52,5.68,5.51 γ.084,.27 247.0703 | Bk 248 >9y β⁻.65 SF | Bk 249(7/+) 311d β⁻.125 α5.41, γ.327,.308 σγ~1000 249.0747 | Bk 250 3.22h β⁻ .73,.176 γ.99,.103, .184 | Bk 251 57m β⁻~5,~1.0 γ.037,.094,.140, .184

Cm (96) — Cm 241(1/+) 35d ε α5.94,5.73–6.08 γ.45 E.77 | Cm 242 163d α6.11,6.07, γ.044 SF σ.20 242.0588 | Cm 243 32y ε α5.99,5.74,5.79, γ.228,.278,.21, SF σ.250 243.06.14 | Cm 244 18.1y α5.80,5.76, γ.043 SF σ.250 244.0628 | Cm 245 8.5×10³y α5.36,5.30, γ.133,.175, σ.2000 245.0654 | Cm 246 4.71×10³y α5.38,5.34 SF σ.1.3 246.0672 | Cm 247 25μs·1.6×10⁷y γ.22 σ.1.80 247.07 | Cm 248 3.52×10⁵y α5.08,5.04 SF σγ.7 248.02 | Cm 249 64m β⁻ σγ~2 E.9 | Cm 250 1.1×10⁴y β⁻ SF | Cm 252 ≤2d

Am (95) — Am 240 0.9ms·51h SF γ.043,.099, 99,.89, Eν1.3 | Am 241 433y α5.49,4.44–5.51 γ.060,.026 SF σ.742 241.056 | Am 242 16ms|152y β⁻ γ.049 σ.5800 242.06 | Am 243 7370y α5.28,5.23 γ.075, 243.061 | Am 244 9ms|10.1h 26m β⁻ γ.744,.90, 043, Eν.903 | Am 245(5/+) 2.04h β⁻.90, γ.036,.252, .240,.296, 245.06 | Am 246 2⁺ 39m|25.0m β⁻1.31,1.60, 2.10 γ680, 205, 7.08,.80, 154, 17–1.74 246.06 | Am 247 22m β⁻ γ.285,0.226 E~1.7

Pu (94) — Pu 239 24,390y α5.15,5.11, γ.052,.038–.77 SF σ.271 239.052 | Pu 240 6600y α5.17,5.12, γ.045,.104–.688 SF σγ.280 240.0539 | Pu 241(5/+) 14.3y β⁻.021 α4.90,4.85, γ.149,.111, σ.1400 242.087 | Pu 242 3.87×10⁵y α4.90,4.86, γ.04 σ.18 242.087 | Pu 243(7/+) 4.96h β⁻.58,.49 γ.84,.042,.112 E.56 244.06 | Pu 244 8.3×10⁷y α4.59,4.54 SF 244.06 | Pu 245 10.5h β⁻.93,1.21 γ.327,.560,.308, 376,.028–1.12 E1.26 | Pu 246 10.85d β⁻15,.33 γ.044,.027– .225 E.40

Np (93) — Np 238 2.12d β⁻.24,.25, γ.44 E.39 | Np 239 2.35d β⁻.44 γ.045–.50.4 σ.,35 E.72 | Np 240 7.5m|65m β⁻2.18,.89 γ.043,.55,.085 26–1.62|.116 E2.18 | Np 241 16.0m β⁻1.3 γ.13,.18 E1.4

U (92) — U 237 6.75d β⁻.23,.25, γ.095,.208,.014– .37 E.514 | U 238 UI 99.27 SF 4.51×10⁹y α4.20, γ.048 σ.2.73,σ.<5mb 238.0508 | U 239(5/+) 23.5m β⁻1.21,1.28, γ.047,.435.031– E1.28 | U 240 14.1h β⁻.36 γ.044 E.48

Pa (91) — Pa 236 12m β⁻3.3 E3.4 | Pa 237 39m β⁻2.30,1.35, γ.46,.92,.09– 1.4 E2.30

Bottom neutron-number axis: 146 | 148 | 150 | 152 | 154 | 156 | 158

LIST OF ATOMIC ELEMENTS

Actinium	Ac	89	Mercury	Hg	80
Aluminum	Al	13	Molybdenum	Mo	42
Americium	Am	95	Neodymium	Nd	60
Antimony	Sb	51	Neon	Ne	10
Argon	Ar	18	Neptunium	Np	93
Arsenic	As	33	Nickel	Ni	28
Astatine	At	85	Niobium	Nb	41
Barium	Ba	56	Nitrogen	N	7
Berkelium	Bk	97	Nobelium	No	102
Beryllium	Be	4	Osmium	Os	76
Bismuth	Bi	83	Oxygen	O	8
Boron	B	5	Palladium	Pd	46
Bromine	Br	35	Phosphorus	P	15
Cadmium	Cd	48	Platinum	Pt	78
Calcium	Ca	20	Plutonium	Pu	94
Californium	Cf	98	Polonium	Po	84
Carbon	C	6	Potassium	K	19
Cerium	Ce	58	Praseodymium	Pr	59
Cesium	Cs	55	Promethium	Pm	61
Chlorine	Cl	17	Protactinium	Pa	91
Chromium	Cr	24	Radium	Ra	88
Cobalt	Co	27	Radon	Rn	86
Copper	Cu	29	Rhenium	Re	75
Curium	Cm	96	Rhodium	Rh	45
Dysprosium	Dy	66	Rubidium	Rb	37
Einsteinium	Es	99	Ruthenium	Ru	44
Erbium	Er	68	Samarium	Sm	62
Europium	Eu	63	Scandium	Sc	21
Fermium	Fm	100	Selenium	Se	34
Fluorine	F	9	Silicon	Si	14
Francium	Fr	87	Silver	Ag	47
Gadolinium	Gd	64	Sodium	Na	11
Gallium	Ga	31	Strontium	Sr	38
Germanium	Ge	32	Sulfur	S	16
Gold	Au	79	Tantalum	Ta	73
Hafnium	Hf	72	Technetium	Tc	43
Helium	He	2	Tellurium	Te	52
Holmium	Ho	67	Terbium	Tb	65
Hydrogen	H	1	Thallium	Tl	81
Indium	In	49	Thorium	Th	90
Iodine	I	53	Thulium	Tm	69
Iridium	Ir	77	Tin	Sn	50
Iron	Fe	26	Titanium	Ti	22
Krypton	Kr	36	Tungsten	W	74
Lanthanum	La	57	Uranium	U	92
Lawrencium	Lw	103	Vanadium	V	23
Lead	Pb	82	Xenon	Xe	54
Lithium	Li	3	Ytterbium	Yb	70
Lutetium	Lu	71	Yttrium	Y	39
Magnesium	Mg	12	Zinc	Zn	30
Manganese	Mn	25	Zirconium	Zr	40
Mendelevium	Md	101			