First 20 elements with atomic mass and atomic number

Learning Outcomes Define atomic and mass numbers. Determine the number of protons, neutrons, and electrons in an atom. Identify the charge and relative mass of subatomic particles. Label the location of subatomic particles in the atom. Determine the mass of an atom based on its subatomic particles. Write A/Z and symbol-mass format for an atom. Atoms are the fundamental building blocks of all matter and are composed of protons, neutrons, and electrons. Because atoms are electrically neutral, the number of positively charged protons must be equal to the number of negatively charged electrons. Since neutrons do not affect the charge, the number of neutrons is not dependent on the number of protons and will vary even among atoms of the same element. The atomic number (represented by the letter Z) of an element is the number of protons in the nucleus of each atom of that element. An atom can be classified as a particular element based solely on its atomic number. For example, any atom with an atomic number of 8 (its nucleus contains 8 protons) is an oxygen atom, and any atom with a different number of protons would be a different element. The periodic table (see figure below) displays all of the known elements and is arranged in order of increasing atomic number. In this table, an element's atomic number is indicated above the elemental symbol. Hydrogen, at the upper left of the table, has an atomic number of 1. Every hydrogen atom has one proton in its nucleus. Next on the table is helium, whose atoms have two protons in the nucleus. Lithium atoms have three protons, beryllium atoms have four, and so on. Figure \(\PageIndex{1}\): The social security number subatomic-the proton. Since atoms are neutral, the number of electrons in an atom is equal to the number of protons. Hydrogen atoms all have one electron occupying the space outside of the nucleus. Helium, with two protons, will have two electrons. In the chemical classroom, the proton count will always be equivalent to an atom's atomic number. This value will not change unless the nucleus decays or is bombarded (nuclear physics). Figure \(\PageIndex{3}\): The periodic table of the elements. (CC BY-SA 4.0 International; DePiep via Wikipedia). Experimental data showed that the vast majority of the mass of an atom is concentrated in its nucleus, which is composed of protons and neutrons. The mass number (represented by the letter A) is defined as the total number of protons and neutrons in an atom. Consider the table below, which shows data from the first six elements of the periodic table. Table \(\PageIndex{1}\): Atoms of the First Six Elements Name Symbol Atomic Number (Z) Protons Neutrons Electrons Mass Number (A) (rounded to two decimals) hydrogen \(\ce{H}\) 1 1 0 1 1.01 helium \(\ce{He}\) 2 2 2 2 4.00 lithium \(\ce{Li}\) 3 3 4 3 6.94 beryllium \(\ce{Be}\) 4 4 5 4 9.01 boron \(\ce{B}\) 5 5 6 5 10.18 carbon \(\ce{C}\) 6 6 6 6 12.01 Consider the element helium. Its atomic number is 2, so it has two protons in its nucleus. Its nucleus also contains two neutrons. Since \(2 + 2 = 4\), we know that the mass number of the helium atom is 4. Finally, the helium atom also contains two electrons, since the number of electrons must equal the number of protons. This example may lead you to believe that atoms have the same number of protons and neutrons, but a further examination of the table above will show that this is not the case. Lithium, for example, has three protons and four neutrons, giving it a mass number of 7. Figure \(\PageIndex{4}\): A/Z format and finding subatomics for elementChromium (Copyright; Elizabeth R. Gordon) Knowing the mass number and the atomic number of an atom allows you to determine the number of neutrons present in that atom by subtraction. \[\text{Number of neutrons} = \text{ rounded mass number} - \text{atomic number}\] Atoms of the element chromium \(\left(\ce{Cr} \right)\) have an atomic number of 24 and a mass number of 52. How many neutrons are in the nucleus of a chromium atom? To determine this, you would subtract as shown: \[52 - 24 = 28 \: \text{neutrons in a chromium atom}\] The composition of any atom can be illustrated with a shorthand notation called A/Z format. Both the atomic number and mass are written to the left of the chemical symbol. The "A" value is written as a superscript while the "Z" value is written as a subscript. For an example of this notation, look to the chromium atom shown below: \[\ce{^{52}_{24}Cr}\] Another way to refer to a specific atom is to write the mass number of the atom after the name, separated by a hyphen. Symbol-mass format for the above atom would be written as Cr-52. In this notation, the atomic number is not included. You will need to refer to a periodic table for proton values. Example \(\PageIndex{1}\) Calculate each of the three subatomic particles and give specific group or period names for each atom. Solutions Hg (transition metal)- has 80 electrons, 80 protons, and 121 neutrons Pt (transition metal)- has 78 electrons, 78 protons, and 117 neutrons Br (halogen)- has 35 electrons, 35 protons, and 45 neutrons Example \(\PageIndex{2}\) Write both A/Z and symbol-mass formats for the atoms in Example \(\PageIndex{1}\). Solutions \(\ce{^{201}_{80}Hg}\) and Hg-201 \(\ce{^{195}_{78}Pt}\) and Pt-195 \(\ce{^{80}_{35}Br}\) and Br-80 Example \(\PageIndex{3}\) Identify the elements based on the statements below. Which element has 25 protons? Which element has 0 neutrons? Which element has 83 electrons? Solutions a. manganese b. hydrogen c. bismuth Need More Practice? Turn to section 3.E of this OER and answer questions #1-#2, #4, and #8. Contributors and Attributions CK-12 Foundation by Sharon Bewick, Richard Parsons, Therese Forsythe, Shonna Robinson, and Jean Dupon. Allison Soult, Ph.D. (Department of Chemistry, University of Kentucky) Species of atoms having the same number of protons in the atomic nucleus For other uses, see Element (disambiguation). The periodic table of the chemical elements In chemistry, an element is a pure substance consisting only of atoms that all have the same numbers of protons in their atomic nuclei. Unlike chemical compounds, chemical elements cannot be broken down into simpler substances by chemical means. The number of protons in the nucleus is the defining property of an element, and is referred to as its atomic number (represented by the symbol Z) – all atoms with the same atomic number are atoms of the same element.[1] All of the baryonic matter of the universe is composed of chemical elements. When different elements undergo chemical reactions, atoms are rearranged into new compounds held together by chemical bonds. Only a minority of elements, such as silver and gold, are found uncombined as relatively pure native element minerals. Nearly all other naturally-occurring elements occur in the Earth as compounds or mixtures. Air is primarily a mixture of the elements nitrogen, oxygen, and argon, though it does contain compounds including carbon dioxide and water. The history of the discovery and use of the elements began with primitive human societies that discovered native minerals like carbon, sulfur, copper and gold (though the concept of a chemical element was not yet understood). Attempts to classify materials such as these resulted in the concepts of classical elements, alchemy, and various similar theories throughout human history. Much of the modern understanding of elements developed from the work of Dmitri Mendeleev, a Russian chemist who published the first recognizable periodic table in 1869. This table organizes the elements by increasing atomic number into rows ("periods") in which the columns ("groups") share recurring ("periodic") physical and chemical properties. The periodic table summarizes various properties of the elements, allowing chemists to derive relationships between them and to make predictions about compounds and potential new ones. By November 2016, the International Union of Pure and Applied Chemistry had recognized a total of 118 elements. The first 94 occur naturally on Earth, and the remaining 24 are synthetic elements produced in nuclear reactions. Save for unstable radioactive elements (radionuclides) which decay quickly, nearly all of the elements are available industrially in varying amounts. The discovery and synthesis of further new elements is an ongoing area of scientific study. Description The lightest chemical elements are hydrogen and helium, both created by Big Bang nucleosynthesis during the first 20 minutes of the universe[2] in a ratio of around 3:1 by mass (or 12:1 by number of atoms),[3][4] along with tiny traces of the next two elements, lithium and beryllium. Almost all other elements found in nature were made by various natural methods of nucleosynthesis.[5] On Earth, small amounts of new atoms are naturally produced in nucleogenic reactions, or in cosmogenic processes, such as cosmic ray spallation. New atoms are also naturally produced on Earth as radiogenic daughter isotopes of ongoing radioactive decay processes such as alpha decay, beta decay, spontaneous fission, cluster decay, and other rarer modes of decay. Of the 94 naturally occurring elements, those with atomic numbers 1 through 82 each have at least one stable isotope (except for technetium, element 43 and promethium, element 61, which have no stable isotopes). Isotopes considered stable are those for which no radioactive decay has yet been observed. Elements with atomic numbers 83 through 94 are unstable to the point that radioactive decay of all isotopes can be detected. Some of these elements, notably bismuth (atomic number 83), thorium (atomic number 90), and uranium (atomic number 92), have one or more isotopes with half-lives long enough to survive as remnants of the explosive stellar nucleosynthesis that produced the heavy metals before the formation of our Solar System. At over 1.9×1019 years, over a billion times longer than the current estimated age of the universe, bismuth-209 (atomic number 83) has the longest known alpha decay half-life of any naturally occurring element, and is almost always considered on par with the 80 stable elements.[6][7] The very heaviest elements (those beyond plutonium, element 94) undergo radioactive decay with half-lives so short that they are not found in nature and must be synthesized. There are now 118 known elements. In this context, "known" means observed well enough, even from just a few decay products, to have been differentiated from other elements.[8][9] Most recently, the synthesis of element 118 (since named oganesson) was reported in October 2006, and the synthesis of element 117 (tennessine) was reported in April 2010.[10][11] Of these 118 elements, 94 occur naturally on Earth. Six of these occur in extreme trace quantities: technetium, atomic number 43; promethium, number 61; astatine, number 85; francium, number 87; neptunium, number 93; and plutonium, number 94. These 94 elements have been detected in the universe at large, in the spectra of stars and also supernovae, where short-lived radioactive elements are newly being made. The first 94 elements have been detected directly on Earth as primordial nuclides present from the formation of the solar system, or as naturally occurring fission or transmutation products of uranium and thorium. The remaining 24 heavier elements, not found today either on Earth or in astronomical spectra, have been produced artificially: these are all radioactive, with very short half-lives; if any atoms of these elements were present at the formation of Earth, they are extremely likely, to the point of certainty, to have already decayed, and if present in novae have been in quantities too small to have been noted. Technetium was the first purportedly non-naturally occurring element synthesized, in 1937, although trace amounts of technetium have since been found in nature (and also the element may have been discovered naturally in 1925).[12] This pattern of artificial production and later natural discovery has been repeated with several other radioactive naturally occurring rare elements.[13] List of the elements are available by name, atomic number, density, melting point, boiling point and by symbol, as well as ionization energies of the elements. The nuclides of stable and radioactive elements are also available as a list of nuclides, sorted by length of half-life for those that are unstable. One of the most convenient, and certainly the most traditional presentation of the elements, is in the form of the periodic table, which groups together elements with similar chemical properties (and usually also similar electronic structures). Atomic number Main article: Atomic number The atomic number of an element is equal to the number of protons in each atom, and defines the element.[14] For example, all carbon atoms contain 6 protons in their atomic nucleus; so the atomic number of carbon is 6.[15] Carbon atoms may have different numbers of neutrons; atoms of the same element having different numbers of neutrons are known as isotopes of the element.[16] The number of protons in the atomic nucleus also determines its electric charge, which in turn determines the number of electrons of the atom in its non-ionized state. The electrons are placed into atomic orbitals that determine the atom's various chemical properties. The number of neutrons in a nucleus usually has very little effect on an element's chemical properties (except in the case of hydrogen and deuterium). Thus, all carbon isotopes have nearly identical chemical properties because they all have six protons and six electrons, even though carbon atoms may, for example, have 6 or 8 neutrons. That is why the atomic number, rather than mass number or atomic weight, is considered the identifying characteristic of a chemical element. The symbol for atomic number is Z. Isotopes Main articles: Isotope, Stable isotope ratio, and List of nuclides Isotopes are atoms of the same element (that is, with the same number of protons in their atomic nucleus), but having different numbers of neutrons. Thus, for example, there are three main isotopes of carbon. All carbon atoms have 6 protons in the nucleus, but they can have either 6, 7, or 8 neutrons. Since the mass numbers of these are 12, 13 and 14 respectively, the three isotopes of carbon are known as carbon-12, carbon-13, and carbon-14, often abbreviated to 12C, 13C, and 14C. Carbon in everyday life and in chemistry is a mixture of 12C (about 98.9%), 13C (about 1.1%) and about 1 atom per trillion of 14C. Most (66 of 94) naturally occurring elements have more than one stable isotope. Except for the isotopes of hydrogen (which differ greatly from each other in relative mass—enough to cause chemical effects), the isotopes of a given element are chemically nearly indistinguishable. All of the elements have some isotopes that are radioactive (radioisotopes), although not all of these radioisotopes occur naturally. The radioisotopes typically decay into other elements upon radiating an alpha or beta particle. If an element has isotopes that are not radioactive, these are termed "stable" isotopes. All of the known stable isotopes occur naturally (see primordial isotope). The many radioisotopes that are not found in nature have been characterized after being artificially made. Certain elements have no stable isotopes and are composed only of radioactive isotopes: specifically the elements without any stable isotopes are technetium (atomic number 43), promethium (atomic number 61), and all observed elements with atomic numbers greater than 82. Of the 80 elements with at least one stable isotope, 26 have only one single stable isotope. The mean number of stable isotopes for the 80 stable elements is 3.1 stable isotopes per element. The largest number of stable isotopes that occur for a single element is 10 (for tin, element 50). Isotopic mass and atomic mass Main articles: atomic mass and relative atomic mass The mass number of an element, A, is the number of nucleons (protons and neutrons) in the atomic nucleus. Different isotopes of a given element are distinguished by their mass numbers, which are conventionally written as a superscript on the left hand side of the atomic symbol (e.g. 238U). The mass number is always a whole number and has units of "nucleons". For example, magnesium-24 (24 is the mass number) is an atom with 24 nucleons (12 protons and 12 neutrons). Whereas the mass number simply counts the total number of neutrons and protons and is thus a natural (or whole) number, the atomic mass of a single atom is a real number giving the mass of a particular isotope (or "nuclide") of the element, expressed in atomic mass units (symbol: u). In general, the mass number of a given nuclide differs in value slightly from its atomic mass, since the mass of each proton and neutron is not exactly 1 u; since the electrons contribute a lesser share to the atomic mass as neutron number exceeds proton number; and (finally) because of the nuclear binding energy. For example, the atomic mass of chlorine-35 to five significant digits is 34.969 u and that of chlorine-37 is 36.966 u. However, the atomic mass in u of each isotope is quite close to its simple mass number (always within 1%). The only isotope whose atomic mass is exactly a natural number is 12C, which by definition has a mass of exactly 12 because u is defined as 1/12 of the mass of a free neutral carbon-12 atom in the ground state. The standard atomic weight (commonly called "atomic weight") of an element is the average of the atomic masses of all the chemical element's isotopes as found in a particular environment, weighted by isotopic abundance, relative to the atomic mass unit. This number may be a fraction that is not close to a whole number. For example, the relative atomic mass of chlorine is 35.453 u, which differs greatly from a whole number as it is an average of about 76% chlorine-35 and 24% chlorine-37. Whenever a relative atomic mass value differs by more than 1% from a whole number, it is due to this averaging effect, as significant amounts of more than one isotope are naturally present in a sample of that element. Chemically pure and isotopically pure Chemists and nuclear scientists have different definitions of a pure element. In chemistry, a pure element means a substance whose atoms all (or in practice almost all) have the same atomic number, or number of protons. Nuclear scientists, however, define a pure element as one that consists of only one stable isotope.[17] For example, a copper wire is 99.99% chemically pure if 99.99% of its atoms are copper, with 29 protons each. However it is not isotopically pure since ordinary copper consists of two stable isotopes, 69% 63Cu and 31% 65Cu, with different numbers of neutrons. However, a pure gold ingot would be both chemically and isotopically pure, since ordinary gold consists only of one isotope, 197Au. Allotropes Main article: Allotropy Atoms of chemically pure elements may bond to each other chemically in more than one way, allowing the pure element to exist in multiple chemical structures (spatial arrangements of atoms), known as allotropes, which differ in their properties. For example, carbon can be found as diamond, which has a tetrahedral structure around each carbon atom; graphite, which has layers of carbon atoms with a hexagonal structure stacked on top of each other; graphene, which is a single layer of graphite that is very strong; fullerenes, which have nearly spherical shapes; and carbon nanotubes, which are tubes with a hexagonal structure (even these may differ from each other in electrical properties). The ability of an element to exist in one of many structural forms is known as 'allotropy'. The standard state, also known as the reference state, of an element is defined as its thermodynamically most stable state at a pressure of 1 bar and a given temperature (typically at 298.15 K). In thermochemistry, an element is defined to have an enthalpy of formation of zero in its standard state. For example, the reference state for carbon is graphite, because the structure of graphite is more stable than that of the other allotropes. Properties Several kinds of descriptive categorizations can be applied broadly to the elements, including consideration of their general physical and chemical properties, their states of matter under familiar conditions, their melting and boiling points, their densities, their crystal structures as solids, and their origins. General properties Several terms are commonly used to characterize the general physical and chemical properties of the chemical elements. A first distinction is between metals, which readily conduct electricity, nonmetals, which do not, and a small group, (the metalloids), having intermediate properties and often behaving as semiconductors. A more refined classification is often shown in colored presentations of the periodic table. This system restricts the terms "metal" and "nonmetal" to only certain of the more broadly defined metals and nonmetals, adding additional terms for certain sets of the more broadly viewed metals and nonmetals. The version of this classification used in the periodic tables presented here includes: actinides, alkali metals, alkaline earth metals, halogens, lanthanides, transition metals, post-transition metals, metalloids, reactive nonmetals, and noble gases. In this system, the alkali metals, alkaline earth metals, and transition metals, as well as the lanthanides and the actinides, are special groups of the metals viewed in a broader sense. Similarly, the reactive nonmetals and the noble gases are nonmetals viewed in the broader sense. In some presentations, the halogens are not distinguished, with astatine identified as a metalloid and the others identified as nonmetals. States of matter Another commonly used basic distinction among the elements is their state of matter (phase), whether solid, liquid, or gas, at a selected standard temperature and pressure (STP). Most of the elements are solids at conventional temperatures and atmospheric pressure, while several are gases. Only bromine and mercury are liquids at 0 degrees Celsius (32 degrees Fahrenheit) and normal atmospheric pressure; caesium and gallium are solids at that temperature, but melt at 28.4 °C (83.2 °F) and 29.8 °C (85.6 °F), respectively. Melting and boiling points Melting and boiling points, typically expressed in degrees Celsius at a pressure of one atmosphere, are commonly used in characterizing the various elements. While known for most elements, either or both of these measurements is still undetermined for some of the radioactive elements available in only tiny quantities. Since helium remains a liquid even at absolute zero at atmospheric pressure, it has only a boiling point, and not a melting point, in conventional presentations. Densities Main article: Densities of the elements (data page) The density at selected standard temperature and pressure (STP) is frequently used in characterizing the elements. Density is often expressed in grams per cubic centimeter (g/cm3). Since several elements are gases at commonly encountered temperatures, their densities are usually stated for their gaseous forms; when liquefied or solidified, the gaseous elements have densities similar to those of the other elements. When an element has allotropes with different densities, one representative allotrope is typically selected in summary presentations, while densities for each allotrope can be stated where more detail is provided. For example, the three familiar allotropes of carbon (amorphous carbon, graphite, and diamond) have densities of 1.8–2.1, 2.267, and 3.515 g/cm3, respectively. Crystal structures Main article: Crystal structure The elements studied to date as solid samples have eight kinds of crystal structures: cubic, body-centered cubic, face-centered cubic, hexagonal, monoclinic, orthorhombic, rhombohedral, and tetragonal. For some of the synthetically produced transuranic elements, available samples have been too small to determine crystal structures. Occurrence and origin on Earth Chemical elements may also be categorized by their origin on Earth, with the first 94 considered naturally occurring, while those with atomic numbers beyond 94 have only been produced artificially as the synthetic products of man-made nuclear reactions. Of the 94 naturally occurring elements, 83 are considered primordial and either stable or weakly radioactive. The remaining 11 naturally occurring elements possess half lives too short for them to have been present at the beginning of the Solar System, and are therefore considered transient elements. Of these 11 transient elements, 5 (polonium, radon, radium, actinium, and protactinium) are relatively common decay products of thorium and uranium. The remaining 6 transient elements (technetium, promethium, astatine, francium, neptunium, and plutonium) occur only rarely, as products of rare decay modes or nuclear reaction processes involving uranium or other heavy elements. No radioactive decay has been observed for elements with atomic numbers 1 through 82, except 43 (technetium) and 61 (promethium). Observationally stable isotopes of some elements (such as tungsten and lead), however, are predicted to be slightly radioactive with very long half-lives:[18] for example, the half-lives predicted for the observationally stable lead isotopes range from 1035 to 10189 years. Elements with atomic numbers 43, 61, and 83 through 94 are unstable enough that their radioactive decay can readily be detected. Three of these elements, bismuth (element 83), thorium (element 90), and uranium (element 92) have one or more isotopes with half-lives long enough to survive as remnants of the explosive stellar nucleosynthesis that produced the heavy elements before the formation of the Solar System. For example, at over 1.9×1019 years, over a billion times longer than the current estimated age of the universe, bismuth-209 has the longest known alpha decay half-life of any naturally occurring element.[6][7] The very heaviest 24 elements (those beyond plutonium, element 94) undergo radioactive decay with short half-lives and cannot be produced as daughters of longer-lived elements, and thus are not known to occur in nature at all. Periodic table Main article: Periodic table vtePeriodic table Group 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Hydrogen &alkali metals Alkaline earth metals Pnictogens Chalcogens Halogens Noblegases Period 1 Hydrogen1H1.008 Helium2He4.0026 2 Lithium3Li6.94 Beryllium4Be9.0122 Boron5B10.81 Carbon6C12.011 Nitrogen7N14.007 Oxygen8O15.999 Fluorine9F18.998 Neon10Ne20.180 3 Sodium11Na22.990 Magnesium12Mg24.305 Aluminium13Al26.982 Silicon14Si28.085 Phosphorus15P30.974 Sulfur16S32.06 Chlorine17Cl35.45 Argon18Ar39.95 4 Potassium19K39.098 Calcium20Ca40.078 Scandium21Sc44.956 Titanium22Ti47.867 Vanadium23V50.942 Chromium24Cr51.996 Manganese25Mn54.938 Iron26Fe55.845 Cobalt27Co58.933 Nickel28Ni58.693 Copper29Cu63.546 Zinc30Zn65.38 Gallium31Ga69.723 Germanium32Ge72.630 Arsenic33As74.922 Selenium34Se78.971 Bromine35Br79.904 Krypton36Kr83.798 5 Rubidium37Rb85.468 Strontium38Sr87.62 Yttrium39Y88.906 Zirconium40Zr91.224 Niobium41Nb92.906 Molybdenum42Mo95.95 Technetium43Tc[97] Ruthenium44Ru101.07 Rhodium45Rh102.91 Palladium46Pd106.42 Silver47Ag107.87 Cadmium48Cd112.41 Indium49In114.82 Tin50Sn118.71 Anti-mony51Sb121.76 Tellurium52Te127.60 Iodine53I126.90 Xenon54Xe131.29 6 Caesium55Cs132.91 Barium56Ba137.33 Lutetium71Lu174.97 Hafnium72Hf178.49 Tantalum73Ta180.95 Tungsten74W183.84 Rhenium75Re186.21 Osmium76Os190.23 Iridium77Ir192.22 Platinum78Pt195.08 Gold79Au196.97 Mercury80Hg200.59 Thallium81Tl204.38 Lead82Pb207.2 Bismuth83Bi208.98 Polonium84Po[209] Astatine85At[210] Radon86Rn[222] 7 Francium87Fr[223] Radium88Ra[226] Lawrencium103Lr[266] Rutherfordium104Rf[267] Dubnium105Db[268] Seaborgium106Sg[269] Bohrium107Bh[270] Hassium108Hs[269] Meitnerium109Mt[278] Darmstadtium110Ds[281] Roentgenium111Rg[282] Copernicium112Cn[285] Nihonium113Nh[286] Flerovium114Fl[289] Moscovium115Mc[290] Livermorium116Lv[293] Tennessine117Ts[294] Oganesson118Og[294] Lanthanum57La138.91 Cerium58Ce140.12 Praseodymium59Pr140.91 Neodymium60Nd144.24 Promethium61Pm[145] Samarium62Sm150.36 Europium63Eu151.96 Gadolinium64Gd 157.25 Terbium65Tb158.93 Dysprosium66Dy162.50 Holmium67Ho164.93 Erbium68Er167.26 Thulium69Tm168.93 Ytterbium70Yb173.05 Actinium89Ac[227] Thorium90Th232.04 Protactinium91Pa231.04 Uranium92U238.03 Neptunium93Np[237] Plutonium94Pu[244] Americium95Am[243] Curium96Cm[247] Berkelium97Bk[247] Californium98Cf [251] Einsteinium99Es[252] Fermium100Fm[257] Mendelevium101Md[258] Nobelium102No[259] Primordial From decay Synthetic Border shows natural occurrence of the element Standard atomic weight Ar, std(E)[19] Ca: 40.078 — Formal short value, rounded (no uncertainty)[20] Po: [209] — mass number of the most stable isotope s-block f-block d-block p-block The properties of the chemical elements are often summarized using the periodic table, which powerfully and elegantly organizes the elements by increasing atomic number into rows ("periods") in which the columns ("groups") share recurring ("periodic") physical and chemical properties. The current standard table contains 118 confirmed elements as of 2019. Although earlier precursors to this presentation exist, its invention is generally credited to the Russian chemist Dmitri Mendeleev in 1869, who intended the table to illustrate recurring trends in the properties of the elements. The layout of the table has been refined and extended over time as new elements have been discovered and new theoretical models have been developed to explain chemical behavior. Use of the periodic table is now ubiquitous within the academic discipline of chemistry, providing an extremely useful framework to classify, systematize and compare all the many different forms of chemical behavior. The table has also found wide application in physics, geology, biology, materials science, engineering, agriculture, medicine, nutrition, environmental health, and astronomy. Its principles are especially important in chemical engineering. Nomenclature and symbols The various chemical elements are formally identified by their unique atomic numbers, by their accepted names, and by their symbols. Atomic numbers The known elements have atomic numbers from 1 through 118, conventionally presented as Arabic numerals. Since the elements can be uniquely sequenced by atomic number, conventionally from lowest to highest (as in a periodic table), sets of elements are sometimes specified by such notation as "through", "beyond", or "from ... through", as in "through iron", "beyond uranium", or "from lanthanum through lutetium". The terms "light" and "heavy" are sometimes also used informally to indicate relative atomic numbers (not densities), as in "lighter than carbon" or "heavier than lead", although technically the weight or mass of atoms of an element (their atomic weights or atomic masses) do not always increase monotonically with their atomic numbers. Element names Main article: Naming of elements The naming of various substances now known as elements precedes the atomic theory of matter, as names were given locally by various cultures to various minerals, metals, compounds, alloys, mixtures, and other materials, although at the time it was not known which chemicals were elements and which compounds. As they were identified as elements, the existing names for anciently-known elements (e.g., gold, mercury, iron) were kept in most countries. National differences emerged over the names of elements either for convenience, linguistic niceties, or nationalism. For a few illustrative examples: German speakers use "Wasserstoff" (water substance) for "hydrogen", "Sauerstoff" (acid substance) for "oxygen" and "Stickstoff" (smothering substance) for "nitrogen", while English and some romance languages use "sodium" for "natrium" and "potassium" for "kalium", and the French, Italians, Greeks, Portuguese and Poles prefer "azote/azot/azoto" (from roots meaning "no life") for "nitrogen". For purposes of international communication and trade, the official names of the chemical elements both ancient and more recently recognized are decided by the International Union of Pure and Applied Chemistry (IUPAC), which has decided on a sort of international English language, drawing on traditional English names even when an element's chemical symbol is based on a Latin or other traditional word, for example adopting "gold" rather than "aurum" as the name for the 79th element (Au). IUPAC prefers the British spellings "aluminium" and "caesium" over the U.S. spellings "aluminum" and "cesium", and the U.S. "sulfur" over the British "sulphur". However, elements that are practical to sell in bulk in many countries often still have locally used national names, and countries whose national language does not use the Latin alphabet are likely to use the IUPAC element names. According to IUPAC, chemical elements are not proper nouns in English; consequently, the full name of an element is not routinely capitalized in English, even if derived from a proper noun, as in californium and einsteinium. Isotope names of chemical elements are also uncapitalized if written out, e.g., carbon-12 or uranium-235. Chemical element symbols (such as Cf for californium and Es for einsteinium), are always capitalized (see below). In the second half of the twentieth century, physics laboratories became able to produce nuclei of chemical elements with half-lives too short for an appreciable amount of them to exist at any time. These are also named by IUPAC, which generally adopts the name chosen by the discoverer. This practice can lead to the controversial question of which research group actually discovered an element, a question that delayed the naming of elements with atomic number of 104 and higher for a considerable amount of time. (See element naming controversy). Precursors of such controversies involved the nationalistic namings of elements in the late 19th century. For example, lutetium was named in reference to Paris, France. The Germans were reluctant to relinquish naming rights to the French, often calling it cassiopeium. Similarly, the British discoverer of niobium originally named it columbium, in reference to the New World. It was used extensively as such by American publications before the international standardization (in 1950). Chemical symbols For listings of current chemical symbols, symbols not currently used, and other symbols that may look like chemical symbols, see Chemical symbol. Specific chemical elements Before chemistry became a science, alchemists had designed arcane symbols for both metals and common compounds. These were however used as abbreviations in diagrams or procedures; there was no concept of atoms combining to form molecules. With his advances in the atomic theory of matter, John Dalton devised his own simpler symbols, based on circles, to depict molecules. The current system of chemical notation was invented by Berzelius. In this typographical system, chemical symbols are not mere abbreviations—though each consists of letters of the Latin alphabet. They are intended as universal symbols for people of all languages and alphabets. The first of these symbols were intended to be fully universal. Since Latin was the common language of science at that time, they were abbreviations based on the Latin names of metals. Cu comes from cuprum, Fe comes from ferrum, Ag from argentum. The symbols were not followed by a period (full stop) as with abbreviations. Later chemical elements were also assigned unique chemical symbols, based on the name of the element, but not necessarily in English. For example, sodium has the chemical symbol 'Na' after the Latin natrium. The same applies to "Fe" (ferrum) for iron, "Hg" (hydrargyrum) for mercury, "Sn" (stannum) for tin, "Au" (aurum) for gold, "Ag" (argentum) for silver, "Pb" (plumbum) for lead, "Cu" (cuprum) for copper, and "Sb" (stibium) for antimony. "W" (wolfram) for tungsten ultimately derives from German, "K" (kalium) for potassium ultimately from Arabic. Chemical symbols are understood internationally when element names might require translation. There have sometimes been differences in the past. For example, Germans in the past have used "J" (for the alternate name Jod) for iodine, but now use "I" and "Iod". The first letter of a chemical symbol is always capitalized, as in the preceding examples, and the subsequent letters, if any, are always lower case (small letters). Thus, the symbols for californium and einsteinium are Cf and Es. General chemical symbols There are also symbols in chemical equations for groups of chemical elements, for example in comparative formulas. These are often a single capital letter, and the letters are reserved and not used for names of specific elements. For example, an "X" indicates a variable group (usually a halogen) in a class of compounds, while "R" is a radical, meaning a compound structure such as a hydrocarbon chain. The letter "Q" is reserved for "heat" in a chemical reaction. "Y" is also often used as a general chemical symbol, although it is also the symbol of yttrium. "Z" is also frequently used as a general variable group. "E" is used in organic chemistry to denote an electron-withdrawing group or an electrophile; similarly "Nu" denotes a nucleophile. "L" is used to represent a general ligand in inorganic and organometallic chemistry. "M" is also often used in place of a general metal. At least two additional, two-letter generic chemical symbols are also in informal usage, "Ln" for any lanthanide element and "An" for any actinide element. "Rg" was formerly used for any rare gas element, but the group of rare gases has now been renamed noble gases and the symbol "Rg" has now been assigned to the element roentgenium. Isotope symbols Isotopes are distinguished by the atomic mass number (total protons and neutrons) for a particular isotope of an element, with this number combined with the pertinent element's symbol. IUPAC prefers that isotope symbols be written in superscript notation when practical, for example 12C and 235U. However, other notations, such as carbon-12 and uranium-235, or C-12 and U-235, are also used. As a special case, the three naturally occurring isotopes of the element hydrogen are often specified as H for 1H (protium), D for 2H (deuterium), and T for 3H (tritium). This convention is easier to use in chemical equations, replacing the need to write out the mass number for each atom. For example, the formula for heavy water may be written D2O instead of 2H2O. Origin of the elements Estimated distribution of dark matter and dark energy in the universe. Only the fraction of the mass and energy in the universe labeled "atoms" is composed of chemical elements. This section needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.Find sources: "Chemical element" – news · newspapers · books · scholar · JSTOR (April 2021) (Learn how and when to remove this template message) Main article: Nucleosynthesis Only about 4% of the total mass of the universe is made of atoms or ions, and thus represented by chemical elements. This fraction is about 15% of the total matter, with the remainder of the matter (85%) being dark matter. The nature of dark matter is unknown, but it is not composed of atoms of chemical elements because it contains no protons, neutrons, or electrons. (The remaining non-matter part of the mass of the universe is composed of the even less well understood dark energy). The 94 naturally occurring chemical elements were produced by at least four classes of astrophysical process. Most of the hydrogen, helium and a very small quantity of lithium were produced in the first few minutes of the Big Bang. This Big Bang nucleosynthesis happened only once; the other processes are ongoing. Nuclear fusion inside stars produces elements through stellar nucleosynthesis, including all elements from carbon to iron in atomic number. Elements higher in atomic number than iron, including heavy elements like uranium and plutonium, are produced by various forms of explosive nucleosynthesis in supernovae and neutron star mergers. The light elements lithium, beryllium and boron are produced mostly through cosmic ray spallation (fragmentation induced by cosmic rays) of carbon, nitrogen, and oxygen. During the early phases of the Big Bang, nucleosynthesis of hydrogen nuclei resulted in the production of hydrogen-1 (protium, 1H) and helium-4 (4He), as well as a smaller amount of deuterium (2H) and very minuscule amounts (on the order of 10−10) of lithium and beryllium. Even smaller amounts of boron may have been produced in the Big Bang, since it has been observed in some very old stars, while carbon has not.[21] No elements heavier than boron were produced in the Big Bang. As a result, the primordial abundance of atoms (or ions) consisted of roughly 75% 1H, 25% 4He, and 0.01% deuterium, with only tiny traces of lithium, beryllium, and perhaps boron.[22] Subsequent enrichment of galactic halos occurred due to stellar nucleosynthesis and supernova nucleosynthesis.[23] However, the element abundance in intergalactic space can still closely resemble primordial conditions, unless it has been enriched by some means. Periodic table showing the cosmogenic origin of each element in the Big Bang, or in large or small stars. Small stars can produce certain elements up to sulfur, by the alpha process. Supernovae are needed to produce "heavy" elements (those beyond iron and nickel) rapidly by neutron buildup, in the r-process. Certain large stars slowly produce other elements heavier than iron, in the s-process; these may then be blown into space in the off-gassing of planetary nebulae On Earth (and elsewhere), trace amounts of various elements continue to be produced from other elements as products of nuclear transmutation processes. These include some produced by cosmic rays or other nuclear reactions (see cosmogenic and nucleogenic nuclides), and others produced as decay products of long-lived primordial nuclides.[24] For example, trace (but detectable) amounts of carbon-14 (14C) are continually produced in the atmosphere by cosmic rays impacting nitrogen atoms, and argon-40 (40Ar) is continually produced by the decay of primordially occurring but unstable potassium-40 (40K). Also, three primordially occurring but radioactive actinides, thorium, uranium, and plutonium, decay through a series of recurrently produced but unstable radioactive elements such as radium and radon, which are transiently present in any sample of these metals or their ores or compounds. Three other radioactive elements, technetium, promethium, and neptunium, occur only incidentally in natural materials, produced as individual atoms by nuclear fission of the nuclei of various heavy elements or in other rare nuclear processes. In addition to the 94 naturally occurring elements, several artificial elements have been produced by human nuclear physics technology. As of 2021[update], these experiments have produced all elements up to atomic number 118. Abundance Main article: Abundance of the chemical elements The following graph (note log scale) shows the abundance of elements in our Solar System. The table shows the twelve most common elements in our galaxy (estimated spectroscopically), as measured in parts per million, by mass.[25] Nearby galaxies that have evolved along similar lines have a corresponding enrichment of elements heavier than hydrogen and helium. The more distant galaxies are being viewed as they appeared in the past, so their abundances of elements appear closer to the primordial mixture. As physical laws and processes appear common throughout the visible universe, however, scientist expect that these galaxies evolved elements in similar abundance. The abundance of elements in the Solar System is in keeping with their origin from nucleosynthesis in the Big Bang and a number of progenitor supernova stars. Very abundant hydrogen and helium are products of the Big Bang, but the next three elements are rare since they had little time to form in the Big Bang and are not made in stars (they are, however, produced in small quantities by the breakup of heavier elements in interstellar dust, as a result of impact by cosmic rays). Beginning with carbon, elements are produced in stars by buildup from alpha particles (helium nuclei), resulting in an alternatingly larger abundance of elements with even atomic numbers (these are also more stable). In general, such elements up to iron are made in large stars in the process of becoming supernovas. Iron-56 is particularly common, since it is the most stable element that can easily be made from alpha particles (being a product of decay of radioactive nickel-56, ultimately made from 14 helium nuclei). Elements heavier than iron are made in energy-absorbing processes in large stars, and their abundance in the universe (and on Earth) generally decreases with their atomic number. The abundance of the chemical elements on Earth varies from air to crust to ocean, and in various types of life. The abundance of elements in Earth's crust differs from that in the Solar System (as seen in the Sun and heavy planets like Jupiter) mainly in selective loss of the very lightest elements (hydrogen and helium) and also volatile neon, carbon (as hydrocarbons), nitrogen and sulfur, as a result of solar heating in the early formation of the solar system. Oxygen, the most abundant Earth element by mass, is retained on Earth by combination with silicon. Aluminum at 8% by mass is more common in the Earth's crust than in the universe and solar system, but the composition of the far more bulky mantle, which has magnesium and iron in place of aluminum (which occurs there only at 2% of mass) more closely mirrors the elemental composition of the solar system, save for the noted loss of volatile elements to space, and loss of iron which has migrated to the Earth's core. The composition of the human body, by contrast, more closely follows the composition of seawater—save that the human body has additional stores of carbon and nitrogen necessary to form the proteins and nucleic acids, together with phosphorus in the nucleic acids and energy transfer molecule adenosine triphosphate (ATP) that occurs in the cells of all living organisms. Certain kinds of organisms require particular additional elements, for example the magnesium in chlorophyll in green plants, the calcium in mollusc shells, or the iron in the hemoglobin in vertebrate animals' red blood cells. Abundances of the chemical elements in the Solar System. Hydrogen and helium are most common, from the Big Bang. The next three elements (Li, Be, B) are rare because they are poorly synthesized in the Big Bang and also in stars. The two general trends in the remaining stellar-produced elements are: (1) an alternation of abundance in elements as they have even or odd atomic numbers (the Oddo-Harkins rule), and (2) a general decrease in abundance as elements become heavier. Iron is especially common because it represents the minimum energy nuclide that can be made by fusion of helium in supernovae. Elements in our galaxy Parts per millionby mass Hydrogen 739,000 Helium 240,000 Oxygen 10,400 Carbon 4,600 Neon 1,340 Iron 1,090 Nitrogen 960 Silicon 650 Magnesium 580 Sulfur 440 Potassium 210 Nickel 100 Nutritional elements in the periodic table[26] vte H He Li Be B C N O F Ne Na Mg Al Si P S Cl Ar K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe Cs Ba * Lu Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn Fr Ra ** Lr Rf Db Sg Bh Hs Mt Ds Rg Cn Nh Fl Mc Lv Ts Og * La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb ** Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Legend: The four basic organic elements Quantity elements Essential trace elements Deemed essential trace element by U.S., not by European Union Suggested function from deprivation effects or active metabolic handling, but no clearly-identified biochemical function in humans Limited circumstantial evidence for trace benefits or biological action in mammals No evidence for biological action in mammals, but essential in some lower organisms.(In the case of lanthanum, the definition of an essential nutrient as being indispensable and irreplaceable is not completely applicable due to the extreme similarity of the lanthanides. The stable early lanthanides up to Sm are known to stimulate the growth of various lanthanide-using organisms.)[27] Mendeleev's 1869 periodic table: An experiment on a system of elements. Based on their atomic weights and chemical similarities. The concept of an "element" as an undivisible substance has developed through three major historical phases: Classical definitions (such as those of the ancient Greeks), chemical definitions, and atomic definitions. Classical definitions Ancient philosophy posited a set of classical elements to explain observed patterns in nature. These elements originally referred to earth, water, air and fire rather than the chemical elements of modern science. The term 'elements' (stoicheia) was first used by the Greek philosopher Plato in about 360 BCE in his dialogue Timaeus, which includes a discussion of the composition of inorganic and organic bodies and is a speculative treatise on chemistry. Plato believed the elements introduced a century earlier by Empedocles were composed of small polyhedral forms: tetrahedron (fire), octahedron (air), icosahedron (water), and cube (earth).[28][29] Aristotle, c. 350 BCE, also used the term stoicheia and added a fifth element called aether, which formed the heavens. Aristotle defined an element as: Element – one of those bodies into which other bodies can decompose, and that itself is not capable of being divided into other.[30] Chemical definitions In 1661, Robert Boyle proposed his theory of corpuscularism which favoured the analysis of matter as constituted by irreducible units of matter (atoms) and, choosing to side with neither Aristotle's view of the four elements nor Paracelsus' view of three fundamental elements, left open the question of the number of elements.[31] The first modern list of chemical elements was given in Antoine Lavoisier's 1789 Elements of Chemistry, which contained thirty-three elements, including light and caloric.[32] By 1818, Jöns Jakob Berzelius had determined atomic weights for forty-five of the forty-nine then-accepted elements. Dmitri Mendeleev had sixty-six elements in his periodic table of 1869. Dmitri Mendeleev From Boyle until the early 20th century, an element was defined as a pure substance that could not be decomposed into any simpler substance.[31] Put another way, a chemical element cannot be transformed into other chemical elements by chemical processes. Elements during this time were generally distinguished by their atomic weights, a property measurable with fair accuracy by available analytical techniques. Atomic definitions Henry Moseley The 1913 discovery by English physicist Henry Moseley that the nuclear charge is the physical basis for an atom's atomic number, further refined when the nature of protons and neutrons became appreciated, eventually led to the current definition of an element based on atomic number (number of protons per atomic nucleus). The use of atomic numbers, rather than atomic weights, to distinguish elements has greater predictive value (since these numbers are integers), and also resolves some ambiguities in the chemistry-based view due to varying properties of isotopes and allotropes within the same element. Currently, IUPAC defines an element to exist if it has isotopes with a lifetime longer than the 10−14 seconds it takes the nucleus to form an electronic cloud.[33] By 1914, seventy-two elements were known, all naturally occurring.[34] The remaining naturally occurring elements were discovered or isolated in subsequent decades, and various additional elements have also been produced synthetically, with much of that work pioneered by Glenn T. Seaborg. In 1955, element 101 was discovered and named mendelevium in honor of D.I. Mendeleev, the first to arrange the elements in a periodic manner. Discovery and recognition of various elements See also: Timeline of chemical element discoveries Ten materials familiar to various prehistoric cultures are now known to be chemical elements: Carbon, copper, gold, iron, lead, mercury, silver, sulfur, tin, and zinc. Three additional materials now accepted as elements, arsenic, antimony, and bismuth, were recognized as distinct substances prior to 1500 AD. Phosphorus, cobalt, and platinum were isolated before 1750. Most of the remaining naturally occurring chemical elements were identified and characterized by 1900, including: Such now-familiar industrial materials as aluminium, silicon, nickel, chromium, magnesium, and tungsten Reactive metals such as lithium, sodium, potassium, and calcium The halogens fluorine, chlorine, bromine, and iodine Gases such as hydrogen, oxygen, nitrogen, helium, argon, and neon Most of the rare-earth elements, including cerium, lanthanum, gadolinium, and neodymium. The more common radioactive elements, including uranium, thorium, radium, and radon Elements isolated or produced since 1900 include: The three remaining undiscovered regularly occurring stable natural elements: hafnium, lutetium, and rhenium Plutonium, which was first produced synthetically in 1940 by Glenn T. Seaborg, but is now also known from a few long-persisting natural occurrences The three incidentally occurring natural elements (neptunium, promethium, and technetium), which were all first produced synthetically but later discovered in trace amounts in certain geological samples Four scarce decay products of uranium or thorium, (astatine, francium, actinium, and protactinium), and Various synthetic transuranic elements, beginning with americium and curium Recently discovered elements The first transuranium element (element with atomic number greater than 92) discovered was neptunium in 1940. Since 1999 claims for the discovery of new elements have been considered by the IUPAC/IUPAP Joint Working Party. As of January 2016, all 118 elements have been confirmed as discovered by IUPAC. The discovery of element 112 was acknowledged in 2009, and the name copernicium and the atomic symbol Cn were suggested for it.[35] The name and symbol were officially endorsed by IUPAC on 19 February 2010.[36] The heaviest element that is believed to have been synthesized to date is element 118, oganesson, on 9 October 2006, by the Flerov Laboratory of Nuclear Reactions in Dubna, Russia.[9][37] Tennessine, element 117 was the latest element claimed to be discovered, in 2009.[38] On 28 November 2016, scientists at the IUPAC officially recognized the names for four of the newest chemical elements, with atomic numbers 113, 115, 117, and 118.[39][40] List of the 118 known chemical elements The following sortable table shows the 118 known chemical elements. Atomic number, Element, and Symbol all serve independently as unique identifiers. Element names are those accepted by IUPAC. Symbol column background color indicates the periodic table block for each element: red = s-block, yellow = p-block, blue = d-block, green = f-block. Group and period refer to an element's position in the periodic table. Group numbers here show the currently accepted numbering; for older alternate numberings, see Group (periodic table). vteList of chemical elements Element Origin of name[41][42] Group Period Block Standardatomicweight[a] Density[b][c] Melting point[d] Boiling point[e] Specificheatcapacity[f] Electronegativity[g] Abundancein Earth'scrust[h] Origin[i] Phase at r.t.[j] Atomic numberZ Symbol Name (Da) (g/cm3) (K) (K) (J/g · K) (mg/kg) 1 H Hydrogen Greek elements hydro- and -gen, 'water-forming' 1 1 s-block 1.008 0.00008988 14.01 20.28 14.304 2.20 1400 primordial gas 2 He Helium Greek hḗlios, 'sun' 18 1 s-block 4.0026 0.0001785 –[k] 4.22 5.193 – 0.008 primordial gas 3 Li Lithium Greek líthos, 'stone' 1 2 s-block 6.94 0.534 453.69 1560 3.582 0.98 20 primordial solid 4 Be Beryllium Beryl, a mineral (ultimately from the name of Belur in southern India)[43] 2 2 s-block 9.0122 1.85 1560 2742 1.825 1.57 2.8 primordial solid 5 B Boron Borax, a mineral (from Arabic bawraq) 13 2 p-block 10.81 2.34 2349 4200 1.026 2.04 10 primordial solid 6 C Carbon Latin carbo, 'coal' 14 2 p-block 12.011 2.267 >4000 4300 0.709 2.55 200 primordial solid 7 N Nitrogen Greek nítron and -gen, 'niter-forming' 15 2 p-block 14.007 0.0012506 63.15 77.36 1.04 3.04 19 primordial gas 8 O Oxygen Greek oxy- and -gen, 'acid-forming' 16 2 p-block 15.999 0.001429 54.36 90.20 0.918 3.44 461000 primordial gas 9 F Fluorine Latin fluere, 'to flow' 17 2 p-block 18.998 0.001696 53.53 85.03 0.824 3.98 585 primordial gas 10 Ne Neon Greek néon, 'new' 18 2 p-block 20.180 0.0008999 24.56 27.07 1.03 – 0.005 primordial gas 11 Na Sodium English (from medieval Latin) soda · Symbol Na is derived from New Latin natrium, coined from German Natron, 'natron' 1 3 s-block 22.990 0.971 370.87 1156 1.228 0.93 23600 primordial solid 12 Mg Magnesium Magnesia, a district of Eastern Thessaly in Greece 2 3 s-block 24.305 1.738 923 1363 1.023 1.31 23300 primordial solid 13 Al Aluminium Alumina, from Latin alumen (gen. aluminis), 'bitter salt, alum' 13 3 p-block 26.982 2.698 933.47 2792 0.897 1.61 82300 primordial solid 14 Si Silicon Latin silex, 'flint' (originally silicium) 14 3 p-block 28.085 2.3296 1687 3538 0.705 1.9 282000 primordial solid 15 P Phosphorus Greek phōsphóros, 'light-bearing' 15 3 p-block 30.974 1.82 317.30 550 0.769 2.19 1050 primordial solid 16 S Sulfur Latin sulphur, 'brimstone' 16 3 p-block 32.06 2.067 388.36 717.87 0.71 2.58 350 primordial solid 17 Cl Chlorine Greek chlōrós, 'greenish yellow' 17 3 p-block 35.45 0.003214 171.6 239.11 0.479 3.16 145 primordial gas 18 Ar Argon Greek argós, 'idle' (because of its inertness) 18 3 p-block 39.95 0.0017837 83.80 87.30 0.52 – 3.5 primordial gas 19 K Potassium New Latin potassa, 'potash', itself from pot and ash · Symbol K is derived from Latin kalium 1 4 s-block 39.098 0.862 336.53 1032 0.757 0.82 20900 primordial solid 20 Ca Calcium Latin calx, 'lime' 2 4 s-block 40.078 1.54 1115 1757 0.647 1.00 41500 primordial solid 21 Sc Scandium Latin Scandia, 'Scandinavia' 3 4 d-block 44.956 2.989 1814 3109 0.568 1.36 22 primordial solid 22 Ti Titanium Titans, the sons of the Earth goddess of Greek mythology 4 4 d-block 47.867 4.54 1941 3560 0.523 1.54 5650 primordial solid 23 V Vanadium Vanadis, an Old Norse name for the Scandinavian goddess Freyja 5 4 d-block 50.942 6.11 2183 3680 0.489 1.63 120 primordial solid 24 Cr Chromium Greek chróma, 'colour' 6 4 d-block 51.996 7.15 2180 2944 0.449 1.66 102 primordial solid 25 Mn Manganese Corrupted from magnesia negra; see § magnesium 7 4 d-block 54.938 7.44 1519 2334 0.479 1.55 950 primordial solid 26 Fe Iron English word · Symbol Fe is derived from Latin ferrum 8 4 d-block 55.845 7.874 1811 3134 0.449 1.83 56300 primordial solid 27 Co Cobalt German Kobold, 'goblin' 9 4 d-block 58.933 8.86 1768 3200 0.421 1.88 25 primordial solid 28 Ni Nickel Nickel, a mischievous sprite of German miner mythology 10 4 d-block 58.693 8.912 1728 3186 0.444 1.91 84 primordial solid 29 Cu Copper English word, from Latin cuprum, from Ancient Greek Kýpros 'Cyprus' 11 4 d-block 63.546 8.96 1357.77 2835 0.385 1.90 60 primordial solid 30 Zn Zinc Most likely from German Zinke, 'prong' or 'tooth', though some suggest Persian sang, 'stone' 12 4 d-block 65.38 7.134 692.88 1180 0.388 1.65 70 primordial solid 31 Ga Gallium Latin Gallia, 'France' 13 4 p-block 69.723 5.907 302.9146 2673 0.371 1.81 19 primordial solid 32 Ge Germanium Latin Germania, 'Germany' 14 4 p-block 72.630 5.323 1211.40 3106 0.32 2.01 1.5 primordial solid 33 As Arsenic French arsenic, from Greek arsenikón 'yellow arsenic' (influenced by arsenikós, 'masculine' or 'virile'), from a West Asian wanderword ultimately from Old Iranian *zarniya-ka, 'golden' 15 4 p-block 74.922 5.776 1090[l] 887 0.329 2.18 1.8 primordial solid 34 Se Selenium Greek selḗnē, 'moon' 16 4 p-block 78.971 4.809 453 958 0.321 2.55 0.05 primordial solid 35 Br Bromine Greek brômos, 'stench' 17 4 p-block 79.904 3.122 265.8 332.0 0.474 2.96 2.4 primordial liquid 36 Kr Krypton Greek kryptós, 'hidden' 18 4 p-block 83.798 0.003733 115.79 119.93 0.248 3.00 1×10−4 primordial gas 37 Rb Rubidium Latin rubidus, 'deep red' 1 5 s-block 85.468 1.532 312.46 961 0.363 0.82 90 primordial solid 38 Sr Strontium Strontian, a village in Scotland, where it was found 2 5 s-block 87.62 2.64 1050 1655 0.301 0.95 370 primordial solid 39 Y Yttrium Ytterby, Sweden, where it was found; see also terbium, erbium, ytterbium 3 5 d-block 88.906 4.469 1799 3609 0.298 1.22 33 primordial solid 40 Zr Zirconium Zircon, a mineral, from Persian zargun, 'gold-hued' 4 5 d-block 91.224 6.506 2128 4682 0.278 1.33 165 primordial solid 41 Nb Niobium Niobe, daughter of king Tantalus from Greek mythology; see also tantalum 5 5 d-block 92.906 8.57 2750 5017 0.265 1.6 20 primordial solid 42 Mo Molybdenum Greek molýbdaina, 'piece of lead', from mólybdos, 'lead', due to confusion with lead ore galena (PbS) 6 5 d-block 95.95 10.22 2896 4912 0.251 2.16 1.2 primordial solid 43 Tc Technetium Greek tekhnētós, 'artificial' 7 5 d-block [97][a] 11.5 2430 4538 – 1.9 ~ 3×10−9 from decay solid 44 Ru Ruthenium New Latin Ruthenia, 'Russia' 8 5 d-block 101.07 12.37 2607 4423 0.238 2.2 0.001 primordial solid 45 Rh Rhodium Greek rhodóeis, 'rose-coloured', from rhódon, 'rose' 9 5 d-block 102.91 12.41 2237 3968 0.243 2.28 0.001 primordial solid 46 Pd Palladium Pallas, an asteroid, considered a planet at the time 10 5 d-block 106.42 12.02 1828.05 3236 0.244 2.20 0.015 primordial solid 47 Ag Silver English word · Symbol Ag is derived from Latin argentum 11 5 d-block 107.87 10.501 1234.93 2435 0.235 1.93 0.075 primordial solid 48 Cd Cadmium New Latin cadmia, from King Kadmos 12 5 d-block 112.41 8.69 594.22 1040 0.232 1.69 0.159 primordial solid 49 In Indium Latin indicum, 'indigo', the blue colour found in its spectrum 13 5 p-block 114.82 7.31 429.75 2345 0.233 1.78 0.25 primordial solid 50 Sn Tin English word · Symbol Sn is derived from Latin stannum 14 5 p-block 118.71 7.287 505.08 2875 0.228 1.96 2.3 primordial solid 51 Sb Antimony Latin antimonium, the origin of which is uncertain: folk etymologies suggest it is derived from Greek antí ('against') + mónos ('alone'), or Old French anti-moine, 'Monk's bane', but it could plausibly be from or related to Arabic ʾiṯmid, 'antimony', reformatted as a Latin word · Symbol Sb is derived from Latin stibium 'stibnite' 15 5 p-block 121.76 6.685 903.78 1860 0.207 2.05 0.2 primordial solid 52 Te Tellurium Latin tellus, 'the ground, earth' 16 5 p-block 127.60 6.232 722.66 1261 0.202 2.1 0.001 primordial solid 53 I Iodine French iode, from Greek ioeidḗs, 'violet' 17 5 p-block 126.90 4.93 386.85 457.4 0.214 2.66 0.45 primordial solid 54 Xe Xenon Greek xénon, neuter form of xénos 'strange' 18 5 p-block 131.29 0.005887 161.4 165.03 0.158 2.60 3×10−5 primordial gas 55 Cs Caesium Latin caesius, 'sky-blue' 1 6 s-block 132.91 1.873 301.59 944 0.242 0.79 3 primordial solid 56 Ba Barium Greek barýs, 'heavy' 2 6 s-block 137.33 3.594 1000 2170 0.204 0.89 425 primordial solid 57 La Lanthanum Greek lanthánein, 'to lie hidden' n/a 6 f-block 138.91 6.145 1193 3737 0.195 1.1 39 primordial solid 58 Ce Cerium Ceres, a dwarf planet, considered a planet at the time n/a 6 f-block 140.12 6.77 1068 3716 0.192 1.12 66.5 primordial solid 59 Pr Praseodymium Greek prásios dídymos, 'green twin' n/a 6 f-block 140.91 6.773 1208 3793 0.193 1.13 9.2 primordial solid 60 Nd Neodymium Greek néos dídymos, 'new twin' n/a 6 f-block 144.24 7.007 1297 3347 0.19 1.14 41.5 primordial solid 61 Pm Promethium Prometheus, a figure in Greek mythology n/a 6 f-block [145] 7.26 1315 3273 – 1.13 2×10−19 primordial solid 62 Sm Samarium Samarskite, a mineral named after V. Samarsky-Bykhovets, Russian mine official n/a 6 f-block 150.36 7.52 1345 2067 0.197 1.17 7.05 primordial solid 63 Eu Europium Europe n/a 6 f-block 151.96 5.243 1099 1802 0.182 1.2 2 primordial solid 64 Gd Gadolinium Gadolinite, a mineral named after Johan Gadolin, Finnish chemist, physicist and mineralogist n/a 6 f-block 157.25 7.895 1585 3546 0.236 1.2 6.2 primordial solid 65 Tb Terbium Ytterby, Sweden, where it was found; see also yttrium, erbium, ytterbium n/a 6 f-block 158.93 8.229 1629 3503 0.182 1.2 1.2 primordial solid 66 Dy Dysprosium Greek dysprósitos, 'hard to get' n/a 6 f-block 162.50 8.55 1680 2840 0.17 1.22 5.2 primordial solid 67 Ho Holmium New Latin Holmia, 'Stockholm' n/a 6 f-block 164.93 8.795 1734 2993 0.165 1.23 1.3 primordial solid 68 Er Erbium Ytterby, Sweden, where it was found; see also yttrium, terbium, ytterbium n/a 6 f-block 167.26 9.066 1802 3141 0.168 1.24 3.5 primordial solid 69 Tm Thulium Thule, the ancient name for an unclear northern location n/a 6 f-block 168.93 9.321 1818 2223 0.16 1.25 0.52 primordial solid 70 Yb Ytterbium Ytterby, Sweden, where it was found; see also yttrium, terbium, erbium n/a 6 f-block 173.05 6.965 1097 1469 0.155 1.1 3.2 primordial solid 71 Lu Lutetium Latin Lutetia, 'Paris' 3 6 d-block 174.97 9.84 1925 3675 0.154 1.27 0.8 primordial solid 72 Hf Hafnium New Latin Hafnia, 'Copenhagen' (from Danish havn, harbour) 4 6 d-block 178.49 13.31 2506 4876 0.144 1.3 3 primordial solid 73 Ta Tantalum King Tantalus, father of Niobe from Greek mythology; see also niobium 5 6 d-block 180.95 16.654 3290 5731 0.14 1.5 2 primordial solid 74 W Tungsten Swedish tung sten, 'heavy stone' · Symbol W is from Wolfram, originally from Middle High German wolf-rahm 'wolf's foam' describing the mineral wolframite[44] 6 6 d-block 183.84 19.25 3695 5828 0.132 2.36 1.3 primordial solid 75 Re Rhenium Latin Rhenus, 'the Rhine' 7 6 d-block 186.21 21.02 3459 5869 0.137 1.9 7×10−4 primordial solid 76 Os Osmium Greek osmḗ, 'smell' 8 6 d-block 190.23 22.61 3306 5285 0.13 2.2 0.002 primordial solid 77 Ir Iridium Iris, the Greek goddess of the rainbow 9 6 d-block 192.22 22.56 2719 4701 0.131 2.20 0.001 primordial solid 78 Pt Platinum Spanish platina, 'little silver', from plata 'silver' 10 6 d-block 195.08 21.46 2041.4 4098 0.133 2.28 0.005 primordial solid 79 Au Gold English word · Symbol Au is derived from Latin aurum 11 6 d-block 196.97 19.282 1337.33 3129 0.129 2.54 0.004 primordial solid 80 Hg Mercury Mercury, Roman god of commerce, communication, and luck, known for his speed and mobility · Symbol Hg is derived from its Latin name hydrargyrum, from Greek hydrárgyros, 'water-silver' 12 6 d-block 200.59 13.5336 234.43 629.88 0.14 2.00 0.085 primordial liquid 81 Tl Thallium Greek thallós, 'green shoot or twig' 13 6 p-block 204.38 11.85 577 1746 0.129 1.62 0.85 primordial solid 82 Pb Lead English word · Symbol Pb is derived from Latin plumbum 14 6 p-block 207.2 11.342 600.61 2022 0.129 1.87 (2+)2.33 (4+) 14 primordial solid 83 Bi Bismuth German Wismut, from weiß Masse 'white mass', unless from Arabic 15 6 p-block 208.98 9.807 544.7 1837 0.122 2.02 0.009 primordial solid 84 Po Polonium Latin Polonia, 'Poland', home country of Marie Curie 16 6 p-block [209][a] 9.32 527 1235 – 2.0 2×10−10 from decay solid 85 At Astatine Greek ástatos, 'unstable' 17 6 p-block [210] 7 575 610 – 2.2 3×10−20 from decay unknown phase 86 Rn Radon Radium emanation, originally the name of the isotope Radon-222 18 6 p-block [222] 0.00973 202 211.3 0.094 2.2 4×10−13 from decay gas 87 Fr Francium France, home country of discoverer Marguerite Perey 1 7 s-block [223] 1.87 281 890 – >0.79[45] ~ 1×10−18 from decay unknown phase 88 Ra Radium French radium, from Latin radius, 'ray' 2 7 s-block [226] 5.5 973 2010 0.094 0.9 9×10−7 from decay solid 89 Ac Actinium Greek aktís, 'ray' n/a 7 f-block [227] 10.07 1323 3471 0.12 1.1 5.5×10−10 from decay solid 90 Th Thorium Thor, the Scandinavian god of thunder n/a 7 f-block 232.04 11.72 2115 5061 0.113 1.3 9.6 primordial solid 91 Pa Protactinium Proto- (from Greek prôtos, 'first, before') + actinium, since actinium is produced through the radioactive decay of protactinium n/a 7 f-block 231.04 15.37 1841 4300 – 1.5 1.4×10−6 from decay solid 92 U Uranium Uranus, the seventh planet in the Solar System n/a 7 f-block 238.03 18.95 1405.3 4404 0.116 1.38 2.7 primordial solid 93 Np Neptunium Neptune, the eighth planet in the Solar System n/a 7 f-block [237] 20.45 917 4273 – 1.36 ≤ 3×10−12 from decay solid 94 Pu Plutonium Pluto, a dwarf planet, considered a planet in the Solar System at the time n/a 7 f-block [244] 19.84 912.5 3501 – 1.28 ≤ 3×10−11 from decay solid 95 Am Americium The Americas, where the element was first synthesised, by analogy with its homologue § europium n/a 7 f-block [243] 13.69 1449 2880 – 1.13 – synthetic solid 96 Cm Curium Pierre Curie and Marie Curie, French physicists and chemists n/a 7 f-block [247] 13.51 1613 3383 – 1.28 – synthetic solid 97 Bk Berkelium Berkeley, California, where the element was first synthesised n/a 7 f-block [247] 14.79 1259 2900 – 1.3 – synthetic solid 98 Cf Californium California, where the element was first synthesised in the LBNL laboratory n/a 7 f-block [251] 15.1 1173 (1743)[b] – 1.3 – synthetic solid 99 Es Einsteinium Albert Einstein, German physicist n/a 7 f-block [252] 8.84 1133 (1269) – 1.3 – synthetic solid 100 Fm Fermium Enrico Fermi, Italian physicist n/a 7 f-block [257] (9.7)[b] (1125)[b] – – 1.3 – synthetic unknown phase 101 Md Mendelevium Dmitri Mendeleev, Russian chemist who proposed the periodic table n/a 7 f-block [258] (10.3) (1100) – – 1.3 – synthetic unknown phase 102 No Nobelium Alfred Nobel, Swedish chemist and engineer n/a 7 f-block [259] (9.9) (1100) – – 1.3 – synthetic unknown phase 103 Lr Lawrencium Ernest Lawrence, American physicist 3 7 d-block [266] (15.6) (1900) – – 1.3 – synthetic unknown phase 104 Rf Rutherfordium Ernest Rutherford, chemist and physicist from New Zealand 4 7 d-block [267] (23.2) (2400) (5800) – – – synthetic unknown phase 105 Db Dubnium Dubna, Russia, where the element was discovered in the JINR laboratory 5 7 d-block [268] (29.3) – – – – – synthetic unknown phase 106 Sg Seaborgium Glenn T. Seaborg, American chemist 6 7 d-block [269] (35.0) – – – – – synthetic unknown phase 107 Bh Bohrium Niels Bohr, Danish physicist 7 7 d-block [270] (37.1) – – – – – synthetic unknown phase 108 Hs Hassium New Latin Hassia, 'Hesse', a state in Germany 8 7 d-block [269] (40.7) – – – – – synthetic unknown phase 109 Mt Meitnerium Lise Meitner, Austrian physicist 9 7 d-block [278] (37.4) – – – – – synthetic unknown phase 110 Ds Darmstadtium Darmstadt, Germany, where the element was first synthesised in the GSI laboratories 10 7 d-block [281] (34.8) – – – – – synthetic unknown phase 111 Rg Roentgenium Wilhelm Conrad Röntgen, German physicist 11 7 d-block [282] (28.7) – – – – – synthetic unknown phase 112 Cn Copernicium Nicolaus Copernicus, Polish astronomer 12 7 d-block [285] (14.0) (283) (340)[b] – – – synthetic unknown phase 113 Nh Nihonium Japanese Nihon, 'Japan', where the element was first synthesised in the Riken laboratories 13 7 p-block [286] (16) (700) (1400) – – – synthetic unknown phase 114 Fl Flerovium Flerov Laboratory of Nuclear Reactions, part of JINR, where the element was synthesised; itself named after Georgy Flyorov, Russian physicist 14 7 p-block [289] (9.928) (200)[b] (380) – – – synthetic unknown phase 115 Mc Moscovium Moscow, Russia, where the element was first synthesised in the JINR laboratories 15 7 p-block [290] (13.5) (700)

(1400) – – – synthetic unknown phase 116 Lv Livermorium Lawrence Livermore National Laboratory in Livermore, California 16 7 p-block [293] (12.9) (700) (1100) – – – synthetic unknown phase 117 Ts Tennessine Tennessee, United States, where Oak Ridge National Laboratory is located 17 7 p-block [294] (7.2) (700) (883) – – – synthetic unknown phase 118 Og Oganesson Yuri Oganessian, Russian physicist 18 7 p-block [294] (7) (325) (450) – – – synthetic unknown phase ^ a b c Standard atomic weight'1.008', regular notation: conventional, abridged value (Table 2, Table 3)'[97]', [ ] notation: massnumber of most stable isotope ^ a b c d e f Values in ( ) brackets are predictions ^ Density (sources) ^ Melting point in kelvin (K) (sources) ^ Boiling point in kelvin (K) (sources) ^ Heat capacity (sources) ^ Electronegativity by Pauling (source) ^ Abundance of elements in Earth's crust ^ Primordial (=Earth's origin), from decay, or synthetic ^ Phase at Standard state (25 °C [77 °F], 100 kPa) ^ Helium melting point: helium does not solidify at a pressure of 1 bar (0.99 atm). Helium can only solidify at pressures above 25 atmosphere, which corresponds to a melting point of absolute zero (0 K). ^ Arsenic: element sublimes at one atmosphere of pressure. See also Biological roles of the elements Chemical database Discovery of the chemical elements Element collecting Fictional element Goldschmidt classification Island of stability List of chemical elements List of nuclides List of the elements' densities Mineral (nutrient) Periodic Systems of Small Molecules Prices of chemical elements Systematic element name Table of nuclides Timeline of chemical element discoveries The Mystery of Matter: Search for the Elements (PBS film)

References ^ IUPAC, Compendium of Chemical Terminology, 2nd ed. (the "Gold Book") (1997). Online corrected version: (2006–) "chemical element". doi:10.1351/goldbook.C01022 ^ See the timeline on p.10 in Oganessian, Yu. Ts.; Utyonkov, V.; Lobanov, Yu.; Abdullin, F.; Polyakov, A.; Sagaidak, R.; Shirokovsky, I.; Tsyganov, Yu.; et al. (2006). "Evidence for Dark Matter" (PDF). Physical Review C. 74 (4): 044602. Bibcode:2006PhRvC..74d4602O. doi:10.1103/PhysRevC.74.044602. ^ lbl.gov (2005). "The Universe Adventure Hydrogen and Helium". Lawrence Berkeley National Laboratory U.S. Department of Energy. Archived from the original on 21 September 2013. ^ astro.soton.ac.uk (3 January 2001). "Formation of the light elements". University of Southampton. Archived from the original on 21 September 2013. ^ foothill.edu (18 October 2006). "How Stars Make Energy and New Elements" (PDF). Foothill College. ^ a b Dumé, B. (23 April 2003). "Bismuth breaks half-life record for alpha decay". Physicsworld.com. Bristol, England: Institute of Physics. Retrieved 14 July 2015. ^ a b de Marcillac, P.; Coron, N.; Dambier, G.; Leblanc, J.; Moalic, J-P (2003). "Experimental detection of alpha-particles from the radioactive decay of natural bismuth". Nature. 422 (6934): 876–8. Bibcode:2003Natur.422..876D. doi:10.1038/nature01541. PMID 12712201. S2CID 4415582. ^ Sanderson, K. (17 October 2006). "Heaviest element made – again". News@nature. doi:10.1038/news061016-4. S2CID 121148847. ^ a b Schewe, P.; Stein, B. (17 October 2000). "Elements 116 and 118 Are Discovered". Physics News Update. American Institute of Physics. Archived from the original on 1 January 2012. Retrieved 19 October 2006. ^ Glanz, J. (6 April 2010). "Scientists Discover Heavy New Element". The New York Times. ^ Oganessian, Yu. Ts.; Abdullin, F. Sh.; Bailey, P. D.; Benker, D. E.; Bennett, M. E.; Dmitriev, S. N.; Ezold, J. G.; Hamilton, J. H.; Henderson, R. A.; Itkis, M. G.; Lobanov, Yu. V.; Mezentsev, A. N.; Moody, K. J.; Nelson, S. L.; Polyakov, A. N.; Porter, C. E.; Ramayya, A. V.; Riley, F. D.; Roberto, J. B.; Ryabinin, M. A.; Rykaczewski, K. P.; Sagaidak, R. N.; Shaughnessy, D. A.; Shirokovsky, I. V.; Stoyer, M. A.; Subbotin, V. G.; Sudowe, R.; Sukhov, A. M.; Tsyganov, Yu. S.; et al. (April 2010). "Synthesis of a New Element with Atomic Number Z=117". Physical Review Letters. 104 (14): 142502. Bibcode:2010PhRvL.104n2502O. doi:10.1103/PhysRevLett.104.142502. PMID 20481935. ^ United States Environmental Protection Agency. "Technetium-99". epa.gov. Retrieved 26 February 2013. ^ Harvard–Smithsonian Center for Astrophysics. "Origins of Heavy Elements". cfa.harvard.edu. Retrieved 26 February 2013. ^ "Atomic Number and Mass Numbers". ndt-ed.org. Archived from the original on 12 February 2014. Retrieved 17 February 2013. ^ periodic.lanl.gov. "Periodic Table of Elements: LANL Carbon". Los Alamos National Laboratory. ^ Katsuya Yamada. "Atomic mass, isotopes, and mass number" (PDF). Los Angeles Pierce College. Archived from the original (PDF) on 11 January 2014. ^ "Pure element". European Nuclear Society. Archived from the original on 13 June 2017. Retrieved 13 August 2013. ^ Audi, G.; Kondev, F. G.; Wang, M.; Huang, W. J.; Naimi, S. (2017). "The NUBASE2016 evaluation of nuclear properties" (PDF). Chinese Physics C. 41 (3): 030001. Bibcode:2017ChPhC..41c0001A. doi:10.1088/1674-1137/41/3/030001. ^ Meija, Juris; et al. (2016). "Atomic weights of the elements 2013 (IUPAC Technical Report)". Pure and Applied Chemistry. 88 (3): 265–91. doi:10.1515/pac-2015-0305. ^ Meija, Juris; et al. (2016). "Atomic weights of the elements 2013 (IUPAC Technical Report)". Pure and Applied Chemistry. 88 (3). Table 2, 3 combined; uncertainty removed. doi:10.1515/pac-2015-0305. ^ Wilford, J.N. (14 January 1992). "Hubble Observations Bring Some Surprises". The New York Times. ^ Wright, E. L. (12 September 2004). "Big Bang Nucleosynthesis". UCLA, Division of Astronomy. Retrieved 22 February 2007. ^ Wallerstein, George; Iben, Icko; Parker, Peter; Boesgaard, Ann; Hale, Gerald; Champagne, Arthur; Barnes, Charles; Käppeler, Franz; et al. (1999). "Synthesis of the elements in stars: forty years of progress" (PDF). Reviews of Modern Physics. 69 (4): 995–1084. Bibcode:1997RvMP...69..995W. doi:10.1103/RevModPhys.69.995. hdl:2152/61093. Archived from the original (PDF) on 28 September 2006. ^ Earnshaw, A.; Greenwood, N. (1997). Chemistry of the Elements (2nd ed.). Butterworth-Heinemann. ^ Croswell, K. (1996). Alchemy of the Heavens. Anchor. ISBN 978-0-385-47214-2. ^ Ultratrace minerals. Authors: Nielsen, Forrest H. USDA, ARS Source: Modern nutrition in health and disease / editors, Maurice E. Shils ... et al. Baltimore : Williams & Wilkins, c1999., p. 283-303. Issue Date: 1999 URI: [1] ^ Daumann, Lena J. (25 April 2019). "Essential and Ubiquitous: The Emergence of Lanthanide Metallobiochemistry". Angewandte Chemie International Edition. doi:10.1002/anie.201904090. Retrieved 15 June 2019. ^ Plato (2008) [c. 360 BC]. Timaeus. Forgotten Books. p. 45. ISBN 978-1-60620-018-6. ^ Hillar, M. (2004). "The Problem of the Soul in Aristotle's De anima". NASA/WMAP. Archived from the original on 9 September 2006. Retrieved 10 August 2006. ^ Partington, J. R. (1937). A Short History of Chemistry. New York: Dover Publications. ISBN 978-0-486-65977-0. ^ a b Boyle, R. (1661). The Sceptical Chymist. London. ISBN 978-0-922802-90-6. ^ Lavoisier, A. L. (1790). Elements of chemistry translated by Robert Kerr. Edinburgh. pp. 175–6. ISBN 978-0-415-17914-0. ^ Transactinide-2. www.kernchemie.de ^ Carey, G.W. (1914). The Chemistry of Human Life. Los Angeles. ISBN 978-0-7661-2840-8. ^ "IUPAC Announces Start of the Name Approval Process for the Element of Atomic Number 112" (PDF). IUPAC. 20 July 2009. Retrieved 27 August 2009. ^ "IUPAC (International Union of Pure and Applied Chemistry): Element 112 is Named Copernicium". IUPAC. 20 February 2010. Archived from the original on 24 February 2010. ^ Oganessian, Yu. Ts.; Utyonkov, V.; Lobanov, Yu.; Abdullin, F.; Polyakov, A.; Sagaidak, R.; Shirokovsky, I.; Tsyganov, Yu.; et al. (2006). "Evidence for Dark Matter" (PDF). Physical Review C. 74 (4): 044602. Bibcode:2006PhRvC..74d4602O. doi:10.1103/PhysRevC.74.044602. ^ Greiner, W. "Recommendations" (PDF). 31st meeting, PAC for Nuclear Physics. Joint Institute for Nuclear Research. Archived from the original (PDF) on 14 April 2010. ^ Staff (30 November 2016). "IUPAC Announces the Names of the Elements 113, 115, 117, and 118". IUPAC. Retrieved 1 December 2016. ^ St. Fleur, Nicholas (1 December 2016). "Four New Names Officially Added to the Periodic Table of Elements". The New York Times. Retrieved 1 December 2016. ^ "Periodic Table – Royal Society of Chemistry". www.rsc.org. ^ "Online Etymology Dictionary". etymonline.com. ^ "beryl". Merriam-Webster. Archived from the original on 9 October 2013. Retrieved 27 January 2014. ^ van der Krogt, Peter. "Wolframium Wolfram Tungsten". Elementymology & Elements Multidict. Archived from the original on 23 January 2010. Retrieved 11 March 2010. ^ Originally assessed as 0.7 by Pauling but never revised after other elements' electronegativities were updated for precision. Predicted to be higher than that of caesium. Further reading Wikimedia Commons has media related to Chemical elements. Ball, P. (2004). The Elements: A Very Short Introduction. Oxford University Press. ISBN 978-0-19-284099-8. Emsley, J. (2003). Nature's Building Blocks: An A–Z Guide to the Elements. Oxford University Press. ISBN 978-0-19-850340-8. Gray, T. (2009). The Elements: A Visual Exploration of Every Known Atom in the Universe. Black Dog & Leventhal Publishers Inc. ISBN 978-1-57912-814-2. Scerri, E.R. (2007). The Periodic Table, Its Story and Its Significance. Oxford University Press. Strathern, P. (2000). Mendeleyev's Dream: The Quest for the Elements. Hamish Hamilton Ltd. ISBN 978-0-241-14065-9. Kean, Sam (2011). The Disappearing Spoon: And Other True Tales of Madness, Love, and the History of the World from the Periodic Table of the Elements. Back Bay Books. Compiled by A.D. McNaught and A. Wilkinson. (1997). Blackwell Scientific Publications, Oxford (ed.). Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). doi:10.1351/goldbook. ISBN 978-0-9678550-9-7.CS1 maint: uses authors parameter (link) XML on-line corrected version: created by M. Nic, J. Jirat, B. Kosata; updates compiled by A. Jenkins. External links Videos for each element by the University of Nottingham "Chemical Elements", In Our Time, BBC Radio 4 discussion with Paul Strathern, Mary Archer and John Murrell (May 25, 2000). Retrieved from "