APPENDIX C

NUCLIDES AND ISOTOPES

ACCOMPANYING THE CHART OF THE NUCLIDES REVISED 1969 BY DR. NORMAN E. HOLDEN AND F. WILLIAM WALKER KNOLLS ATOMIC POWER LABORATORY, SCHENECTADY, N.Y.

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 prodicted the properties of gallium, scandium, and germanium, which were subsequently discovered. Pairs of elements (for example, teckel 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 highenergy 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 v, related to the energy E by the relation $E_{\rm energy}$ 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 I are in the innermost orbit, called the number n 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 highfrequency 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 that, 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 hemical 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 N + Z. Isotopes are nuclides with the same A 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 and mc², 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 1975.

to represent the transformation as follows:

$$\frac{14}{7} \xrightarrow{4}{2} \frac{17}{8} \xrightarrow{17}{1} \frac{17}{8} \xrightarrow{1}{1}$$

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 d deuteron

t triton (hydrogen-3 nucleus)

d deuteron p proton

 α alpha particle

³He 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 socalled "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

r			
a, 3n	ar, 2n ³ He ,n	a, n	
p,n	Ρ,γ d,n ³ He,np	a, np t, n ³ He, p	
у.п п.2п	Original Nucleus	d,p η,γ Ι,ηρ	1, p
y.np	Y , P	n, p	
n a	n , ⁵ He		

Fig. 1. Changes Produced by Various Nuclear Reactions

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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 \dots 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_i 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 evenor 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
Α	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 given sample disintegrate. Additional lines а 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 longlived, 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 thermalneutron 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 57minute 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 i.) 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 crosssectional 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 a.) 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 a_0, a_0 , and a_1). 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 a_0 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 μ b following the crosssection value indicates that the units of the cross section are millibarns per atom (10⁻²⁷cm²/atom) or mircobarns per atom (10⁻³⁰cm²/atom), respectively. When no mb or μ b 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 $h/2\pi$, the nuclear spin (in units or 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 $5 \rightarrow$, where the 2 in the denominator of 5.2 has been removed to improve the readability of the chart. The ground states of all eveneven 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 '2-. 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_i , 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.



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

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 nep-tunium, 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

The authors thank the large number of persons who by correspondence and in discussions contributed generously of their time and information. It is not possible to acknowledge specifically in this limited space everyone who sent his experimental results in advance of publication and whose assistance was needed in the comparison of the various experimental data. Special thanks are due to John R. Stehn of the Brookhaven National Laboratory, Geoffrey C. Hanna of the Chalk River Laboratory, David T. Goldman of the National Bureau of Standards, Earl K. Hyde and Albert Ghiorso of the Lawrence Radiation Laboratory, Arve Kjelberg of CERN, Jere D. Knight of Los Alamos Scientific Laboratory, W. Bruce Ewbank of the Nuclear Data Project at Oak Ridge National Laboratory, R. Van Lieshout of the Instituut Voor Kernphysisch Onderzoek, and T. Leo Collins, Jr., and the mass spectrometry group at KAPL, for their assistance in various stages of the preparation of the accompanying Chart of the Nuclides.

227-App-C

LIST OF ELEMENTS

ATOMIC NUMBER	SYMBOL	NAME	ATOMIC WEIGHT	ATOMIC NUMBER	SYMBOL	NAME	ATOMIC WEIGHT
0	n	neutron		52	Te	tellurium	127.60
1	н	hydrogen	1.00797	53	I	iodine	126.9044
2	He	helium	4.0026	54	$\mathbf{X}\mathbf{e}$	xenon	131.30
3	Li	lithium	6.940	55	Cs	cesium	132.905
4	Be	beryllium	9.0122	56	Ba	barium	137.34
5	В	boron	10.811	57	La	lanthanum	138.91
6	С	carbon	12.01115	58	Ce	cerium	140.12
7	N	nitrogen	14.0067	59	Pr	praseodymium	140.908
8	О	oxygen	15.9994	60	$\mathbf{N}d$	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	$\mathbf{G}\mathbf{d}$	gadolinium	157.25
13	A1	aluminum	26.9815	65	Tb	terbium	158.924
14	Si	silicon	28.086	66	$\mathbf{D}\mathbf{y}$	dysprosium	162.50
15	Р	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	к	potassium	39.102	71	Lu	lutetium	174.97
20	Ca	calcium	40.08	72	$\mathbf{H}\mathbf{f}$	hafnium	178.49
21	Sc	scandium	44.956	73	Та	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	T1	thallium	204.37
30	Zn	zinc	65.37	82	РЬ	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	$\mathbf{N}\mathbf{p}$	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	nobeli um	· • · • • •
51	Sb	antimony	121.75	103	Ĺr	lawrencium	
				1			

Relative Locations of the Products of Various Nuclear Processes

						He ³	in	a	in
		β [−]	out	p	in	đ	in	1	ìn
		n	out	Or in Nuc	ginal teus	n	in		
1	out	d	out	p	out	β ⁺	out r		
a	out	He ³	out		n = ne p ≖ pr	nutron Toton			
					d ≖ de	nuteron			

- t = triton (H³)
- a = alpha particle
- β^- negative electron
- $\beta^+ = \text{positron}$
- < = electron capture

Displacements Caused by Nuclear Bombardment Reactions

α, 3n	a, 2n He ³ ,n	a,n	
p , n	P,y d,n ³ He,np	a, np t, n 3 He,p	
y,n n,2n	Original Nucleus	d,p n,y t,np	t, p
γ, np	γ,Ρ	n , p	
n , a	n , He ³	Chemical Element	-
		H 1.0079 ~0.332	Symbol Atomic Weight (Carbon-12 Scale) Thermal Neutron Absorption Cross Section in Barns
Pero Moss (Co	ent Abundance - rbon - 12 Scale) -	Stable P() (C) 36,71 9(19+11)	Even Z, Even N Nuclides Hove Spin and Parity O+
Mades Radiat in Mer, Radiat Lived	of Decay, ion and Energy () Indicate ions from Short- Doughter	$ \begin{cases} Artificially Radioactiv Radioactiv 21.3h \beta^{45}(2.85,,,,,,,, $	e Symbol, Mass Number
	Nat	urally Occurring Available but Rad	or Otherwise diooctive
Symbol Perci Thermol N Cross Sect	I, Mass Number - ent Abundance - Hait-Life : Ioutron Capture - Ion in Barns		Spin and Parity Mades of Decay and Energy Mass
	Symbol –	Member of Not Radioactive Dec PO218 4 6000,517 8 -0.020 218,0089	turdly ay Chain Symbol, Moss Number 5m Half-Life 9 Modes of Decay and Energy In Mev In Order of Intensity
Ma Ra En	Half-Life – Ides of Decay, diations and ergies in Mev ladioactive Uppe	Two Isomeric S One Stable V Sni 17 14d 74 11.159 7.16 Interest Isomer Stable	totes Spin and Parity of Ground State, 1/2+ Symbol, Mass Number Parcent Abundance Mass Fission Product, Slow Neutron Fission of U235 e Lower Isomer
R	adloactive Uppe	Two Isomeric S Both Redicoct MOIO3 75.3h 66 75.3h 67 75.3h 67 75.3h 67 75.3h 67 75.3h 67 75.3h 67 75.3h 67 75.3h 67 75.3h 67 75.3h 67 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h 75.3h	hates live

SYMBOLS

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μs

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hours

da ys

years

RADIATIONS AND DECAY

	Naturally Occurring or Ot
	Available but Radiooct
alpha particle	Symbol, Mass Number
negative electron	Percent Abundance
maitron	Holf-Life
poarrior	Thermal Neutron Capture
gamma ray	Cross Section in Borns
neutron	
	Member of Naturally
proton	Radioactive Decay Ch
electron capture	
isometic transition	a 6.000,5.179
	β −0.020
radiation delayed	218,0089 -
spontaneous fission	
disintegration energy	Two Isomeric States
conversion electron	One Stable
	"Sn/17"
	Half-Life — 14d 7.61 -
	Rodictions and y 161
46	Energies in Mev
,	
milliseconds (10 ⁻³ s)	Radioactive upper Isomer - Stable Low
micro seconds (IO ⁻⁶ s)	Two Isomeric States
eessed.	Both Redicoctive
BOLUTILB	MolO3 -
minutes	

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		CI		CI 32 ++	CI 333/+	3+CI 34 0+	CI 3534	CI 362+	CI 373+	CI 38 ^{2~}	CI 39 3/+	CI 40(2 ⁻)		
	17	35.453		B+ 9.47,47, 72.23427246;	2.025 8*45 72.93	IT:46 8*4.5 8*25,	σy 43 σp.45.σg0.1mb	3.07x10 y β7,709,€,β12	24.23 σγ(,005+.43)	U.05 57.2m IT.66 β ⁻ 49l, 11,2.8	β=191,218,344 γ127,25,152	β~~32,~ 75,		
		σο 33 3		(p) (F) (F) (2.8	656	7213330 1186441E548	34,96885	E* 71 E*1.14	36.96590	E4 92	E 3.44	5.9 E~8		
S		S 29	S 30	S 31 "+	S 32 95.0	S 33 34	S 34	S 35 ^{3/†} 87.2d	S 36 0.014	S 37 ^{(7/)-} 5.06m	S 38 2.87h		04	
32.064		β+ γ	8+442,508 + 677	R*44. γ127	σ _α 4 m b	σ _p 2 m b σy.02	a. 22	β= 167 noγ	σv.14	β 1 .64,475,t04 γ311,3.71	8=1.1,(4.91,) ,188(2.167,		24	
σ <u>1.52</u>		6159,386,360, E 14	E6	E 5 4	31,97207	σ _a .16 32.97146	33.96786	E 167	35.9671	L48	E3	L		
Р		P 28 3+ 270 ms	P 29 1/* 4.23s	P 30 1+	P 31 1/+	P 32 14	P 33(1/)H	P 34 ⁺⁺						
30.9738		B*11.5, y1780,4,499, 284-750	B ⁺ 3 95, y 128, 2 4 3	B*324. >223	σy.19	β-1709 noγ	8-248 noy	B=51,3.2, y21,40						
σ. 19		E14.3	E49	E 4 2	30.97376	E 1 71	E 25	٤5			L			
SI 25 0 22 5	SI 26	SI 275/7 4.20s	SI 28 92.21	SI 29"* 4.70	SI 30 3.09	2.52h	SI 32 ~650y				22			
6 1 04 25 195,347 82 5 90	β* 585, γ 825	72 21	oy.16	σγ.3	σγ.10	β 148,… γ1.27 σ_~1.1	β=.21(1,71) noy				22			
10000	1051	E4.81	27.97693	28.97650	29.97376	E148	E.21		I					
01295 2095	AI 20 "	64s 74x10°y	AI 27 31	A1 28 2,27m	A1 29 3/1 6.52 m	AI 30	40		~~					
90 y. 37 71 90 y. 37 71	1, 1.6, 1	B B H6 32 € noy jy181,112,	σy 234mb	8 285 y1779	y 128, 2 43	y 2.24, y 2.24, 3.52 3.52	18		20					
E 4 4 E 14 0	E4 26	E4.00	26.98154	E463	E 3.7	E 7.	4							
12s	78.9 9	10.00	11.01	1V1Q_2/ 9.5m	21.3h	ļ								
, 44	ay .05	oy.2	oy.03	B" (76,159 7.844,1015,175 9v < .04	p.032,135,.40, 95,(178)									
114 06	23.96504	24,98584	25.98259	E2.61	E1.84]							
2602y	100	199ms 15.00h	NO 23"	NG 20	ING Z (
17 2745	0,140+.131	y 2 75,	7.98, 58, 40, 1.61,	y 809,⊡										
E2 84	22.98977	E5 51	E38	E 9.										
0.266	9.22	37.6s	3.38m		40									
	oy.04	7.44, 1.64,***	y.472D,.88		16									
20.99346	21.99134	E4.38	E2.5	l]										
F 20*	4.36s	4.0s												
71633,	y.35,1.38	y 1.28,2.06	14											
E7.03	E5.7	E12.5												
26.8s	14s	021												
y.20,136,	y1.06													
£4.82	E3.6													
0.635	1415													
71 98,165, 82, 2 47														
C17														
	12													
	14													
L	l													



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18

Ge 67 19.0m H ⁺ 31, 2.3, e	Ge 68	Ge 695/ 51µ5 39.2h 7085 €,8+121	Ge 70 20.5	200msi 11d	Ge 72	^{6/4)} Ge73 ^{9/1} 40 μ s 7.8 110135	Ge 74 36.5	1/4)Ge751/) 46s 82.8m 1r β ⁻¹ 20.92, 139	Ge 76 7.8	(v) Ge77(v) 55s 30h $g^{-2.9}$ 30h $2^{-2.9}$ 312	Ge 78 1.45h 8 ⁷⁰ 7.278.294	Ge79 /* ^{- 1m}
E44	Ervs	y1 107, 574, 872, 235-204 62,227	69,92425	E.235	71.92208	53s 11053372.92346 701350	73,92110	e y 265,066 - 618 E 1.20	75.92141	y 215, 416, 11 159 12 2 34 E 2 95 E 2 19	E.98	
Ga 66(11) 95h 8*4 (53) (Ga 67 * 78 2h	Ga 68 ''	Ga 693/-	Ga 70 ''	Ga 71 *- 39.84	Ga 72 3 37ms; 14.1h 11.100 8 97,	Ga 73(5/1 4.8h 8 - 119.1	Ga 74 79m 8 26.43	Ga 75	Ga 76(3.) 32s # ~6 55.112	Ga77	Ga78 ~4s
P34 4806	20913 888 10913 888	2 34	σ[19 68.92557	F 166 1 654	ισ(.2+4.8) 70.9247:	v 835.2 20, 630, 2901 3 34	(0533,0135) E155	36 155	E 5 3	1~1		
Zn 65 5/ 243.7d €.8+ 325	Zn 66 27.81	[₩] Zn 67 × - 9 3μ5 4 11	Zn 68 18.57	^M Zn 69 137h 58m 11 439 β 93	Zn 70 0.62	94 <mark>Zn 71</mark> 113 397h 2.4m 8 145 8 2.61	Zn 72 46.5h				46	<u> </u>
yr 115.	0y '	y 0933 0y 6 7	G2 02486	M0 y	40γ(8.2mb+88mb	988,60,9512 12-148 6295 F26	112 (100)					
Cu 64 It I2.75h 8.5736754 8.654	63.92005 Cu 65 3- 30.83 σ _y 19 64,92779	Cu 66 ¹⁴ 5 10m θ 265,159 γ1639,834 σ ₇ 160 ε265	Cu 67(V) 61 6h 8 40, 48, 58 7 185, 090,0930	$\frac{12.93}{Cu 68}$	3.0m 8 - 2.66. 1007, 898. 17 - 2.03 12 2.66	2233 22.01			44			
Ni 63 17 92 y 8 16 99 70 y 6 06 59	Ni 64 1.16 σ _γ 17 63 92796	Ni 65 57 2 55h 8 214 610 71 481/115, 366, 7, 20 6 2 14	Ni 66 54.6.h 19 20 109 E 20	Ni 67 50s 8 41,2,32 2 90, 89, 126 141								
Co 62 16m 139m 8 H 184 7 T 44 1 M 2 03 1522	Co 63 525 # 36 7 0882 # 36	285 285 7 095 β ~~35					42	4				

36 38 40

Co 54 **	Co 55 **-	Co 56 4	Co 57 "	+Co 58 2+	Co 59 7-	21Co 60 51	Co 61 **	Co 62	Co 63	r Co 6	4 😐			
14m iO 194 s 8*455i8*7 s	18h β*≑50104,⊴€	77,3d €,β*:46,:	271d	191h (714d 11025) - 8 48	100	104 (mb.258) 11 0586 8 318	l,65h β=122	1.6m 1 3.9m β [−] β [−] 2.88	52s β ⁻³⁶	28s <	28s ~35			
304	y 931,1408,477, 10920 - 5-17	9 y 18441238.,732 -355	y 122, 014, 136, · ·	1045	σ _y τ!9+18)	1333 1173 71333 0v 20	y 070	y	y .0882	7 095				
E8252	E346	E457	L.85/	11 053 E 2 309	58.933(9	7,58 E2819	E129	E5.22	E 3 6	+			 	
2.13m853m	582	2 7v	91.66	219	0.33	1 FE 39		6.06m	1	1				
, 102 A-28.	9-23	€ 100×	T. 2.6	0.25	σ	8 467,273,1573	8 135.: 37; 1 0586.1 U272	B 2 6,2 5,2 8;					40	
2 340	-,			C y L y	~, .		(+332,1+73,)	12-27						
2. Mp 525	Mn 53 //-	Mn 54 3	Mn 55 9	Mn 56 31	57.9333 Mn 57	Mn 58	E.19	1.5.8		+				
214nd= 63d	2 x 10 ⁶ y	313 d	100	2 582h	17m	LIm						20		
# * 2.63.4 £*2.75 1 * 38 , y * 4.34,	f€ noy	с у.8346	oy 13 3	8 12 85 204,73,	β 2.6,±1 γ±22, 014, 136,	β- γ 36-2 B						JO		
F 43 9.36.244	17718×10 ⁴ £ 598	σ ₂ < 10 1513/9	54.93805	13702	E 2 7 71	E 7								
Cr 51 *	Cr 52	Cr 53 ^{3/-}	Cr 54	Cr 55 ^v	Cr 56						•			
278d	83.79	9.50	2.365	3,5.3m	5.9m				20					
↓ 5.95	0,08	σ_f in	0 y 0 38	1 52,2 24	y 083, 026				30					
1.75	51.94051	52,94065	53 93888	62.54	£16									
V 50**	V 5I "-	V 52 *	V 53	V 54										
0 24	99.76	575m ∦:25,	2.0m p 2.5	55s β 3 1					ł					
21.56 E 1.013	σγ49	y1434.	,100	y 835-99,2-21										
494715	50.94396	E 5 91	134	8.7				<u> </u>	J					
Ti 49	1,50	1151″-	Ti 52											
5.51	0.04	B~214,15	BIBB				34							
• γ • •	σy 20.2	y jaco, 33, 161	017,				•••							
48,54787	41.94479	E2 46	E1.97	ļ										
1.824	57.5m	0.4s 1.73m	125											
8 ⁻ .65,.48	β 201,···· x178	11,258 B 3 6 Al2,156	A 5,		22									
.175-1212 F 3 98	F2008	.52 E6.8	F6 52		UL									
Co 477/-	Co 48	Co 493/-	Ca 50											
4.53d	0.18	8.70m	Its											
p 68,198, 7 1.297, 489	σγιι	3.08.4.07	7.072.(,26)											
.808 E1.98	47,9825	E 5.26	E 5.4											
K 46	K 47				-									
15 s ∌⁻6.3,…	17.5s β=41,∿6,		30											
y 1.35,3.70,	y 2.0, 2 6		50											
E 7.72	£ 6.65	L	j											





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42	44	46

Se 76 9.02 n ₂ (20+65) 75.91921	7"Se 77"	Se 78 2352 5(3)+07) 779(73)	1/ Se 797/+ 39m ≤6.5×K 11.096 a=15 e= 047 €.154	Se 80 49.82 a ₂ (.09+ 53) 79.91853	7/11 Se8 1//− 57m 18m 11.105 β - 58, - y1 - 51 225, 236 189, 166 188 - 650 11.58	Se 82 9.19 xy(.04+.006) 81.91671	W+Se8390+ 69s 23m β 3.5, β 93,15, 1.5,2.4 52 y.101,201,9356, -65,35 992,226, -35	Se 84 3.2m ^{B⁺1.4} ^{y.408}	Se 85 ^{39s}	Se86 ≥ ^{16s}	Se 87 5.8s ^{β⁻}	
⁹⁴ As 75 ³²⁻ 16.4ms 100 (1024) χ28 γ28 (4.92160	As 76 ² 19µs 264h 19µs 264h 19µs 264h 19µs 264h 19µs 264h	(16,45,73,73,73,73,73,73,73,73,73,73,73,73,73,	As 7821 1.525 P.4.11	As79 ^{(8)*} 9.0m 8*21412*15 9.0%2, % 89 9.0%2, % 89 12.2	As 80 14 15s 6-60.53,30-45 7.666, 78 2 35 660	As 8 13/- 323 8-38 107 E38	As82 15s γ-655,.817	As83 β ⁻ (4s	As84 5.8s	As 85 2.(s ^{#*}	As86	As87 <1.5s
Ge 74 36.5 ⁹ 7(15+31) 73.92118	Price75 46s 82.8m 11 p 20.9c 139 y 265065 56 j€12c	Ge 76 78 592141	VIGe77 55s 1130h 8 29 8 312 7 195 746 11 59 12 5 4 12 59 12 5 4	Ge 78 45 n 5 70 70 70	Ge79 *!m	48		50		52		54

Zr 87	Zr 88	Zr 89	⁵ Zr 90	Zr 91	Zr 92	Zr 93*	Zr 94	Zr 95₩	Zr 96	Zr 97	Zr98	Zr 99	Zrloo	Zrioi
8*210	6 000 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	IT 588 (6,8*90) (6,8*9.) 9040	0.805 5196 172319, 07-07 	σ _γ 0.9	17.11 o _y 0.18	9.5 x 10 5 y 8~.063, 034	¢,05	65.00 8*.40, 36,89, (160)	2.80 5, 0.2	16.0n ∦~194,…,(4,27,… y.11=1.85(.743)) B ⁻	β-		₿ ⁻
£350	e-	24. 715 E2.83	¥218 699€0470	90.90564	91.90503	E.09	93,90631	y.756,.723,1.23, E1,121 .765)	95.90829	E2.67	E~1.5	E4.5		E~6.5
8+ Y 86 4- 48m 14.6h	941Y 871/-	0.30msil06.6d	15.7st 100	(7+)Y 902-	9/+ Y 91 1/ 505rt 58.8d	Y 922	Y 93	Y 94	Y 95	Y 96	Y97	1	Y99	
1T010-€,8*:2, 1-208, 6:3)	1T 38 €, 8* 8 • • • • • 48.(.39)	11 39 €.8*78	17.909 ç(imb + e ⁻ 71.28)	IT 48 A" 2.27 75 נער 20	11.551 B-154,-	B" 363,132, 159-271	B~2.89, y.27, 94, 49-2.	B- 5.0, 4 y.92, 55, 1.14, 1.67	8~4.3, 76,L17 7.95,2.18,1 32,	8-3.5 7.7,10,	β-]		
18-49 1527	E18	17 25 90, 7 45 E 3 621	86.90587	B".62 0, < 6."	E1.54	.07-2 4 E363	E 2 89	3.5 E5.0	E4.3	E7	E5.7			
70m 64.7d	Sr 86 9.87	2.83hi 7.04	Sr 88 82.53	Sr 895'' 508d	Sr 90 28.9v	Sr 91 54	Sr 92	Sr 93	Sr 94 129m	Sr 95	Sr96	Sr97 ~ 0.4s		
11008. 23 y 540	σ ₇ (.84 + ?)	I⊺ 39 €	თ , მოს	₿ 146, ¥910	B-546.(2.27)	β ⁻ 109,136, 2.67,	855.1.5 y1.37,44,.23	8~2.9,2.6,2.2 y.60,.80,.3~2.1	β ⁺ 2.1 γ1.42	₿ ⁻	β-			
4.+15 E	85.90929	· (05.90900	87.90564	0,015 <u>E1463</u>	6,0.9 E 546	E2 67	E19	E4.8	E3.5					
⁶⁺ Rb 84 ² 20m 33.0d	Rb 85 -	Rb 86 ²	Rb 87	Rb 88 ^{}~}	Rb 89	Rb 90	Rb 91	Rb 92	Rb 93	Rb 94	Rb 95 0.36s	Rb96	Rb97	
461 y Bec	¢(.06+40)	IT 56 (8) 178, 75, 9108,	5.0x 10 ¹⁰ y #7.27 may	₿152,33,2 9184,899,2.68,	B-126,2.21,4.49 y103,125,.65	8 8 66, 58,22,- 1,83,53	B-4.6 7.094, 35	(n)	β~ (n)	B - (n)	(n)	β ⁻ (n)	(n))
1 891 2000	84,91180	ie1.78	9,12 E.274	αμίο Εύχ	2.20, 1.55° 3.5 £.4.49	£6.6	EG	E8						
186h 11.55	Kr 84	" Kr 85** 44h 1074y	Kr 86	Kr 87 76m	Kr 88	Kr 89 3.18m	Kr 90 32.3s	Kr 91 8.6s	Kr 92	Kr 93	Kr 94	Kr 95 Short		
11032 051/3 70090	(.09 + .042)	8-83 8 67 - y 150 y 514	ay.08	813,8,13,3,3 7403,2.56, AS	β 52, 2.7. 7 2.4, 191, 85,	8-49,46,3.8, 7 22,.59,086-4.7	B-2.8, 7.1215,540,1.12	B ⁺ 3.6.11	β~ (n)	8~ (n)	<i>₿</i> ⁻	₿ ⁻	60	
E ON: 48.945	83.91150	E 67	65,91062	<u>E3.84</u>	E28	E5	1.538, .11 - 3.6 E46	E5.7						
6.im 35.4h	2.40h	6.0m 31.8m	Br 85 ¹³	Br 86 54s	Br 87 55.6s	Br 88	Br 89 4.5s	Br 90			=0			
8" / 36.9777.564 8" / 36.9777.564	₿".93 · y 52	1920	β*~2.9 5-80,392	B * 3, 5, 74, y 16, 1 4, 2 P,	β°26,⊷ γ14,26,10:50	8 ~ (n)	# - in1 5	B - (n)			58			
L14 1.309	(e) E.97	189 E47	E2.8	176	E 6.									
57m 18m	Se 82	69s 23m	Se 84 3.2m	Se 85 39s	216s	5.8s								
11103 #158,0 5 275,290 1829,966	σ ₂ (.04+.006)	1.5,2.4 3-2 910:20/y 356	β~:4 γ 408	β-	в	<i>β</i> -			56					
e eso Elitæ	81.91671	165, 35, 582,226. 135						L						
	40		50		50		E A							
	40		JU		JZ		J 4							





	54		56		58		60						
<i>q,</i>	2r 94 17.40 05 93.90631	21 95 ⁵⁷ 65.5d (160) 756.723,123 E1.121 7651	2,80 5,0.2 96,90829	21 97 16.8h 7-191,- (127, 1) 7 (-1.85 - 24.1) E2.67	2198 315 E~15	2,45 β ⁻ ε4.5	2rioo ~ is	∠r101 ~3.3s £~6.5	62				
8	7h 35.1d 235 8 60 765 765 765 765 765	NU 90 23.4h β ⁻⁷⁴⁰ 5 ⁻⁷ ⁷ (, 569 - 14 16 - 15 E3.5	58s 736m 1175 A 127 658 1275 E193	2.85 5lm β ⁻⁰⁴ 5.1823 3 1.24 5.1823 3 1.24 1.14 1.14 1.14 1.14 1.14 1.14 1.14	145 24m 8 24m 8 24m 10,26 10,26 10,26 10,26	6 65 2 9m 6 65 2 9m 7 16 60 9 53, 36, 12m 45, 14- 13 5, 31, 10 6 13 5, 31, 10 6	7.05 B	7-10			64		
	95,90467	96,90602	97,90541	E137	99.90747 N.5 QQ	08-166 62.82		149 149	1y 1170 1.36.88,4			i •	
σ,	Mo 96	Mo 97 Μ 9.46 σ _γ 2	Mo 98 23,78	Mo 99 * 66.6h #=123, 44,11	Mo 100 9.63 9.20	Mo 101 14.6m 8 ^{-2,23}	Mo 102 11.im 81 vite 41	MolO3 5.3h? 66s	Mo 104 1.3 m 8 * 2 2,4 5	Mo 105 415	MolO6 9.55		
	y? *	р 7-6.66 (7,3) Е:7	002, 7, 2 142 no. 7140 E 237	2 54.6 E34	E165	147.63 74 63 146 10 24 27 2-45	E2.4	9 24, 9 36, 53, 88, 63, 614 7 E 5 9	5 5 4,1 8 5 143, 159, 108, .324,** £3 4	1	-		
90	Tc97 10-	Tc 98 ~15x10 ⁶ y	TC 9994	Tc 100"	Tc 1019/+	Tc 102	Tc 103	Tc 104 18.0m	Tc 105 7.8m	Tc 106 375	Tc 107 295	Tc 108	
q	,< 8 97,90529	σ _γ 4 98.90594 ∡	99.90422	σ _y 5 100,90558 ∡	101,90435 ▲	р 2 - 7200 уалт 501 и - д Е 74	σ _y .5 103,90543	8 - 115,111,113,11 9725 - 26 - 1721 29 09 - 21 ET 87	8 -0394, 304, - (y 5)2, 62 - 306) 67, 2: E 0394	# 12,930 99937513 €12	B 3,12 y 17 E - 3		00
	Ru 98	Ru 99 ⁵⁴ 12.72	Ru 100 12.62	Ru 10 M	Ru 102 3161	Ru 103%	Ru 104 18.58	Ru 105°	Ru 106 368d	Ru 107	Ru 108 45m	Ru109 35s	~~
, 81	6 1.0.0 1.4 1.0.0 1.2 1.9	y 54 - 3× 1 - 1 F E 3 64	ο η τη την την 1. Την παι την 1. <u>Ε.5</u> 4	6	(02.9095	710 19 556124 71 71 ⁴ 512 19 10 17	9 775103+1-2.03 6.565	7517,201623,60 28 300 E3.67 E3.54	γ 31,12 ° 68 Ε1 5ι	y 43, 62	y 49, 31 E~2.5	y 374 En:5.5	
4	HN 99 75 15.0d 9****/8****	21h 6.87260	™ RhIO™ 447a` 3y €11:58 €	Rh 102	55m 103 ² 55m 100	1 Rh 104 436m 42s 8 247	1" Rh105" 38s 35.5h 11 (29 8 565.35	2.18h 30.0s	22.4m	Rh 108" 	* Rh 109 ~50s ~30s	Rh 110''	
	D 1 O 0	01.100											

Rh 106 (Rh107 %) Rh 108 (Rh 109 Rh 110 %) 15 N 22 4m (A 10 A 1	
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64

62



- 18 -

											55	Cs 132.905	Cs 120
							54	Xe 131.30	Xe115 ' ^{19s}	Xe116 55s •.#* * 104	Xell7 65s •.8* r 059, 107, 222,	σ ₀ 29.9 Xe118 6m ϵ.β ⁺ γ 053,117, ·	Xe 119 6m ε.β* r 098.231
							53	°₀25 I I26.9044		I115 13m 8 ⁺	I116 < 5m #* y104	I 117 24m 8 ⁺ 7 ^{16, 33, 72, 1}	I 118 9m 14.2m #+61.4 7 60.61 755.605
	52	Te 127.60	Te 107 2.25 8+ 9.3.28	Te 108 5.3s a 3.08 (p3.4, 37, 2.6	Tel09?		Tell12 19.3s	σ ₀ 6.2		Te 4 7m #*(40,27) r(89,130)	Te 115 0.10s 6m 17.28 8+2.812 21, 6 772,128, 138,96	Te 116 2.5h €, 8⁺(2.3, -) y.094, 10.29, 93,97,2.22,)	E ~7 Te II7 64m •,β+ 75 7 720,1 12, 09. 57 - 2 30
	51	∞4.7 Sb 121.75	4						Sb 112 0.9m #*.e y 27'	Sb113 6,7m 8+2.42,+85 6 y 3-(5,1079)	50114 3.4 m β+4.0.2 7 y 89,1 30	ELG ϵ^{-1} Sb 115 ^{5/4} 31.9m $\epsilon, \beta^{+15:}$ γ 499,114-2.22	E350 60.4m 16 m 60.4m 16 m 71.2936
	50	-∞5 Sn 118.69				Sn 108 9m 7 28, 42	Sn 109 15m 18 lm #* 4,8*~16 7,34(12, 891661	Sn 110 4.0h 6 (8*2 25) 7 283, (66)	Sn III 35 im 4.8+1 5! 7:15,076,19! 373-232	5n 112 0.96 5y (3+B)	E63 (^{7/1})Sn113 ⁽¹⁾ 20m 115d 11079 6 6 7255 6 (392)	53.03 Sn 114 0.66	E46 Sn 115 ¹⁰⁺ 159μs 0.35 159μs 0.35 151 0 45 152 0 45 153 0 45 153 0 45 154 0 45 155 154 0 45 155 0
	49	σ₀63 In 114.82	<u> </u>		In 106 5.1m #*31.49 x165.185	In 107 32m #*23. 6 ; 22,.28 25	In 108 40m 57m $57m$ $277y 24, 15$ $6341, 18+105$ $53841, 18+105$	0215 42h 1168 64 80 117, 004, 52, 63	1E2.52 7H IN 1102+ 49h 67m 6 8+225 7 12,66,6.7 66, 11-94	H1,9048 VIn 9/+ 8m 2 820 IT.54 F y 247, 173,	4*In 112 * 1208m 14.4 m 11 156 B 66 e69*157 γ62.69*155	113.9028 11 In 11394 166h 4.28 11 392 57 (2.8+ 5 0+3)	44ms 719s 7 31 B 98 5 500d B 40 1 5 90 B 40 1 5 90 B 40 1 5 98
48	Cd CdIO 112.40 P*	Cd IO2 5 5 m β ⁺ γ 118, 481,104,	Cd 103 7 3m #+ 7 108,145,146	Cd 104 55m € (β ⁺ 2 7) 7.084, 067. (556) e [−]	$\begin{array}{c} \textbf{E6.54} \\ \hline \textbf{Cd.105} \\ \textbf{57m} \\ \textbf{\epsilon}, \textbf{\beta}^+ \textbf{169} \\ \textbf{y.06, 35, 168} \\ \textbf{131}, \end{array}$	E35 Cd 106 1.22 7y1	(38) [Ĕ4.5 Cd 075/+ 6.5h €,8+30 7(093),033 +22	¹¹⁶⁶ E2 02 Cd IO8 0.88 σ _γ Η	¹⁰ L ¹ E.3.93 ¹⁰ Cd IO9 ⁵⁴⁴ 12 µs 453d LT 060 6 (r. 088.) 07 700	jeii Cd 110 12.39 v ₇ (1+11)	E 66 E*259 10 Cd III 1/4 48.6mJ 12.75 11 151 7 247D 05 24 10 3049	1230409 Čd 112 24.07 (03+2.2)	7.72.56 E* 43 10 CC 113 I/r 13 Gyl 12.26 8 58 17 27 592x10 ⁴ 102.90441
	52	54	.L	56	<u> </u> E∼28	105.90646 58	E 4 7	60	<u>ε 160</u>	109.90301 62	· · · · · · · · · · · · · · · · · · ·	64	

- 19 -	•
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66		68		70		72		74					
04 114 28.86 0 ₇ (04+30) 113 90336	600110 8 44 (d. 5356 8 443, P 318, 7 46, P 318, 7 46, P 318, 1 45, P 318, 1 45, P 318, 1 45, P 145, E 163, E 145,	258 m(03+06) 115,90478	CG 117 3.28 (2.25) 5.27 (0.84) 5.27 (0.84) 2.24 (2.25) 2.24 (2.25) 2.24 (2.25)							76			
450n 95.72 450n 95.72 450n 95.72 450n 95.72 900 694 47 900 694 47 900 694 47 900 694 47	¹⁸ In 116 ¹⁴ 2.3s (142s) 15 (64) (533) 45 41 (65) 4 (00, 67 65) 6 (29) (6 (16) 20) 8 (00, 16) (16) (16)	$\begin{array}{c c} In 117^{nx} \\ 19^{n}n & 4a_m \\ p & 77 & p & 7a \\ 16^{n} & 16^{n} & 16^{n} \\ 17^{n} & 1147 \\ 7^{n} & 1147 \\ \hline Cd 116 \end{array}$	In 118 + 45m 51s (+3, e 4) (+3, e 4)	1971 - 220 1971 - 220 1972 - 220 1973 - 220 1974 - 200 1974 - 200 1974 - 200 1974 - 200 1974 - 200 1974 - 200 1974 - 200 1977 - 200	176 120 125 48s 109 86 199 25	Jn 121 31m (- 30s 	In 122 85 17:14.10 167	In 123 365 / 65 8 45 8 2110 2110	In 124 ~ 45 x+13, 99,3.21 £~74	In 125 185 255		78	
Sn 116 14 30 07y ^{CU06+21} 11 ⁺ 40174	14d 761 14d 761 1119 773 16 1159 773	Sn 118 24.03 97(05+7) 112,00151	5011914 2454 958 1294 958 1294 958 1294 952 1899*1	Sn 120 32,95 eyr~oor+ ist 09.90220	- Snl21***	Sn 122 472 07(00++15) 121 90344	1-1Sn 12314 4-03m129d 8-280 8-142 9-80 9-108 E1 42	Sn 124 5.94 (14+4mh) (23.90527	14-50 25-10 9.6m 9.654 9.32 7102915 28-195 23-228 E2.34	Sn 126 ~ 10 ⁵ y # ⁻⁽¹⁻⁹⁾ #092,067,060 (42,67,-) E~3	Sn 127 4.2m 2 12h 8*27 8 7 49 710,82, 27*28 E~31	$ Sn 128 59.0m \beta^{-6,7,(2.5,)}_{7.04-57,(75,3],} -1 E13 $	
2.80h (4,81.57 (1.82	0975 35m 112 35m 142 99755 14 99755 14 99755 14 99755 14 99755 105 25 04 236	381h , 1024/ 1 1 50	5.76d - 16.0m 5.76d - 16.0m 5.76d - 16.0m 5.76d - 16.0m 7.76 7.76 1.2003	57,25 57,25 0yr:06+2+4:01 120:90382	1000 CCC 1000 CCCC 1000 CCCCCCCCCCCCCCCC	42,75 79:02:10:142	2030 (2.9 110:52 6024 110:52 60269 110:54 27 22:22:22 23:22:22 24:22:22:22 24:22:22:22 24:22:22:22:22:22:22:22:22:22:22:22:22:2	2,73y 2,73y 9,30 v. 6l, - 9,428 600,000 67009,035 8,76	SU 120 190m - 124d 8 19 - 819 2 42, 67 2 42, 67 11 2 E3,7	380d <i>B</i> 79:15(11),, 169.) 7686,473,78,28 (42.)006(- £160.) (29.)	10.4m 9.0h 8 '2 6, 18 1.0- 15 17 75, 31 (7 31- 75 14.3	30123 4.34h (145,-) (145,-) 78154.92.18-21 (027-140) E~25	
(B*26) (B*26) (Sh U7)	15 204 21 074 15 204 21 074 15 204 21 074 1024 10241 12 204 Sh 118 1	50000 σχ(34+20) <u>μη 2040</u> Shi 119 Se	PS-b120 **	ад ні 10 гонала 121 Ум	E OT E OT	0-(05+7) (23.00294 Sh1237	1 Sh 124	σ ₇ ((3+9) (25,90332 Sh125 ²⁰	10997 8-69 8-, y 42, 36 06 E 69	^σ γ (.016 + 20) 127.90448 Sb (27)7**	11.05 8 14510 e . 8 7028,45 16.9 70 74602 21-126 7.140 E 148 Sh128	05, (.02 + .20) 129, 90524 Sh 129	
Te 118 6001	Te 119	Te 120 0.089	Te 121	Te 122		Te 124	1" Te 125" 584 599	Te 126 18.71	1094 (93h	Te 128	"Te 1293" 341d 69m	E.970 ^σ γ~7 Te I30 34.48	/
I 119 (20) m (4*) (158,063000	I 120 53m 135h 8*39 € 8*35 960-9 2 9	I 121-57 080% 213h 21 6.8+12 216 - 721/05/2	7 122 " 35" 8*310 256 K	1.12354 17.15 1.12354	I 124 - 174 - 174 - 174 - 175 -	I 125* *97d	· 1 1252 1304 6767,74142 2139-125	I 1275/4 100 7-62	I 128 ** 25.01m β ^{-214,167} γ 443,525-114	I 129 ^{7/+} 1.6 × 10 ⁷ y β ⁻¹⁵ 7040	I 130 ⁴ 89m 12.4h 11048β-62.104 β 17	I 1317/+ 8.065d 8606,25-81 7.364,0800-	
д+ + 164 до 5 нове - 14	,β*7.8,δ γ.096.090, 322, 44 Ε3.8	н (АСС) В (АСС) 5 (У Сразна с Це	E 2.9	ay 122 + 6401 123,206	in the second	ry(3+3) 12590429	17.17.27 9.125 (* 203.177 * 375 (* 54	σ _γ (.4+<8) 127,90354	27,055 ~ 04.0 my 20 1249,475	σy(4+<26) 129.90351	17.164 e ⁻ σ _Y 90 3090505	7773. 67, 54, 07(D3+4) 60, 18 13,90446	
Xe 120	Xe 121	Xe i22	Xe 123	Xe 24	Xel25	Xe 125	* Xel27	Xe 128	10 Xe 1291	E.35 Xe 130	×465,567,1031 E ⁺ 208 E L2	132.9054 Xe 132	
2 m	6.5	, 55m		45.00 6 18 - 20 - 1	14 m	5,25 2,617,17 1,61,17,462 20,138	38m 8*296246 e 443.526 296	32.3h	30m *,8*1.97 7536,596,894 1.12-215	969d e noy	6 58d 6 8 4 7 668 363 - 1985 8 7	100 07 (2.7 + 27.2)	
Cs121	1 Cs1222	Cs 123	Cs!24	65105	Cs 125 *	Cs 127"	+ Cs 128 +	Cs 129"	Cs 130"	Cs 131 **	Cs 1322	Cs 133"	

	P Cs 134 ⁴⁴ WCs 135 ⁷⁷ 2904 206y 53ml23x10 ⁶	Cs 136 ⁵¹ y 13d 8 M 65 187 (C5, 164) 0167 126	Cs 137 ²⁴ 30.2y 15 514,1176 15 691 16 17	Cs 138 32.2m (* 24.34 (* 44.54) 222.157.37	Cs 139 9.3m 8 42~27~3 7128, 63,	Cs 40 6385 8 ^{3 - 544} 59, ^{99 - 3} 15	Cs 141 24 7s	Cs 142 1.7s	Cs 143	Cs 44 	
	¹⁷ Xe 133 ^{3/4} Xe 134 12 26-4 527d 30 5 10 44 12 27d 30 5 10 10 44 12 27d 30 5 10 10 10 10 10 10 10 10 10 10 10 10 10	Xo 135	Xe 136 9 87 15 99722	Xe 137	Xe 138 14 2 m 6 192 2 70 55 2 92 2 42 20 15 174	Xe [39 4/1a 8 - 48, • 219, 075, 297,-	Xe 40 13 6s P	Xe 4 1.72s 8" (n)	Xe-142 122s ^{β⁻}	Xe 143 096s	Xe 144 9s
	I 13244 I 1337 2.284h 8.80-1.14 5.7.77.52 15.2.7 E356 KLP	⁴ I 134 523m 8243,13,14 22 14 A47,884 14 18 14 18	I 135 74 6 75 6 75 6 75 6 75 6 75 6 75 6 75 6 75	1 136 ^{β2} 85s 8143,65,27 70, ² 7132,20-32 ε7-1	I 137 22.3s β ⁻ Int 6	I 138 60s	I 139 2.0s	I 140 1.5s β ⁻			90
	Tel31 Tel32 30h 25.0m 78h 8 42, 4721/2, 270 h 274 51 446, 45,45 53 271 1 186 785 53 271 1 186 7828 451	53m 125m 53m 125m 8 32 487 75 Katana 405 024 209395 590 17344	19134 43m	Te 135	Te136				88		-
	Sb130 8m + 37m 2017 - 19 215 1014	Sb 132 455 1 3 im	Sh137 2.7 m 1 0.2 m 2 m 2 m 2 m 2 m 2 m 2 m 2 m 2 m 2 m	Sb134 1135 (n:	Sb135 1.708 (n)						
/	Sn 129 ~ 2m 2 5m e _ c ~ (B_{1}) ~ (B_{1})	Sn 131 13m	5n (22 10n	Sn133 ~ 555 e			86	4			
	80		82		84	-					



Pm 61

Nd137 38m

€, B*

Nd136

Nd135

Nd

144.24

		78		80		82		84		86		88		90
61	Pm	Pm139? #* **	Pm 140 58m 2 ¢, 8* yli 03, 43, 78/j	Pm 141 209m ∦*~26,€ ; 122,89,195 ; 235 €36	Pm 142 ⁺ ^{36s} ^{β+38,+} ^{γ+57} ε48	Pml4354 265d 742 E108	Pml44 ^{ir} 1 363d • • 6i8, 697, 477, 302 1 51 52 37	Pm 145 ¹²¹ 18y 072,067D 2224 E 14	Pm 146 553y ε.y 454, 736, β ⁻⁷⁹ , y 747, ^{noέ†} σy 8400 ε ⁻¹ 54, ε ⁺ 149	Pm 147" 2 6234y β 225 y 12'0 σy (51+102) ε,225	#150 148 4150 540 #397 #147 665 495 100,47 11.0615 #,1700	Pm 149 ⁷⁺ 53.1h β ^{-1.07, 78,} γ 286-85 σ ₇ 1350 ε1.071	Pm 150 2 68h 6 2 3.18, 4,33 7 33,117,1 33, 83, 175, 41 - 3 E3 4	Pm 1515/* 28 4h 8-85 93 7 340,026 96 7 340,026 96 7 340,026 96
62	50.35 150.35 9,5860	5mi40 ^{14m}	5m141 23m (a*~26)	5m 142 725m +,8* 10(38 - 1 (y 57) E21	500 1430	Sm 144 3.09 ^σ γ~.7 143.9120	5m 145 340d 7 7 0514, 49 07, 510 E.63	SM 146 1.0 × 10 ⁸ y a 2.50 145.9130	14.97 10.7 × 10 ¹¹ y α 2.23 σy € 5 .46.9149	511148 11.24 >3x 10 ¹⁴ 5y 4 7 147.9148	3.83 ≥1x10 ¹⁵ y a1842 oy 41,800 or 05 148,9172	5Π.IDU 7.44 ^σ γ 102 149.9173	Sm151 93y , 222 9, 520	51.9198
	63	Eu 151.96 134.2×10 ³	Eu 142** 5. m 5. ** 7. *****3	Eu 143°** 2.6m ****** ******	Eu 144 ¹¹ 105 9 52 566295 5 52 566295	Eul45 ^{(5,9} 6 5,96d 7,894,166,111 2,51 1,272	Eu146 ⁴⁻⁹ 4.6d 6.8*14780211 737.033.666 703.145-236 5.3.87	Eu 47 ^(5/4) 24.3 d 6. 8 ^{+75,62,55} 7.197,121,-076- a2.90 E177	Eul48 ⁵⁵ 54.5d 5.959 550,630,414, 7.966 61,53 61,53	11/2EU 14915/41 24745 93d 5350 7 497 923 56 697 923 56	EU150 6. Dy 12. 6.h 9. 334, 16. 871 21, 440, 16. 334.407 30. 164, 209, 46 164, 209, 46 164, 209, 46 16, 209, 47 16, 209, 47 17, 47 16, 209, 47 16, 209, 47 16, 209, 47 16, 209, 47 16, 209, 47 16, 209, 47 17, 400, 47 17, 400, 47 17, 400, 47 17, 400, 47 18, 400, 47 19, 400, 47 10, 400, 400, 400, 400, 400, 400, 400, 4	Eul51 544 60дав. 47.82 11 - 12 - 21,44 11 - 12 - 21,44 13 - 21,44 13 - 21,44 15 - 310,51 160 - 914н		Eu153 57 52.18 7. 451 157 9212
		64	Gd 157.25 g 4 6 x 10 ⁴	Gdl44 45m #*	Gd 145 22,9m €,8*25 2176,188, 33- 1.6** €5.4	Gd 146 2 9h 50d 722 7 16	Gd 47(7/-) 38h € #*97,125 1279,436, 1274,370, 107133 €2.22	Gd148 93y a 318 147 918:	Gd 149 ⁽⁷⁻¹ 9,5/1 (9,5/1 (9,5/1-0.9 (3,0) (48,9/9	Gd 150 1.8 x 10 ⁶ y a z 73 149 9186	Gd151(17-1 120a 7 (220)54, 125, 12 35, 12 35	0.20 0.20 0.1 × 10 ¹⁴ y a 2.74 cy< 190 151 9198	Gd 153314 76µs 24.2d 1* 1/4-27 103 0974 1: 243	Gd 154 2.15 (53.9209
			65	Tb 158.924 σ ₉ 27		Tb 147 100m 24m	Tbl48 70m €,8*4.6, y 78,⊡2 £5.6	Tb149 415m, 4.13h ε (ε.α.395 α.3.99 γ.17+121 ξε.3.8	Tb150 3.1n y 64, 43 a £473	Tb 151 179 h v 168, 16-13 a 1-92 150 923	Tb 152 4m ¹ 176h 6.8 ⁺ 6.8 ⁺ 2.819 7 ²³ 344 587 a 1.2 ⁻² a 1.2 ⁻²	Tb 153 ⁽⁵⁷⁾ 0.19ms - 24d 17 081 - ¢ y088,2t2 40,7 016 36 1 to : 9	Tb 154 8h 18h 528 7423 7434	Tb 155'3' 5.4d • 0866, 1.*3, 019 - 6* En. 9
				66	Dy 162.50 ₀₀ 930		Dy I49 ← ^{~15m}	Dy 150 72 m 87.4 442 7 39 6 - 17	Dy 151 18m A 1.8 a 4 06 y 15 E 2.9	Dy 152 2.385 7.256 6.37 6.4 1619247	Dy 153 61 9 581, 100, 1082 4 3 5 152 926	Dy 154 13h ~10 ⁶ y 3 5 5 9 2.85	Dy 155 ⁽³⁷⁾ 10.2h 4 925765-195 1270	Dy 156 0.052 2 x 10 ¹⁴ , a~3 155.924
					67	Но 164.930 ∞ 65	Ho 150 V 20s	Ho 151 42s 36s a 4 60 a 4 51	Ho 152 525 2.5m a4.45 a4.38	Ho 153 65m 93m a 400 e a 395	H0154 3,25m (118m 814 (63.9) 9356(2) 473,156 1.25	Ho 155 216.5m 47m β* ar € β*21 α 3.96 χ.040, 14, e ⁻	Ho 156 55m •.#*18,2 9,4 3 7138, 266, 366 160 - 141	Ho 157 15m #*



2 3Ho 158:51 24m j 13 3m	Ho 159	¹²¹ Ho 160 ⁽⁵¹⁾ 47h 25m	4Ho 161 7- 683 2.5h	67m 13m	1075 ~33y	Ho 164	Ho 165*	17H0 1660-	Ho 167(#1	Ho 168	Ho 169 ⁷⁷⁻¹ 4.7 m	Ho 170 44s		
699 1 07 1 07 2 67	17 206 / 4 y 030-395	11 060 - 30.57 (4,5° 77)9.966 (5,197 7 11-2 8 087-2 8	078,044	111~01 (6 8 1 08) 13 7.058, 7.08 9.08 9.08 1	11.30	y 04(5 y 073 11 046(7) y 027(3)	oy (3.2+52)	18 ~.06, 18 (5), 70806, 176, 7184, 811, 70806, 712, 184, 183	8.32,97,51 7.346.321,079 2080,074- 745	β ⁻ 2.0 γ.85,····	β ¹ .20,195, γ.78,85,.06 .92	β 3.3, ·· γ.43		
Dy 1570	Dy 158 0 0 2 9 0	1/Dy 1593/- 0122ms 144d	Dy 160 2.29	Dy 161 5/+	Dy 162 25.53	Dy 1635- 24.97	Dy 164 28.18	Dy 165 ²⁴ 32si 2.35h	Dy 166 81.5h	Dy 167 4.4m	<u> </u>			-
7 326, 82, 143, 7 360, 144, 128 8 -	ey 100 157,9244	2 2 8 22 E 36	ay 5.9 (59.9252	7y 590 1609269	σ ₇ 200 (6) 926 8	σy140 162.9288	og (1820 + 780) 163.9292	2 1/20041,362, 1/200,0297 1/200,0297 1/108 1 0 5 10 0 10 10 10 10 10 0 10 10 10 10 0 10 10 10 10 0 10 10 10 0 10 10 10 0	β ,40, 48,… γ 082,028-43 Έ 48	β 7 1957			104	
p#Tb156 ⁰¹¹ 51 513 51 513	Tb 15734 150y	1.0158.024 C4041.151.024 Π.01.2546.964 1.04-27.946.964 1.075.129 10.74.87.85.	Tb15934 100 9,27	Tb 160 3 72 4d 879 209 366,	Tb 161 3/+ 7,0d 81 51, 58, 45, 20256, 0489,	Tb 162 2 244 1 747m 8- 125, 89, 726, 81, 89, 081	Tbl63(3/4) 195m 6.5h 8-63-8-14.17 4 150-11 7 35-19, 733, 03,	Tb164 3.04m 8-3.2 756,611,215, 169,06-144			102			
Gd 155 -	E.07 Gd 156 2047	Gd157*	150.9254 Gd 158 24.87	Gd 159 V 46ms 18 0 b	Gdigo	Gd I6 (5/)	Gd I62							
α, 6 + 10 ⁴	σ ₂ 8 55.9222 ∡	σ ₂ 2.50 ± 4 ⁻²	o, 2.4	11. 70 8 95,69 59 9363,0580 0795 85	σ _γ .77	18 1.56, 17 361,.315,102, 05653 0710 ³ E 2.0	y.41,.43							
Eu 154 7 8y 81 (4), 26, 87, 186, 125, 124, 723 1004, 054, 1146	Eu 155 54 5 Oy 8 - 1 - 1 - 244 7 - 365 - 1 - 244 7 - 365 - 1 - 264	Eu 156 15 2d 8 48,245 30 23 7 0990,199-219	Eu 157 15.2h 81 1.28.1 35 9.41.0650.16- .97	Eu 158 45,9m #=::5,09;1, r.380,95,89,	Eu 159 18.1m 8 2.57,190,10- 175 2067,67,092,	Eu 160 ~25m 8-36			100	£,,	J			
Sm 153 ³⁴ 46.8h # 70,65,80,	Sm 154 22.71	22.3m 8 155 ³ 8 154	E135 Sm 156 9.4h 8° 43, 70	E3.5 Sm 157 9- ^{0.5} m	E 2.57	<u>E3.6</u>								
083-636	4,5 153.9223	Y 1044, 246, 141 026 - 130 E1 65	-,087-20,04= .29 E 72	y.57										
Pm/52(1-) 4.2m 8 ⁻² 2,34 5.122, 245,:-	Pm 153 5.5m ∌ :~~i 65 y iz5,:i8	Pm 154 2.5m #`~?5					98							
-	92		94	<u></u>	96	d								

Tm 65 ^{1/+} 9μ 30h 000,03,1+,8+30 80μ 1054,243 80μ 1054,243 1064 11069 9+17 9+17 15,37	Tm166 2* 7715 4.8419372 2.68 2.68 E304	Tm167 ^{1//+} 9.3d 7.208, 057 25 - 532 EU16	Tm168 ⁽³⁾ 931d v98,86,448, 184,0798-149 6172	Tm1691/+ 100 σ _γ (10+103) 168.9342	Tm170 4 μ4 μ 129d 1 144, β .967, 88 058,7 0843 6, 9 γ 95 Ε.967 Ε*5	Tml7l ^{1/+} 2.5μs 192γ γ308, β 098, ¹¹² , 037 0051; γ067 γ4.5 Ε098	Tm172 636h 816,188 1094,1387, 1530,1466, 0790-1622 5.188	Tm173 ¹¹⁴ 8.2h β ⁻ .86,.90, γ.400,.47, EI.32	Tm174 5.5m β ⁻ 12, 7 γ 3670, 9920, 2730,- £3.0	Tm175 ⁽¹⁴ 16 m β 9,15,19, γ36,94,042- 1.51	Tm176 1.4m 8-20,115,3.05 7.19,105,87,1.8, (.096389) E4.1	
Er 164 1.56 0,15 163.9293	Er 165*-	Er 166 33.41 α _γ (12+17) 165.9303	17 Er 16774 2.35 22.94 17 208 9 07651KT	E r 168 27.07 σ ₂ 1.91 167,9324	Er 1691/- 9.3d 81.34.33 7.0084 e ⁻ 8.340	Er 170 14.88 97 57 169.9356	Er 171 5- 7.5h β 106,58-149 3083,2959 106,012-140 Fil.490	Er 172 49h 8= 28.36,9 7.05.41.61,0 E.89	Er 173 12.0m 8-2.3,1,8 9.20,40,18, 037-0.52			108
1940 163 97 1713 - 2139 11	Ho 164	Ho 1657- 100 oy(3,2+62; :64,9304	"Ho I66" 2x103,26.9h 8~06, 81.85, 180,811,060, 184,811,080, 12.164-183 21ms 5185	Ho 16717/1 3.1 h 9.32 97, 61 346, 321, 079, 2080, 074- 745 E 0.9.7	Ho 168 3.0m #12.0 #12.0	Ho 169 ^{7/1} 4.7 m # (20,195,) 7.78, 85, 06 92 521	Ho 170 44s 8= 3.3,			106		
96		98		100		102		104				

- 24 -

	.	84	4 4. 	86	 88	L	90	L	92	1	<u>94</u>	15 3 9 0	96
69	Tm 168.9 34 	Tml53 158s #5%	Tm154 2.985 55 2504 2496						Tml61 30m 5.046373	Tm 162 79m 22m * 102. #2.3, 24 3.8,9 >102.	Tml63 ^{1,4} 1.8h €, β+11,14 7104,242,022- 1.80	Tm 164"+ 1.9m #+2 94,,4 y.091,.21-2 38	Tm 1651/4 9μs 30h γ.040,031 €,8 * 30 80μs γ.054,243 11 059 e- 2 * 1.5
70	Yb 173.04 _{9,37}	TD104 0.39s 9.5.15	1 6 5 1 6 5 0 5 21						f D 162 ~ 23m ¢ 7 041	I DI65	TDI64 77m € β⁺29	10100 10m β*158,	1 D 00 57h € 7 082 € 5
71	Lu 174.97 	LU 155 0.07s @ 563	LUIDO 0.233 ~0.55 a5.54 a5.43						21.160				LU107 55 m c.8-15.1 7 030,239, 056-40 E30
	72	Hf 178.49 ₀₀₁₀₆	Hf 157 0.12s a 568	Hf 158 35 9 5 27	 								Hf 168 22m , 13.17
					 				73	T0 180.948 % ²²			
									74	W 183.85 g ¹⁸			
									75	Re 186.2 • 87			
									76	- 190.2 σ _a 15			
										Os 1902			

- 25 -

104	25 532 EL16	<u>ua i</u>	-68 9342	36-11	5945 2018	े जिल्ला सहाई 15 तम्म	F1.32	1 YC	1.5(E 4.1	389)]	
Tm166 2* 771h 8*193,12 081,184, 071	Tm167 ** 9 3d 7 208, 057	Tm168	Tm169 100	Tm 70	7 (m.) 7 (1) 2 (1) (1) (1) (1) 3 (1) (1) (1) (1) (1) (1) (1) (1	Tm172 635in 8-8:48 	Tm17364 8 25 A 46,00 y 400, 47	Tm174 55m	Tm175 16m 8 9.15.19, 936,94,04	14 Tml 1,4 β=2 0,11 12- 7-19,105,	76 m :,305 97,18,				110
126 152 196	167.934	108 1512	-63 9 M	170 9364	-1-650-0	172 9381	173 9387	114, E 467	1941 1941 (1978)	427 E	08, 139 24 140				
на на ж. 1130	σ. 3,200	11-00-4 + yPOR-198 - 7,02-	e, 44	a. *>		10,10 11,10,10 11,10,10	110 (1. σ (46 + 1. 1. 1. σ (19)	11 513 8 467, 17 396, 28	3 0 H 0 F	1123 B	140, 26, 500,122			1	
Yb 16750-	Yb 168	Yb169	Y6170	Y617110	Yb172	Yb173%	0.80ms 31.84	WYD175	4. Yb176	₩Yb1	779/4 9h				
.ж. ~4.6	071	F 14	1 353 1	Tradu Landor	F 69		174 9406	0, 7+3154 DB	B IEmsi (ii)	093 0889)	44 E21	E135	E 3,3		
β112.≪ ≪ 90,γ.087	11 029 8 3 4 1 029 8 3 4 1 027 6 1	,048,6.8 18 048,784,191,1 11,142	unin a Anarypikan Ali unin akari	ta Marina da Santa da	17 .24 <mark>*</mark> .272,779		c (iA+3)	8 123 2.6 x 10 8 42 7 48 5 42	5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	i2 ∦ ~1 2 ~ 8 5 3 y 332 2) 7 y2 - 326, [y	1 - 2.05 31 - 96 35,093 - 1	β=L35,108 γ.217	B= 3.5		
Lu 168	020Lu169-224 12.7m; 1,53	4-1 (g) 20 0.75 - 208	- 6171 ···	nder på stander Redefingsforstore	1944 J 7312*	1k Lu 174 1 1964 - 13004	Lu1757	Lu 176	23/Lu177	7/+ (7-) LU	78,1 ⁺	Lu17904	Lu 18	30	
04, 92	045	د به و در از در ا	•	1. 12.1	a, 14 .13.9404	1.4%	175,9416	76.94	45/8-111 (1990-1 94) - 526, 211-426,	545 × 217.4 1910 - 14	78,9460	444, 216,0933, E114	σ _y ~49 E1.023	Er	~.5
*24.13	 μ μ	r 107,662,	ي وي. المحرفية إلى ال	lipan a.	20.0	1.106, 143,089	1.07 0,220	27% 	+ y 426, 9452 4) 574, 1775	34) IT. 161. 0 439 375	(.33+	11.0575, a, 12.2 .501 179.947	#=.408, 7.482,004	470 y	270,····
Hf 169	Hf 170	Hf171	Hf 172	11173	RE(174	**************************************	Hf 176		Hf 178	₩ Hf I	7994	Hf 180	Hf 18	(1/-) d	Hfl82
		1.212		i	214. j. 1 8	1 091 2 9 1	105 8 4116	21/-147 (DB6 21/-147 42		71	β 9.9475	346,156, 19/-16.8µ317.006	7.8200 03	2.1272 2.145 ELB07 ET	614, 2443, 0410 - 407 .07
	i	4415 	n alter Alter Le alter de		a A A Maria Maria (19	9110 	216-15 P	(β) 3m (2.2 (ε,β) 89, ε,β (- 69 (γ.33)	n 14μ31∿00 x:03 : € no χ	v 0930	1.012.5	0.2003 995900 11.153 00,001+22 7.482, 100,9480	11.185,356 7,172,147, 310	β 518 β 25,43 β	- 5.00 - 62,
	•	Ta172	Tq173	(G) W	TO: 75%	Tai76	Ta177.	Tal78	194Ta179	74) 11-1 Ta 1	80%+	"+Tal81 "	a+]Tal€	32,	To183%
		7 I			4	1997 (1997) - 1997 (1997) 1997 - 1997 (1997) 1997 - 1997 (1997) - 1997 (1997) 1997 - 1997 (1997) - 1997 (1997) (1997) - 1997 (1997) (1997)	F 09	7 28 A. 2 1 9,	0 15, 234 104 10799	470	153,136 E 19	181,9483	, 105, "7 .053. .046 · · #2	2.9503	183,9510
		1000	4 1.907	n in de la constante Le constante de la constante de La constante de la constante de	 2 0 ° 4 4 5 1 0 ° 	e E Diffe deside	21 D0 4 181 89, 800 5.093 20047	10/11 22. 6 11 222. 6 120 14 03	mio.4705 U 1139 Gyn Diz 450	^{/10} 11.366. 25.2	7.006D	20.41 ar 20.7	0.25 IT./02 210	14,4 10	3U.04 τ(2mh + 18)
	•	W173	W174	6	W176	W177	W178	WW 179	W 180	\$4+)W1	81%+1	W182	WW 18	31-	W184
				1		0-257, 05, 1-3915 356	1 2221, 299. 1 44: 149. 191. 514.	076-826	639,.02	0-032-7.01 e- E-2.86	•-	162.053 041-40	7 6 7 6 7 033- 1.11 1.37	10, 216-	104 0632
			iy me	gan Albert Albert	1978 197	i - Efren Neter	20m	2.45m 6.8113	19h	12.7h 58*17.5	64h	1.0ms 70d 17.194 C 1.11-30-046	165d 3	38d	37.07 ,110
·	<u>}</u>		Cel Co		Fro	Re 178	Re 179-54	Re 180	Rel8le	/+1 Re	182	²⁵ 4Re 183 ⁵²⁷	18+)Rel8	34(3-)	Re185*
			વન્ય				- 020	67 (47 118)	17(020-3	44) 7 UO 1035	115145 .4.4		07272	2	
			• •		فق بر	. M///	- 2 /4 /m 21	2.8m 105	n < m 21	5h 9.9h	(4h (302	0.018 7,3000	e 94d	1	1.59



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												81	T 204.37	
					80	Hg 200.59 σ ₀ 3.7 κ10 ²	Hg179 3.5s 4.6 08	Hg180 6s a 5 96	Hg 81 3.6s a 6.00,5.91	Hgl82 10s 8*, 4 9 5 85	Hg183 9s #*.e #590583	Hg184 32s 3 ^{4*.6} 7 ^{15.7} 237 9 ^{5.54}	Hg 185 52s 2565.557	Hg186 1.4m 6.8* 7.5.25 a.5:
				79	Au 196.967 σ ₆ 98.8	Au 177 1.35 a 6 12	Au 178 3s a 5 49	Au 179 7.55 a 5 85		Au 181 11 s a 562,5 48		Au 183 495 a 534	Au184 1.0m 4.8* 7 163, 275, 362	Au185 4.3 m 4.5 m
	78	Pt 195.09 ആസ	Pt173 Short (1.519	Pt 174 0.7 s a 6 03	Pt 175 2.1 s 1 5 95	Pt176 6.6s a 5.73	Pt 177 6.95 ¢ 5 52	Pt 178 21 s a 5 44	Pt 179 33s a 5 15	Pt180 525 a 1 - 4	Pt 181 515 a 5 02	Pt 182 2.9m a 4 Rq	Pt 183	"Pt 184 10ms 42m 18m 16 5 64 a 14 64 a 14 64 a 14 64 a 14 64 a
77	[r 192.2 192.6	Ir171 1.05 articl	Ir 172 2s	Ir 173 35 a 5 67	Ir 174 45 05 48	Ir175 55 95 39	Ir 176 85 4 5 12	Ir177 21s a 5 0				Ir 181 Short	Ir 182 15m + д+ + 13, 28,	Ir 183 58m • 24.
76	Os 190.2 ga ¹⁵							Osl76 3.6m y 776,1.//31,857,		Os178 5m	05179 8m	Os180 24m \$ nec	Os 8 2.8m, 105m 4.8 ^{+1.7514} 7.165, 7.239, 8.47, 118, 1.47	Os 182 <im 21.5h<br="">>6:56 5 61:18, (028:35 (027:14)</im>
		94	•	96		98		100	L	102	L	104	L	106

	108		110		112		114		116		118	
7. (.44	183.9587	E 98	185.9538	195.9338	187.9561	188.9583	¹⁸⁷ 189.9588	E 310	191,9615	σy~150() EU32	E.097	2.0
171 5.382, 0	47,30×10 ⁸	y 65, 88, 87, .07272		110.57		ary (28mb) y +?) 5	503, 7,361	11074 μ 138 γ 042D, 1294,	σ _y 2.0	y 46i, 139, 559 28i, 073 - 874	γ.043,··	<u>н</u> г
Os 183 ≁* ^{9h} ¦_i4h	Os 184	Os 185#	Os 186	0 5 1874 2344 164	Os_188 13.3	Os 1894 00	Os 190	13.0h 15.5d	Os 192	Os 193	Os 194 6.0y	Os 19 6.5 m
		435,071 E383 2.75	E~16	51 2 G E 2 84	301 224 47.6	17-01.2h C 17-026 C	997, 982 190,9606	1,201 489	192.9630	y.33,29,59-211 12,25		-1.564 E
8* 364,∔20,.594	¥.024 · 667	y 137, y 137, 297,	065 0 5 065	*,8*166.12. 7 1550,633,478,	2004 (1970) 2014 (1971) 245 (1986)	1,187,941,17,097,099,1 1,1149,17,7	1042 (c) (4+520 129, 7+436)	101 .4 m у ыс. ака СЕОБН — 136 і 18	$\sigma_{y}(05+\sigma_{y}(1)\times10^{2})$	7.112, 72.24	433, 319, y 0987,- 120-800, 1296	7.355, 7.
3.2h	14h	17h 15h	29ms H.2h	414h	12ms 13.3d	3.th 12d 4	95 37.3	~650y 74.3d	12d 62.7	171d 500 178h	4.1h 2.8h	53s
		1 11 100	A 8 10.77		11100							1 1 1 4

			TI 191	S61 174	WIT1 193	TI 194	WIT1195	TI 1962	19747+TI 198	2-13/-1T11994	H7+T12002-
			e lom	1100 1 100 16 - 2 16 - 40	(∠.181) ∠.297 E1≤£2555× ⊾365 ⇒24	4 097 + 43	13.05 1.1711 11.099 €,8*~18 17.383 ∞037	€ 7 ⁽³⁸⁴ , 7, 7426	$11222 \in \epsilon_{\gamma}048, \epsilon_{\beta}^{+2}$	4,11.383, (029)7455,	1T0.21 €, 8 + y0.538 1.06
					25, 26 27 - 5	a 5.82	.226 84 E 3.0	911120 E4.6 yC34, 241, 275	018 - 1.01 17.261 17.412, E.2.2 7.283, 195- E.3.5 2	2.6 ELI 035-49	9,368,121, ^{1,44} , 9,116-2,01 E2,454
Hg 187	Hg 188	Hg 189	Hg 190	Hg	Hg 192	WHg193*	Hg 194	11-Hg195"	Hg 196 13+Hg197	Hg 198	13+Hg1991-
om •.β	⊃.⊡91 €,β1 ⊄5.14."	87m	201	251 274	0.8 1.6* 	ilih 4n ∈,β*πζ € ∵ ∞0380	10.40s ~ 1.5y	11:23 706.03/ y 78.06	0,146 23.80,164.17 g(120+3.0x10) 11.165, [6 134] = 077	α _γ (18mb+?)	4.5m 15.54 IT.370
a 5.14 2	y014 114, 193	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	,		41	47:251 187 11:02 76- 039 #234	134	5161,561	195,9656 130, 191, 130, 12,75	197,98676	196.96628
Au 186	Au 187	Au 188	Au 189	Au 190'	Au 191×	+ Au 192 **	₩ Au193*	Au 194	11/Au 1953/+ 12-Au 196	2 - V-Au 1974	Au 1982-
(∠m ∢,β*	e e e e e e e e e e e e e e e e e e e	8 m	γ Om 20m 7.096cy ζ. α	472 m 1€.9* 155 € 176	5.28 • • • • • • • • • •	4.7 h 6.8*249.219	11032. (4 290 1916.112	€ 8*149 € 8*149	$30.5s$ 1840 11.175 $\epsilon, \beta +$ 11.057, ϵ 318 $\star, 099$, 7148, 7356,3	1.55 100 IT.130 0,98.8	8 .96,.29,137
y 16, 27, 30, 41	DOY	(. 6	E 6.4	03-2.0	3:04 E3:51	γ 258,0 103-998 € ξ.~01	E2.51	261 031-211 88, 15 26 200,80 E.23 E*1.48 E684	96,9685	o, 2.6 x 10 ⁴ E 1.37
Pt 185	Pt 186	Pt 187	Pt 188	Pt 189	Pt 190	Pt 1911	Pt 192	10/4Pt1930/	Pt 194 Pt 195	Pt 196	13/11Pt197 1/- 80m 1 20.0h
() ()	i ∠on €	2.0h β',+	10.20 7 9 195, 188, 055, 1	۲ ۲	7 10 ⁴ y	107µs 1 5.00	σ _γ ί2+<μ	2 30 < 300) ΠΕΙ36 ε 1 013 mm	32.3 440 33.8 11130	q(.05+.9)	11 347 B .67,48- 7.0502 70779
y 035, 65,156	y 065, 14, 19, .68, 1.40,	322 2.01	0 192 E 51	- 220, 107, 107 .91	a 3.18	1 E-~ 8	191,9612	E 05	193.9627 194.964	195.9650	130, 130, 279 E.75
Ir 184	Ir 185	Ir 186	11 Ir 187 (34)	Ir1880	In 189 1	III Ir 190 (41)	" Ir 19134	"Ir 192	"Ir 193" Ir 194	1 Ir 195 B	Ir 196
i 3.2 h ∉,#* ∞264.⊔20.444⊡	i4n € × 024 : 667	α ⁺ 193 ^μ .β ⁺ 194. 137.	2,5015,101,200 1,10 ; C 2065,102,065	44144.0 ≮,8*166.12, ≂1550_631478	17.072.17 258 - 4070	8 20 187, 581 - 187, 091	4 95 37.3 (1 042 q (4+52 (129 7 +436)	1: 361 // 67,54 11:11,4 m , 36, 468	120 62,7 74 3lms 182 117.060 3lms 182 7.112 192	4433,319, 9.0987	β-3.2 β-1.16 γ.355, γ.394,
4.3		435,071 E343 2.75	is 10 £∼1.6	31 2 2 E 2 84	201 - 22 10,047 - 22 114,047 - 22	47-01.2h 11-026	047, 082 190,9606	6 - 7.201 485 E 146E 12 - 7.10X	72.62) 7	1120-800 1296	779,333,521,103- -1.564 1.48 E3.4
051834/H	Os 184	Os 185	Os 186	Os 1874	Os 188	* Os 189*	¹⁰ Os190	1305 1918	Os 192 Os 193	Os 194	Os 195
11 171 7.382,	4,30×10	¢ y 65, 88, 87,	1.54	110.57		11.0305 07,128mb	11.0.39 ay (10+3)	10.30 1074 B- 138 7 0420,	β (13,1.06, φ,2.0 γ 461,139,559	β ⁻ .097,054, γ.043,	B ⁻ 2
1035, 115, 145 1035, 1.44	103.9507	.072+.72 E 98	(85.9538	165.9338	187.9561	108.9543	5:7.364 ¹⁸⁷ 199.9568	1294, E 310	191,9615 y~1500 E113	SZ E.097	E2.0



- 28 -

							86	Rn		Rn200? 35 9 6.77	Rn201 3s 4677	Rn202	Rn203 28s 45s 4655 4650	Rn 204 75s a 6 42
			85	At	At 194 Short	At 195 Short	At 196 0.3s	At 197 0.4s 26.96	At 198 1.5s 5s 1.685 6675	At 199 7s	At 200 4.3s 42s 6 0 5 41, 6 46	At 201 1.5m 6634	At 202 2.6m2 3.0m	At 203 7.4m • •
		84	Po	Po 192 0.5s a 6.58	Po 193 Short 9 5 98	Po 194 0.65 9 6 85	Po 195 2.0s 5s a 5 70 a 6.61	Po 196 ~ 5.5s a 6 52	Po 197 265 565 16.58 4.6.28	Po 198 1.75m a 6 18	Po 199 4.2m 5.2m 4.406 45.95	Ро 200 Н.5 m бовь	<u>ік «8)</u> Ро2ОІ 9.0m : 15.4m абля — тобя	En 58 Po 202 44m ε α 5 55
	83	Bi 208.980 _{06.} 34mb	Bi 190 ? ***	Bi 191 ? 145 a 5 9 a 6 31	Bi 192 ~~ 405 #6.05	Bi 193 3.2s ~70s 0.55 a 5.89	Bi 194 855 956	Bi 195 ~60s 2.5m a 610 a 5.4	Bi 196? 7.8m	Bi197?	Bi 198 11,9m ∳ 98 ⊮064	E 36 Bi 199 ⁹⁷ 24.7m a 5 50	Bi200 35m ((104.46) E 55	Bi 2019- 53m 111m a5 25 y 6290 E 42
	82	Рb 207.19 _{Ф.18}						Pb 194	Pb 195 17m 5,0990, 383	Pb 196 37m 5 7H2, 240, 253, - E	1377 P597 197 42 m 2 5 2020 11 2 34 11 2 34 7 985 E-141	Pb 198 2 4h ¢ 77540. 	12 3m 1.5h 12 3m 1.5h 11 424 4.87 28 12 424 4.87 28 12 42 12 42 12 42	Pb 200 21h 9 (48142, 235, 2580331 45 8 5 9.
81	ΤΙ 204.37 σ ₆ 3.7					T 9 ^{IOm}	74 9212 11m 10m € 9 (1,42) €	(9/4)TI 193(1/) 2.1m 23m 11<.025 y.365 y.24, 25.26, 27-33	TI 94 32.8m 34m 5.097 5 43 4587 E~5.4	9/ 171 195 ^{μ4} 3.6s 1.17h 11.099 τε,β*~1.8 7.383 y 037, 226 88 E3.0	(*+11196) 1.41h 18h *084, * 11120 E4.6 y034, 241, 275	9/TI 1971/ 0.54s 2.83h 17222 6 y 385 y.152, 018-101 E2.2	7:TI 1982- 187h 5h 6. y 048, 6. 8*24, 21, 17.261 y.412, y 283, 195 6.35 2.8	9 TI 994 287ms 7.4h 11383. 029 7.455. 367.35, 208. 727 EU 035-49
		106		108		110		112		114		116		118

	120		122		124		126		128		120	
*T12002 54ms (26.1h *	197120117 1.9ms 1 73h 17.22, 6 56 1 7167, 7 331, 1 135,031 18,4 166	(%)TT2022 0.58ms12 2d IT460 + 7490 - 744, 	TI 203 ⁴⁴ 29.50 9/10 202.97235	саТ 204° 62да 380у , астория , аст	TI 205 ^{μ+} 70.50 σ, 204,97444	1 206 RoE 4.21m ^B 2 ^{NOS} El 524	TI 207100 ACC11 477m 6144 2160 111135 111135	TI 208 ⁵⁺ 55.C²¹ 306m (* 180.64-238 * ² 615.583,58, 04 (09 14995	T1209(#1 2 2m # 18 + 120, 45,156 E393	TI 210 RaC 1.3m <i>B</i> 19,13,23 (n) <i>y</i> 79,30,01-243 £5.47		
³ Pb201 ⁶ 61s 9.4h 7629 ε,β+ 7.330, 76.14 Ε.2	9 Pb 202 3.6/h (~ 3xl0 ³ y 1.797) 6 1.997) 6 422 940 (xi 44 422 940 (xi 44 5 98) 999 (24 - 490	1919 D203 9 62s 52.1h 17825 6 401.64 E.82	95 Pb 204 66 9m 1.48 10 1 2 H4x10 ¹⁰ y 2 89 2.6 80 2.6 80 2.6 80 2.6 80 2.6 80 2.6	ty=Pb205 44ms .5x10/y (13.252 (23.199 (23.199 (23.199) (23.199)	Pb 206 0 126ms 23.6 11 5-45 - 147 30 - 205 97447	124 Pb207 1/- 0.80s 22.6 17106 - 57- 17,71 - 206.97590	Pb 208 52.3 σ ₅ ~15mb 207.97665	Pb2099# 3.31h ₫164 137 164	Pb2lO RaD 22y β 015, 061 γ.0465 (13.72 Ε 061	Pb 21 (9/+) ACE 36.1m $\beta^{-1.37,55,\cdots}_{\gamma405,632,427,}$ E137 065-1,270	Pb 212 T=E 10.64h β=34,58,·· y 239,300,115- E 58	
95m € 7.422.96 . 455	11.8h 6,81,35,74 7,063,1995 4,857 4,857 E3.19	11.3h e 7024,325 080 125 Eise44	15.31d 2.31.64 2.03,164,159 1.31.6 1.31.6	178), s 16 243d	C Prins 1 30y	2.57ms i3:68× 11 921 - 10 ⁵ y 1511 - 10 ⁵ y 1511 - 10 ⁵ 2.65 12.87	100 >2 x 10 y q _y (15mb + 19mb) 208.98039	Cat 5.01d ~5x10° y nu; as 45,4 91,1a465, 2 57. NS. 1465, 2 58. NS. 1660	AcC 2.14m a 6 622,6.278, y 351 A 60 210,9873	ThC 60.60m y727,785-180 (a879-10.55) a605,609, y0399,616 E2.25	46m β=1.42,1.02 γ.440, α.5.87,5.55 E1.42	
Bi 202 '	Bi 203*	Bi 204 ^{6*}	Bi 205%	"Bi 206**	Bi 207***	" Bi208'''	Bi209*	⁹ Bi2l0	Bi 21198887	Bi 212 1-	Bi 213.99520	·
e . 2538	€ 07:5:38 9:88,27,	t⊺i6 i€ y∄i d1522	র সরাচার্কের বিজয় জাচান্য	lan and in 555 lan 115 lansety	аў. 1. у 6. 28	0 4 88. 7 267 .003	α 5 305 γ.803 σ(< 5mb +<.03)	y1.063, 0.555 571,897 a 7448, 571,897 y106,	α 11 7 ··· 0.304μs γ 2 615, α 8 785 583	a 8.38,7.62	α 7.688,6.89 γ.792	/
Po 203 30m	Po 204 35h	Po2055/ 64ms 18h	Po 206	**Po207**	Po 208 2.896y	Po 209 ¹⁴ 103y	Po 210 Raf 138.40d	250 27383 AcC	1891P0212 45s ThC	Po213 (94) 4µs	Po214 Roc 164µs	
<u>E~ZI</u>	E~49	1~60	E37	1	49-3-44-9	12.168	u 5 86 U 750	2119907	212.993	213.9963	214.9987	

Rn 205 2 8m 4 6 26

204 93

At 204

€ α 5 95

Rn 206 63m 63r

205 4

At 205

€ a 590

Rn 207

At 206 2.8h 1 3lm

) Sim

613

~48

Rn 208

6 0.615

≠ 0 ∿ 76

At 207

Rn 209 Rn 210 30m 24h 7 nut

At 208 At 209%

. . (35) . 4 $\pm \epsilon$ 2:79.9895

€ 12:5-04



Rn 212 25m a 6 27

211.9907

At 211% 7.21h

. 48.y1.06.

Rn 211

032 - FR V28,5 85,5 6 269, 12, 23 2383

At 210' 8.3h

Rn213 19ms a 8.09

212 9939

At 212 0125 0.225 a782, a766, 788 760 y 06 y.06?

Rn 214 Short

214.00

At 213

a 9.07

Rn 215 ~ 1µ\$ a 867

214.999

At 214 ~ 2µs a 8.78,...

Rn 216

216.0003

A: 215 .IOms α 8.00, 7.60 γ~.40

214.9987

a 8.05 no y

- 30 -

									90	Th 232.038 g ⁷⁴	Th213 .15s ¤ 769	Th214 .13s ¤ 768	Th215 1.2s 1.739,752, 733
						89	Ac	Ac209 0 ls 9 7 58	Ac2IO ~035s @746	Ac211 ~ 0.25s a 748	Ac212 ~0.93s @7.38	Ac213 0.8s a 7.36	Ac214 8.2s a7.21.708, 7.00
				88	Ra	Ra 206 0.4s	Ra207 1.3s a 7 13	Ra208 1.2 s 4 7 13	Ro209 47s	Rg210 385 9702	Ra211 15s	213.01 Rd212 13s a 6 87	214_01 Ra213 2.7m a 662.673, 6 52 213.000
		87	Fr	Fr203 0.7s	Fr 204 2 2s = 3,3s 7.03 = 86.97 :	Fr 205 3.7s 9 6 92	Fr 206 157s 4679	Fr 207	Fr 208 38s 9665	Fr 209 54s a 6 65	Fr 210 3.0m a 6 57	Fr 211 3 08m a 6 53	Fr 212 19m 46 26 6 38 6 41 6 34
86	Rn	Rn2 35 a 6.77	200? Rn201 3s 4 6 77	Rn202 11s 9.64	Rn2O3 28s 45s #6.5 ^c #6.50	Rn 204 755 a 6.42 203.99	206.00 Rn 205 2.8m a 6 26 204 99	Rn 206 6.3m 4 6.26 6 205 99	Rn 207 IIm 4 613 E 4 8	209.00 Rn 208 22m a 615 E~39	Rn 209 30m α 6.04 E~4 0	209955 Rn 210 2.4h a 6 04 6 209.9895	Rn 21 1√-7 15 h ∮ 032 - 1 80 a 5 78,5 85,5,62 y 069, 17, 23 E2,89
	112	11	4	116		118		120		122		124	

150

Pa236 ^{12m}

Th235

Pa 234 UX₂ j UZ

Pa 233

Th232 Th233 Th 100 p 22 2 m (41 x 10 p 8 24 - x 10 Pa 235

Th234

			11, 11,	10, 00, 0, 000 20, 20, 00, 10, 20, 00, 00, 00, 00, 00, 00, 00, 00, 0	F 194	3, 7.4, 0, 41 µb 232,0381	ημάδο σμιδ Ει 245	6, NUB 1, 27 94 026			L		J
				Ac229	Ac230	Ac231						-1 4 0	
			у сын оону нь. 1079 - 4,4			1 - 1 - 1 1 - 1 - 1 1 - 1						148	
		1	Ra227	Ra228	Ra229	Ra230					4		
			41.21m 8 13: 5 23,50,027	METAR, DAR JUNE'S	10 × 5 m	51h 4 2					-		
			Eraac	F .:55		I	ļ		1		1		
			14m					144		146			
										140			
			Rn225	Rn226	•			1					
			e e	6									
			l			<u> </u>							
				140		142							
						Pa	Pa224	Pa 225	Pa 226	Pa227(5/-	Pa 22813+	Pa229(5/-)	
					91	, u	a U.65	~ 1s a ? 25	1.8m a 6.86,6.82, ·· e	08.5m a 6.47,642, y.065,	\$.058-1.89 46.08,5.71-6.14	5.58,5,67,	
TE ALC 1			+	TTUDOO		TLOOD	TL 007	225 03	E 2 78 226.028	E 1.00 227.0288	E 2 10 228.0310	x 026071 E.35	
1 N216 25ms	1 N 217 - 5 ms	1		1 n220	1 h221 1,7ms	+h222 ~2.8ms	06s	1.15 1.15 a717,699	10220 ³⁴ 8m a648,631 6.80	1 N 2 20 31 m a 6.33,622,	RdAc 18.72d a 6.0375.958,	RdTh 1.913y	
a 192	2925				ge 6 é d'	1.1.98	2010200	y 77,	y 322, 362, 246 €	y 10, 242, 131, ··	5 755 7 236,006 443 7,~450	γ 084, 216, 13, 17 $\sigma_{\gamma} \sim$ 123, $\sigma_{\gamma} < .3$	
Ac2!5	Ac2I6		Ac218	Ac219	Ac220	Ac 22I	Ac222	Ac 223	Ac224	Ac225(3/-	Ac226	Ac227 -	
017s 9-5	0.56ms-0.58ms 01.9 H (19.03) 9 07 i8 20,826	1	5norf 9321	bhor! a 4 66	24 ms a k - P	0.005 0.764,7.43	05 a 7.00,6.96 €	α£ 648,6.659,·· γ 08-17	2.311 4 7.216, 132 46.044,6203,	α5.82,5.79 5.73; γ.037~,529	# 88,11 1,0721230	β ⁻ 044 9 < 2 γ.009-025 9495.4.94 ···	
0.01				0.00		221 0.57	222.0-78	e 223 0191	6.139, E i 39 224.0217	225 0232	05.44 ? E ⁺ 62 E ⁻ 1.12	7.013-19 E.044 17790 227.0278	
Ra214 2.6s	Ra215 1.56ms	Ra2l6 Ins	Ka217 <03ms	Ra218 Chort	Ra 219	Ra 220 ∼23ms	29s	R0222 38s	Acx 11.43d	Ka224	Ha 225 ¹⁵⁷⁻	Ro 1602 y	
2714	ан 10, гын н. : Энь сооз	a 9 1	a 900	an u	a 76,8 794	465	6 665, > 089, 152, 176,	7.325	7 270, 031-580 7 130, 041	y 2004, 290- 65 y 241, 290- 65 y 12	y 040 no a	γ 186, 260 - 610 σ 20, σ, < ,1mb	
Fr 213	Fr2l4	Fr215	Fr 216	Fr 217	Fr 218	Fr 219	Fr 220	Fr 221	Fr 222	Fr223	Fr 224	Fr225	
34.7s	3.4ms' 50ms 2815 0842 848 840	(تد ف م م ف م م	Short 199	Short a 8 M	~ 5ms a *95	21 ms	28s a 6 68,6 54	4.8m a 6 14, 6 12,-	15m #"	Ack 22m	2.7m #-	3.9m β	
s Sanna a shendar	1/ 5740	الا سان وال	gifters.	. 105	.* #(1**		120 0123	2210:42	62.03	015 44 11 49 223 0197	د~ ٤.١		
Rn 212 25m	Rn213	Rn214	Rn 215 ~ 1µs	Rn 216 05ms	Rn 217 5s	Rn 218	Rn 219 An 3.96s	Rn 220	Rn 221 25m	Rn 222	Rn 223	Rn 224	
1627	177 H 1	1.1 m	ань"	ura tri Noti	. 1 1 4	g 115654 71	27 9070,000 + 323,0 + 275 4 3, 5	0.6286,5747 7.542 0.512	8- a	a 5 486. y fil 7y ~ 72	β [−]	₿ ⁻	
1967	012 11 13 1	214	214 999	2.6 (9)13	2.7.0039	.:-8 XV56	2.3 200	220 01:4	15~10	222.0175		<u>ا</u> ــــــــــــــــــــــــــــــــــــ	1

Pa 2313-Pa 2324x05y 322d

> **Th23**I³ ພາກາ2552 ທີ່ດູຊູ້ສູ່ແລະ ດາ

Pa230

10

126 128 130 132 134 136 138



					105					260? > 10ms a 9.7	261? 0.1-3s a 9.4		
					104			257 ~4.5s α 9.00,8 95,8.78, 8.70	258? 11ms SF	259 ~3s ab 77, 8.86	260 ? 0.3s SF	261? ~Im ¤8.2-8.3	
			103	Lr				Lr 256 ~ 35s ¤ 84	Lr 257 a 8.5 8.6	Lr 258 or 259 ^{8s}			
		102	No	No 251 0.85 a19.60,8.68	No 252 2.4s ⁽¹⁾ 8.41 SF	No253 1.6m a 8.01	No 254 56 s sF	No 255 3.0m a 8 08	No 256 3.2s 9.8 43 SF	No257 23s a 8,23,8.27			
	101	Md				Md252 8m	254.091	255.09	Md 255 28m a 7.34 E~.85 255.0906	Md 256 I.3h ∉ 7.18	$ \underset{\substack{\sim 5 \text{ h} \\ \text{a 708} \\ \text{SF} }}{\text{Md 257}} $	Md 258 54 d a 6.73,6.78	
Fm245	Fm246 1.3s a 8.24 SF	Fm247 95 355 a818 47.87, 7 9 3	Fm 248 .61m 0 7 87, 7 83 .5 248 (77)	Fm 249 ~26m #7.53	Fm 250 30m	Fm 251 7h ¢ 6.9 7.41 Fot 2	Fm 252 23h 2704, 7.00 SF	Fm 253 2.6 d a 6.95, 6.68, y, 145, 272	Fm 254 3.24h a 720,716,706 y.041,098,15 SF 254,0868	Fm 255 ⁷⁴ 20.1 h 9.702.6.97.6 41- 7.081.059 5F 9.26 255 00	Fm 256 2.63h ^{SF} α 6.9	Fm 257(9/+) 80d a 6.52,670, 56,44, 7.062, 18, .24, SF	Fm 258 < 0.2 s
	Es 245	Es 246 7.7 m	Es247 5.0m a 7.33 Fv 2.3	Es 248 25m 4688	Es 249 2h 6 9 677 E 1 41 249 0763	Es 250 8h	Es 251 1.5d 6 6.48 Ev 6 251 0799	Es252(7+) ~ 140d a 6 64,5.9- 6.6 7.40,07-57 252 0828	Es253//+ 20.5d a664.5.73-6.63 y.04(8,0088-90) SF 0/560 of (180 + 14)	233.03 2-1Es 2541/4 39.3h 276d 8 48,113. 6644, 5 48,044 606 6 49,139 663 6 49,034 605 6 39156 7, < 40 25 39156 7, < 40	Es 255 39d a 6.31,6.27,6.22 SF Gr ~ 40	Es 256 ^{22m} ^{g-}	Es257 β ^{-<20h}
Cf243 11m 6 a 7.06, 7,17	Cf 244 20m a * 21	Cf 245 44m	Cf 246 36h a 676,672, y 042,096,146 SF	Cf 247 2.5h 2.255 42.46	Cf 248 350d a 6 27. SF	Cf 24999. 352 y a5.81,590,593, 6,70,	Cf 250 13.19 9.043 SF 0.7 × 1500	Cf 251 ^{1/+} 900 y 95.67,5 84,6.01, 7 18,22 of ~ 3000 5	Cf 252 2.65y a 6.12,6.08, y.043,.100, SF 57,20	Cf 253 17.6d β^{27} a 5.98, 5.92 $a_{7} \sim 165$ f = 27	Cf 254 60d sf a 5.83, 5.79 $\sigma_{y} < 2$		
 	Bk 243 46h 7.75, 95, 84 2657,654,618 676,04-55, 6149	Bk244 44h 7218 89 45 151 0667.662 E~2 2	Bk 245(3/-) 4.98d 253, 381, 385 2589,615,636, 7207, 47, 166 E 84	Bk246 2 18d + Po108,734-	Bk247 14x10 ³ y a 5.52,568,531 y 084,27	249.0/47 Bk 248 ^(c) ≥9y 16h a β ⁻ 55 β ε sr ε ⁻ 65	Bk 2497* 3ms 311d 3ms 311d 3ms 311d 3ms 311d 3ms 325 3ms 325 3ms 326 3ms 326 3	⁽²¹⁾ Bk 250 ⁽²⁻¹ [21ms] 3.22h ×043 β 73,176 41 799,103,- 29μs σ ~1000 ×036 c 176	$\begin{array}{c} 7 & 252.08\\ \hline & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ $				
Cm24 (1/4) 35d 7 47, 60 0594,573-6.08 7 145	Cm242 163d a 61 60 1 2 344 - 100 - 94 2 344 - 100 - 94	Cm243* 52, 54, 74, 75 74, 74, 75 74, 74, 75 74, 74, 75 74, 74, 75 74, 75	Cm244 34mi 18 y 11 /6 34 67 99 2041 87 799 2041 87 2041 87 2041 87 2041 87 2041 87 2041 87 2041 87 2041 87 2041 87 2044	Cm245 ²² 6 3 x 10 ³ y 7 1 ² 5, 13 <i>a</i> ₇ ~2 ² 6, -9, 2 ³ 00 2050554	Cm246 4.71 x 10 ³ y 4.5 34 7,9	Cm247, 25μ3 1.6×10'y γ.27 α σ, 180 σ, 108	Cm248 3.52 x 10 ⁵ y a 5.08.5 04 sF g ⁷	Cm 249 64m ^{#-9} ⁻ ,~2	Cm250 1.1 x 10 ⁴ y SF		Cm252 ≤2d		
Am 240 0.9ms 51h 55 51h 9043, 099, 99, 89,	Am 24 / 2 433 y 549,4 455 5 2696 244 55 5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Am242 ^{iH} isoni	Am2435 7370y 52552340 535 9075. 2022	Am24464 9mst - 0.16 26m / A - 9 26m / A - 9 3 - 5 - 1 - 3 - 3 9 - 5 - 1 - 3 - 3 9 - 5 - 1 - 3 - 3	Am245(5/4) 2.04h 890. 2.036, 252, 240,296,	Am246 2+ 39m 250m y680, g1.3,160, 205, 210 154, 108, 80, 172, 22, 18 172, 18 174,	Am247 22m 70.285,0.226						
Pu239" 24,390y 516,515,511 357,059,771 55,742 q,271	2410%5 Pu 240 6600y 15:7.5:2 у 045, 04:688 5: 7, 080 - 7, 08	Pu 24 15/* 14.3y a 490, 485, - y 149, 11, of v 364e , vH00*	7 243.0614 Pu 242 3.87 x 10 ⁵ y x 90, 4.86 x 0 ⁴ x 20, 4 x 2	Pu 24 3 ⁽²⁾ 4.96h 2 ⁻⁵⁶ , 49 564, 642, 612 9, 564, 642, 612 16 9, 57, 70, 79, 516	Pu 244 8 3 x 10 ⁷ y α 4 59,4 54 Sr σ _y 1.8	Pu 245 ⁽⁹⁻⁾ IO.5h # 93,121 y 327,560, 308. 376,028-102	Pu 246 10.85d 8-15,33 9.044,027 225						
Np 238 2 12d 2 12d 2 . 24. 25. 7 . 44 7 . 26.70	240.0539 Np 23954 2 354 7 645 - 504 6/45 - 504	E 10208 1(-) Np 240 75m 65m 8-218 65m 9-043 53 7085 26-162 116 9-	Np 241 16.0m β ⁻ 13 γ.13, 18	<u>L 56</u>	244.05	67 - 200 E1.26	E_40				156		158
6.75d <i>β</i> : 23, 25, 37 <i>φ</i> : 9595, 206, 014- 371 <i>σ</i> ₂ 460, <i>σ</i> ₁ < 35 Ε 514	E 24 U238 UI 99.27 SF 4.51x10 ³ y a ^{4.20,} y 048 cy ^{2.7} 3, cyc. 5mb	<u>22.18 [52.1]</u> U 239 ^(5/1) 8 ^(1,2) : 28, 7 ⁽³⁷⁴⁾⁽⁴³⁵⁾⁽³¹⁾ 9 ⁽⁴⁾ 7 ⁽³⁷⁴⁾⁽⁴³⁵⁾⁽³¹⁾ 9 ⁽⁴⁾ 9	U240 14.1h 8-36 y 044					<u> </u>	154				
Pa236 ^{12m} ^{8-3.3}	238,0508 Pa237 39m β ⁻² 30,135, γ.46,92,09- 1.4 E230	F),48	. 40		-		152	1					

146 148

150

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LIST OF ATOMIC ELEMENTS

Actinium	Ac	39	Nercury	Hq	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	Ał	85	Niobium	NЪ	41
Barium	Ba	56	Nitrogen	Ν	7
Berkelium	Bk	97	Nobelium	No	102
Beryllium	Be	4	Osmium	Os	76
Bismuth	Bi	83	Oxygen	0	8
Boron	B	5	Palladium	Pd	46
Bromine	Br	35	Phosphorus	P	15
Cadmium	Cd	48	Platinum	Pt	78
Calcium	Ca	20	Plutonium	Ρυ	94
Californium	Cf	98	Pelonium	Po	84
Carbon	C	6	Potassium	ĸ	19
Cerium	Če	58	Proseodymium	Pr	59
Cesium	Cs	55	Promethium	Pm	61
Chlorine	CI	17	Protactinium	Pa	91
Chromium	Cr	24	Radium	Ra	88
Cobalt	Co	27	Radon	Rn	86
Copper	Ču	29	Phenium	Re	75
Curium	Cm	96	Rhodium	Rh	45
Dysprosium	Dv	66	Rubidium	RP	37
Finsteinium	Es.	99	Ruthenium	Ru	44
Erbium	Ēr	68	Samarium	Sm	62
Europium	£υ	63	Scendium	Sc	21
Fermium	Em	100	Selenium	Se	34
Fluorine	۶	9	Silicon	Si	14
Francium	Fr	87	Silver	Aa	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	Но	67	Terbium	Th	65
Hydrogen	н	1	Thallium	τI	81
Indium	In	49	Thorium	ть	00
Iodine	1	53	Thulium	Tm	60
Iridium	lr	77	Sin	Sn	50
Iron	Fe	26	Titanium	Ti	22
Krypton	Kr	36	Tunasten	Ŵ	74
Lanthanum	La	57	Uranium	U.	92
Lawrencium	Lw	103	Vanadium	v	23
Lead	Pb	82	Xenon	Хр	54
Lithium	Li	3	Ytterbium	Yb	70
Lutetium	Lu	71	Yttrium	Ŷ	39
Magnesium	Mg	12	Zinc	Zn	30
Manganese	Mn	25	Zirconium	Zr	40
Mendelevium	Md	101			-

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