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core of the atom; nuclear power reactor Stellar · Big Bang · SupernovaNuclides: ♪ ♪ ♪ ♪ ♪♪ ♪♪
♪♪ A model of the atomic nucleus that shows it as a compact beam of the two types of nucleons: protons (red) and neutrons (blue). In this diagram, protons and neutrons seem small balls stuck together, but a real nucleus (as understood by modern nuclear physics) cannot be explained in this way, but only using quantum mechanics. In a nucleus that occupies a certain level of energy (e.g., the earth state,) each nucleon can be said to occupy a range of positions. The atomic nucleus is the small, dense region consisting of protons and neutrons at the center of an atom, discovered in 1911 by Ernest Rutherford on the basis of the gold foil experiment 1909 Geiger-Marsden. After the discovery of neutron in 1932, the models for a nucleus of protons and neutrons were quickly developed by Dmitri Ivanenko[1] and Werner Heisenberg. [2][5][6] An atom is composed of a positive nucleus, with a cloud of negative charged electrons surrounding it, linked by an electrostatic force. Almost all the mass of an atom is located in the nucleus, with a very small contribution from the cloud of electrons. Protons and neutrons are tied together to form aby nuclear power. The diameter of the nucleus is between 1,70Â fm (1,70°10â¤15Â m[7]) for hydrogen (the diameter of a single proton) and about 11,7Â fm for uranium.[8] These dimensions are much smaller than the diameter of the atom itself (nucleus + electron cloud), of a factor of about 26.634 (uranium atomic radius is about 156Â pm (156â ¢10â ¢12Â m)) [9] at about 60.250 (hydrogen atomic radiation is about 52.92Â pm). of the atomic nucleus, including its composition and forces that bind it together, is called nuclear physics. Introduction History Main article: Rutherford's model The nucleus was discovered in 1911, as a result of Ernest Rutherford's efforts to test Thomson's "Prust Pudding Model".[10] The electron had already been discovered by J.J. Thomson. Knowing that atoms are electrically neutral, J.J.Thomson postulated that there must also be a positive charge. In his plum pudding model, Thomson suggested that an atom consisted of randomly spread negative electrons within a positive charging ball. Ernest Rutherford later created an experiment with his research partner Hans Geiger and with the help of Ernest Marsden, who planned the deflection of alpha particles (helium nucleus) directed towards a thin metal sheet. He reasoned that if J.J. Thomson's model was correct, positively charged alpha particles would easily pass through the sheet with very little deviations in their paths, since the sheet should act as electrically neutral if negative and positive charges are so intimately mixed that it would make it look neutral. With its great surprise, many of the particles were deviated at very wide angles. Since the mass of an alpha particle is about 8000 times that of an electron, it became evident that a very strong force had to be present in order to deviate the massive alpha particles and in rapid movement. It was realized that the model of plum pudding could not be accurate and that the deviations of alpha particles could only be explained if the positive and negative charges were separated from each other and that the mass of the atom was a concentrated positive charge. This justified the idea of a nuclear atom with a dense center of positive charge and mass. Etymology The term nucleus derives from the Latin word nucleus, diminutive of nux (‘noce’), which means ‘the hazelnut’ (i.e., the small walnut’) within a type of aqueous fruit (like a peach). In 1844, Michael Faraday used this term to refer to the "central point of an atom." The modern atomic significance was proposed by Ernest Rutherford in 1912.[11] The adoption of the term "nucleus" to atomic theory, however, was not immediate. In 1916, for example, Gilbert N. Lewis stated, in his famous article The Atom and the Molecule, that "the atom is composed of the nucleus and an atom or outer shell"[12]Nuclear A figurative representation of the helium-4 atom with the cloud of electrons in shades of grey. In the core, core, two protons and two neutrons are represented in red and blue. This representation shows the separate particles, while in a real atom of helium the protons overlap in space and most likely are located in the center of the nucleus, and the same goes for the two neutrons. So all four particles are most likely in the same space at the central point. The classical images of separate particles fail to shape the power distributions known in very small nuclei. A more accurate picture is that the spatial distribution of nucleons in a helium nucleus is much closer to the helium electron cloud shown here, although on a much smaller scale than the imaginary image of the nucleus. Both the helium atom and its nucleus are spherically symmetric. The nucleus of an atom consists of neutrons and protons, which in turn are the manifestation of the most elementary particles, called quarks, which are held in association by the strong nuclear force in certain stable combinations of arons, called barions. The strong nuclear force extends far enough from each barion to bind together neutrons and protons against the repulsive electric force among positively charged protons. The strong nuclear force has a very short flow, and essentially drops to zero just beyond the core edge. The collective action of the positively charged nucleus is to hold electrically negative charged electrons in their orbits around the nucleus. The collection of negatively charged electrons orbiting the nucleus shows an affinity for certain configurations and numbers of electrons that make their orbits stable. The chemical element that an atom represents is determined by the number of protons in the nucleus; the neutral atom will have an equal number of electrons orbiting that nucleus. Individual chemical elements can create more stable electron configurations by combining to share their electrons. It is that sharing of electrons to create stable electronic orbits around the nuclei that appears to us as the chemistry of our macro world. Protons define the full charge of a nucleus, and therefore its chemical identity. Neutrons are electrically neutral, but they contribute to the mass of a nucleus almost to the same extent as protons. Neutrons can explain the phenomenon of isotopes (the same atomic number with different atomic mass). The main role of neutrons is to reduce electrostatic repulsion within the nucleus. Composition and shape Protons and neutrons are studs, with different values of the quantum number of strong isospins, so two protons and two neutrons can share the same spatial wave function since they are not identical quantum entities. Two stoppers, like two protons, or two neutrons, or a proton + neutron (deuterone) can show bosonic behavior whenfreely tied in pairs, which have full spin. In the rare case of a hypernucleus, a thirdcalled hyperone, containing one or more strange quarks and/or other unusual quarks, can also share the wave function. However, this type of nucleus is extremely unstable and is not on Earth except in high-energy physics experiments. The neutron has a positive radius of 0.3 fm surrounded by a negative compensatory charge of radius between 0.3 fm and 2 fm. The proton has a positive charge distribution in exponential decay with an average square radius of about 0.8 fm.[15] The nuclei can be spherical, shaped like a rugby ball (prolate deformation), shaped like a disk (oblated deformation), triaxial (a combination of oblate and prolated deformation) or pear-shaped.[16][17] Nuclei Forces are linked together by the residual strong force (nuclear force). The residual strong force is a lower residual of the strong interaction that binds the quark together to form protons and neutrons. This force is much weaker among neutrons and protons because it is mostly neutralized within them, as well as electromagnetic forces between neutral atoms (such as van der Waals forces acting between two inert gas atoms) are much weaker than electromagnetic forces holding together atoms (e.g. forces holding electrons in an inert gas atom bound to its core). The nuclear force is very attractive to the distance of the typical nucleon separation, and this surpasses the repulsion between the protons due to the electromagnetic force, thus allowing the existence of the nuclei. However, the residual strong force has a limited range because it quickly decays with the distance (see Yukawa Potential); therefore only smaller nuclei of a certain size can be completely stable. The largest fully stable core known (i.e. stable to alpha decay, beta and gamma) is lead-208 which contains a total of 208 nucleons (126 neutrons and 82 protons). Larger nucleuses of this maximum are unstable and tend to have an ever shorter life with a greater number of nucleons. However, bismuth-209 is also stable at beta decay and has the longest half-life to the alpha decay of any known isotope, estimated at one billion times longer than the age of the universe. The residual strong force is effective in a very short range (usually only a few phymtometers (fm); approximately one or two nucleons diameters) and causes an attraction between any pair of nucleons. For example, between protons and neutrons to form [NP] deuterone, and also between protons and protons, and neutrons and neutrons. Halogen nucleus and limits of the range of nuclear power The absolute actual limit of the range of nuclear force (also known as residual strong force) is represented by halogen nuclei such as lithium-11 or boro-14, in which dineutrons, or other neutron collections, orbit at distances of about 10Â fm (approximately similar8Â fm radius of the uranium-2 core). 38). These nuclei are not at most dense. Halogen nucleus form at the extreme edges of the nuclid graphâ ¦ ¦Drip lines and proton drip lines are all unstable with short half-lives, measured in milliseconds; for example, lithium-11 has a half-life of 8.8 ms. Halons represent an excited state with nucleons in an outer quantum shell that has unfilled energy levels. “below” (both in terms of radius and energy). It can be made up of neutrons [NN, NNN] or protons [PP, PPP]. Nuclei that have only one halo of neutrons include 11Be and 19C. A two-neutron halo is exhibited by 6He, 11Li, 17B, 19B and 22C. Two-neutron halogenated nuclei divide into three fragments, never two, and are called borromean nuclei because of this behaviour (referring to a system of three interconnected rings in which the rupture of one ring frees both others). 8He and 14Be both have a four-neutron halo. Nuclei that have a proton halo include 8B and 26P. A two-proton halo is exhibited by 17Ne and 27S. Proton halons should be rarer and more unstable than neutron specimens, due to the repulsive electromagnetic forces of the excess protons. Nuclear Models Main article: Nuclear Structure Although the Standard Model of Physics is believed to fully describe the composition and behavior of the nucleus, generating predictions from theory is much more difficult than for most other areas of particle physics. This is due to two reasons: In principle, physics within a nucleus can be derived entirely from quantum chromodynamics (QCD). In practice, however, current computational and mathematical approaches to solving QCD in low energy systems such as nuclei are extremely limited. This is due to the phase transition that occurs between high-energy quark matter and low-energy hadronic matter, which renders the perturbative techniques unusable, making it difficult to construct an accurate QCD model of the forces between nucleons. Current approaches are limited to phenomenological models such as the Argonne potential v18 or the chiral effective field theory.[18] Although nuclear force is well limited, a significant amount of computational power is required to accurately calculate the properties of ab initio nuclei. Developments in many-body theory have made this possible for many relatively stable, low-mass nuclei, but further improvements in both computational power and mathematical approaches are needed before heavy or highly unstable nuclei can be tackled. Historically, experiments have been compared to relatively crude, necessarily imperfect, models. None of these models can fully explain the experimental data on nuclear structure.[19] The nuclear radius (R) is considered one of the basic quantities that any model must predict. For stable cores (not halons or unstable distorted nuclei) the nuclear radius is approximately proportional to the cubic root of the mass number (A) of the nucleus, and particularly in nuclei containing many nucleons, as they are arranged in more spherical configurations: spherical: has a rough density and therefore the nuclear radius R can be approximated by the following formula, R = r 0 A 1 / 3 {\displaystyle R=r_{0}A^{1/3,\ where A = atomic mass number (the number of Z protons, plus the number of N neutrons) and r0 = 1.25 fm = 1.25 × 10−15 m In this equation, the constant r0 varies by 0.2 fm, depending on the nucleus [20] In other words, the packing of protons and neutrons in the nucleus gives approximately the same result of total size as the packing of hard spheres of a constant dimension (such as the marbles) in a spherical or almost spherical tight bag (some stable nuclei are not spherical enough, but are known to be prolate). [21] Nuclear structure models include: Liquid Drop Model Main Item: Semi-empirical mass formula The first models of the nucleus saw the nucleus as a drop of rotating liquid. In this model, the trade-off of long-range electromagnetic forces and nuclear forces relatively short-range, together they cause behaviors that resemble surface tension forces in liquid drops of different sizes. This formula has managed to explain many important phenomena of the nuclei, such as their variation of amount of binding energy such as their size and composition changes (see semi-empirical mass formula,) but does not explain the special stability that occurs when the nuclei have particular "magic numbers" of protons or neutrons. The terms of the semi-empirical mass formula, which can be used to approximate the binding energy of many nuclei, are considered as the sum of five types of energies (see below). Then the image of a nucleus as a drop of incompressed liquid approximately represents the observed variation of binding energy of the nucleus: Volume energy. When a nucleon assembly of the same size is packed together in the smaller volume, each inner nucleon has a number of other nucleons in contact with it. This nuclear energy is therefore proportional to the volume. Surface energy. A nucleon at the surface of a nucleus interacts with fewer nucleons of one within the nucleus and therefore its binding energy is less. This term of surface energy takes account of this and is therefore negative and is proportional to the surface. Coulomb Energy. The electrical repulsion between each pair of protons in a nucleus contributes to decrease its binding energy. Asymmetric energy (also called Pauli Energy.) An energy associated with the principle of exclusion Pauli. If it were not for Coulomb's energy, the more stable form of nuclear matter would have the same number of neutrons as protons, since non-equal neutrons and protons imply the filling of higher energy levels for a particle type, while at the same time leaving levelslower energy vacancies for the other type. Combining energy. An energy that is a correction term that derives from the tendency of proton and neutron pairs to occur. An even number of particles is more stable than an odd odd number Shell models and other quantum models Main article: Nuclear shell model Several models for the nucleus were also proposed in which nucleons occupy orbitals, very similar to atomic orbits in atomic physics theory. These wave models imagine that nucleons are dot particles without size in the potential wells, or waves of likelihood as in the “optic model”, that orbit without high-speed friction in the potential wells. In the above models, nucleons can occupy pairs orbits, since they are stunts, which allows the explanation of equal/uneven effects of Z and N well known by experiments. The exact nature and capacity of nuclear shells differ from those of electrons in atomic orbits, mainly because the potential well in which nucleons move (especially in larger nuclei) is very different from the central electromagnetic well that binds electrons in atoms. A certain similarity to orbital atomic models can be found in a small atomic nucleus such as helium-4, in which the two protons and the two neutrons separately occupy orbital of 1s analogous to the orbital of 1s for the two electrons of the helium atom, thus obtaining unusual stability for the same reason. The nucleons with 5 nucleons are all extremely unstable and short-lived, however helium-3, with 3 nucleons, is very stable even without a closed orbital shell 1s. Another nucleus with 3 nucleons, the hydrogen-3 triton is unstable and will decay into helium-3 once isolated. A weak nuclear stability with 2 nucleons {NP} in the 1s orbital is found in hydrogen-2 deuterone, with only one nucleon in each of the potential proton and neutron wells. While each nucleon is a stud, the {NP} deuterone is a boson and therefore does not follow Pauli’s exclusion for tight packaging within the shells. Lithium-6 with 6 nucleons is highly stable without a second closed orbital shell 1p. For light nuclei with total nucleons of 1 to 6, only those with 5 show no evidence of stability. Observations on beta stability of light nuclei outside closed shells indicate that nuclear stability is much more complex than the simple closure of shell orbitals with magical numbers of protons and neutrons. For larger nuclei, the shells occupied by nucleons begin to differ significantly from the electron shells, but despite the current nuclear theory, the magic number of full nuclear shells for both protons and neutrons. The closure of stable shells predicts unusually stable configurations, similar to the noble group of almost inert gases in chemistry. One example is the closed shell stability of 50 protons, which allows the tin to have 10 stable isotopes, more than any other element. Similarly, the distance from the shell clasp explains the unusual instability ofwhich have a number of these particles far from being stable, such as radioactive elements 43 (technetium) and 61 (promethium), each of which is preceded and followed by 17 or more stable elements. However, there are problems with the shell model We are trying to take into account nuclear properties far from the closed shells. This has led to complex post-hoc distortions of the form of the potential well to adapt to experimental data, but it remains to be wondered whether these mathematical manipulations actually correspond to spatial deformations in real nuclei. Problems with the shell model have led some to propose realistic effects of nuclear force to two bodies and three bodies involving groups of nucleons and thus to build the nucleus on this base. Three of these cluster models are John Wheeler's 1936 Resonant Group Model, Linus Pauling's Closed Spheron Model and MacGregor's 2D Ising Model. Model coherence Main article: Nuclear Structure As in the case of superfluous liquid helium, atomic nuclei are an example of a state in which they apply both (1) “ordinary” physical rules of particles for volume and (2) non-intuitive quantum mechanical rules for undulating nature. In the superfluid helium, helium atoms have volume, and essentially “touch” each other, but at the same time they have strange mass properties, consistent with a condensation of Bose’ Einstein. Nutrins in atomic nuclei also have an undulatory nature and lack standard fluid properties, such as friction. For nuclei made up of arons that are studs, the condensation of Bose-Einstein does not occur, however many nuclear properties can be explained in the same way only by a combination of particle properties with volume, as well as the motion without friction characteristic of the undulatory behaviour of objects trapped in the quantum orbitals of Erwin Schrödinger. See also Giant Resonance Particle List James Rainwater, Non-Spherical Numerals Modeled Nuclear Medicine Radioactivity Notes 26.634 comes from 2 x 156Â pm / 11.7142Â fm; 60.250 comes from 2 x 52.92Â pm / 1.7166Â fm References ^ Iwanenko, D.D. (1932). "The hypothesis of neutrons." Nature. 129 (3265): 798. 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