

INTRODUCTION TO NUCLEUS

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In chemistry, a nucleus is the positively charged center of the atom consisting of protons and neutrons. It's also known as the "atomic nucleus". The word "nucleus" comes from the Latin word *nucleus*, which is a form of the word *nux*, which means nut or kernel[1-8]. The term was coined in 1844 by Michael Faraday to describe the center of an atom. The sciences involved in the study of the nucleus, its composition, and characteristics are called nuclear physics and nuclear chemistry.

Protons and neutrons are held together by the strong nuclear force. Electrons, although attracted to the nucleus, move so fast they fall around it or orbit it at a distance[9-15]. The positive electrical charge of the nucleus comes from the protons, while the neutrons have no net electrical charge. Nearly all the mass of an atom is contained within the nucleus, since protons and neutrons have much more mass than electrons[16-22]. The number of protons in an atomic nucleus defines its identity as an atom of a specific element. The number of neutrons determines which isotope of an element the atom is.

Size of the Atomic Nucleus

The nucleus of an atom is much smaller than the overall diameter of the atom because the electrons can be distant from the atom's center[23-28]. A hydrogen atom is 145,000 times larger than its nucleus, while a uranium atom is around 23,000 times larger than its nucleus. The hydrogen nucleus is the smallest nucleus because it consists of a lone proton.

It is 1.75 femtometers (1.75×10^{-15} m). The uranium atom, in contrast, contains many protons and neutrons. Its nucleus is about 15 femtometers.

Arrangement of Protons and Neutrons in the Nucleus

The protons and neutrons are usually depicted as compacted together and evenly spaced into spheres. However, this is an oversimplification of the actual structure[29-32].

Each nucleon (proton or neutron) can occupy a certain energy level and a range of locations. While a nucleus can be spherical, it may also be pear-shaped, rugby ball-shaped, discus-shaped, or triaxial.

The protons and neutrons of the nucleus are baryons composed of smaller subatomic particles, called quarks. The strong force has an extremely short range, so protons and neutrons must be very near to each other to be bound[33-39]. The attractive strong force overcomes the natural repulsion of the like-charged protons.

Hypernucleus

In addition to protons and neutrons, there is a third type of baryon called a hyperon. A hyperon contains at least one strange quark, while protons and neutrons consist of up and down quarks. A nucleus that contains protons, neutrons, and hyperons is called a hypernucleus. This type of atomic nucleus has not been seen in nature[40-45], but has been formed in physics experiments.

Halo Nucleus

Another type of atomic nucleus is a halo nucleus. This is a core nucleus that is surrounded by an orbiting halo of protons or neutrons. A halo nucleus has a much larger diameter than a typical nucleus. Its also much more unstable than a normal nucleus. An example of a halo nucleus has been observed in lithium-11, which has a core consisting of 6 neutrons and 3 protons, with a halo of 2 independent neutrons.

The half-life of the nucleus is 8.6 milliseconds. Several nuclides have been seen to have a halo nucleus when they are in the excited state, but not when they are in the ground state.

References:

M. May (1994). "Recent results and directions in hypernuclear and kaon physics". In A. Pascolini. PAN XIII: Particles and Nuclei. World Scientific. ISBN 978-981-02-1799-0. OSTI 10107402

W. Nörtershäuser, Nuclear Charge Radii of $^{7,9,10}\text{Be}$ and the One-Neutron Halo Nucleus ^{11}Be , *Physical Review Letters*, 102:6, 13 February 2009,

Nuclear Isomer Definition

Nuclear isomers are atoms with the same mass number A and atomic number Z, but with different states of excitation in the atomic nucleus. The higher or more excited state is call a metastable state, while the stable, unexcited state is called the ground state.

How Nuclear Isomers Work

Most people are aware electrons can change energy levels and be found in excited states. An analogous process occurs in the atomic nucleus when protons or neutrons (the nucleons) become excited.

The excited nucleon occupies a higher energy nuclear orbital. Most of the time, the excited nucleons return immediately to the ground state, but if the excited state has a half-life longer than 100 to 1000 times that of normal excited states, it is considered a metastable state. In other

words, the half-life of an excited state is usually on the order of 10^{-12} seconds, while a metastable state has a half-life of 10^{-9} seconds or longer. Some sources define a metastable state as having a half-life greater than 5×10^{-9} seconds to avoid confusion with the half-life of gamma emission. While most metastable states decay quickly, some last for minutes, hours, years, or much longer.

The *reason* metastable states form is because a larger nuclear spin change is needed in order for them to return to the ground state. High spin change makes the decays "forbidden transitions" and delays them. Decay half-life is also affected by how much decay energy is available.

Most nuclear isomers return to the ground state via gamma decay. Sometimes gamma decay from a metastable state is named *isomeric transition*, but it's essentially the same as normal short-lived gamma decay. In contrast, most excited atomic states (electrons) return to the ground state via fluorescence.

Another way metastable isomers can decay is by internal conversion. In internal conversion, the energy that is released by the decay accelerates an inner electron, causing it to exit the atom with considerable energy and speed. Other decay modes exist for highly unstable nuclear isomers.

Metstable and Ground State Notation

The ground state is indicated using the symbol g (when any notation is used). The excited states are denoted using the symbols m, n, o, etc. The first metastable state is indicated by the letter m. If a specific isotope has multiple metastable states, the isomers are designated m1, m2, m3, etc. The designation is listed after the mass number (e.g., cobalt 58m or $^{58\text{m}}_{27}\text{Co}$, hafnium-178m2 or $^{178\text{m}2}_{72}\text{Hf}$).

The symbol sf may be added to indicate isomers capable of spontaneous fission. This symbol is used in the Karlsruhe Nuclide Chart.

Metstable State Examples

Otto Hahn discovered the first nuclear isomer in 1921. This was Pa-234m, which decays in Pa-234.

The longest-lived metastable state is that of $^{180\text{m}}_{73}\text{Ta}$. This metastable state of tantalum has not been seen to decay and appears to last at least 10^{15} years (longer than the age of the universe). Because the metastable state endures so long, the nuclear isomer is essentially stable.

Tantalum-180m is found in nature at an abundance of about 1 per 8300 atoms. It's thought perhaps the nuclear isomer was made in supernovae.

How Nuclear Isomers Are Made

Metastable nuclear isomers occur via nuclear reactions and can be produced using nuclear fusion. They occur both naturally and artificially.

Fission Isomers and Shape Isomers

A specific type of nuclear isomer is the fission isomer or shape isomer. Fission isomers are indicated using either a postscript or superscript "f" instead of "m" (e.g., plutonium-240f or $^{240f}_{94}\text{Pu}$). The term "shape isomer" refers to the shape of the atomic nucleus. While the atomic nucleus tends to be depicted as a sphere, some nuclei, such as those of most actinides, are prolate spheres (football-shaped). Because of quantum mechanical effects, de-excitation of excited states to the ground state is hindered, so the excited states tend to undergo spontaneous fission or else return to the ground state with a half-life of nanoseconds or microseconds.

The protons and neutrons of a shape isomer may be even further from a spherical distribution than the nucleons on the ground state.

Uses of Nuclear Isomers

Nuclear isomers may be used as gamma sources for medical procedures, nuclear batteries, for research into gamma-ray stimulated emission, and for gamma ray lasers.

REFERENCES

1. Ramamoorthy, R., Kanagasabai, V., Kausalya, R., Impact of celebrities' image on brand, International Journal of Pure and Applied Mathematics, V-116, I-18 Special Issue, PP-251-253, 2017
2. Ramamoorthy, R., Kanagasabai, V., Vignesh, M., Quality assurance in operation theatre withreference to fortis malar hospital, International Journal of Pure and Applied Mathematics, V-116, I-14 Special Issue, PP-87-93, 2017
3. Ramya, N., Arthy, J., Honey comb graphs and its energy, International Journal of Pure and Applied Mathematics, V-116, I-18 Special Issue, PP-83-86, 2017
4. Ramya, N., Jagadeeswari, P., Proper coloring of regular graphs, International Journal of Pure and Applied Mathematics, V-116, I-16 Special Issue, PP-531-533, 2017
5. Ramya, N., Karunagaran, K., Proper, star and acyclic coloring of some graphs, International Journal of Pure and Applied Mathematics, V-116, I-16 Special Issue, PP-43-44, 2017
6. Ramya, N., Muthukumar, M., On coloring of 4-regular graphs, International Journal of Pure and Applied Mathematics, V-116, I-16 Special Issue, PP-491-494, 2017
7. Ramya, N., Muthukumar, M., On star and acyclic coloring of graphs, International Journal of Pure and Applied Mathematics, V-116, I-16 Special Issue, PP-467-469, 2017
8. Ramya, N., Pavi, J., Coloring of book and gear graphs, International Journal of Pure and Applied Mathematics, V-116, I-17 Special Issue, PP-401-402, 2017
9. Ramya, P., Hameed Hussain, J., Alteration framework for integrating quality of service in internet real-time network, International Journal of Pure and Applied Mathematics, V-116, I-8 Special Issue, PP-57-61, 2017

10. Ramya, P., Sriram, M., Tweet sarcasm: Peep, International Journal of Pure and Applied Mathematics, V-116, I-10 Special Issue, PP-231-235, 2017
11. Sabarish, R., Meenakshi, C.M., Comparision of beryllium and CI connecting rod using ansys, International Journal of Pure and Applied Mathematics, V-116, I-17 Special Issue, PP-127-132, 2017
12. Sabarish, R., Rakesh, N.L., Outcome of inserts for enhancing the heat exchangers, International Journal of Pure and Applied Mathematics, V-116, I-17 Special Issue, PP-419-422, 2017
13. Sangeetha, M., Gokul, N., Aruls, S., Estimator for control logic in high level synthesis, International Journal of Pure and Applied Mathematics, V-116, I-20 Special Issue, PP-425-428, 2017
14. Sangeetha, M., Gokul, N., Aruls, S., Image steganography using a curvelet transformation, International Journal of Pure and Applied Mathematics, V-116, I-20 Special Issue, PP-417-422, 2017
15. Saraswathi, P., Srinivasan, V., Peter, M., Research on financial supply chain from view of stability, International Journal of Pure and Applied Mathematics, V-116, I-17 Special Issue, PP-211-213, 2017
16. Saravana Kumar, A., Hameed Hussain, J., Expanding the pass percentage in semester examination, International Journal of Pure and Applied Mathematics, V-116, I-15 Special Issue, PP-45-48, 2017
17. Saravana, S., Arulselvi, S., AdaBoost SVM based brain tumour image segmentation and classification, International Journal of Pure and Applied Mathematics, V-116, I-20 Special Issue, PP-399-403, 2017
18. Saravana, S., Arulselvi, S., Dynamic power management monitoring and controlling system using wireless sensor network, International Journal of Pure and Applied Mathematics, V-116, I-20 Special Issue, PP-405-408, 2017
19. Saravana, S., Arulselvi, S., Clustered morphic algorithm based medical image analysis, International Journal of Pure and Applied Mathematics, V-116, I-20 Special Issue, PP-411-415, 2017
20. Saravana, S., Arulselvi, S., Networks, International Journal of Pure and Applied Mathematics, V-116, I-20 Special Issue, PP-393-396, 2017
21. Saritha, B., Chockalingam, M.P., Adsorptive removal of heavy metal chromium from aqueous medium using modified natural adsorbent, International Journal of Civil Engineering and Technology, V-8, I-8, PP-1382-1387, 2017
22. Saritha, B., Chockalingam, M.P., Adsorptive removal of brilliant green dye by modified coconut shell adsorbent, International Journal of Pure and Applied Mathematics, V-116, I-13 Special Issue, PP-211-215, 2017
23. Saritha, B., Chockalingam, M.P., Photodegradation of eriochrome black-T dye from aqueous medium by photocatalysis, International Journal of Pure and Applied Mathematics, V-116, I-13 Special Issue, PP-183-187, 2017
24. Saritha, B., Chockalingam, M.P., Photodradation of malachite green DYE using TiO_2 /activated carbon composite, International Journal of Civil Engineering and Technology, V-8, I-8, PP-156-163, 2017

25. Saritha, B., Chockalingam, M.P., Synthesis of photocatalytic composite Fe-C/TiO₂ for degradation of malachite green dye from aqueous medium, International Journal of Pure and Applied Mathematics, V-116, I-13 Special Issue, PP-177-181, 2017
26. Saritha, B., Chockalingam, M.P., Removal of heavy X`X`l from aqueous medium using modified natural adsorbent, International Journal of Pure and Applied Mathematics, V-116, I-13 Special Issue, PP-205-210, 2017
27. Saritha, B., Chockalingam, M.P., Degradation of malachite green dye using a semiconductor composite, International Journal of Pure and Applied Mathematics, V-116, I-13 Special Issue, PP-195-199, 2017
28. Sartiha, B., Chockalingam, M.P., Photocatalytic decolourisation of textile industry wastewater by TiO₂, International Journal of Pure and Applied Mathematics, V-116, I-18 Special Issue, PP-221-224, 2017
29. Sartiha, B., Chockalingam, M.P., Study on photocatalytic degradation of Crystal Violet dye using a semiconductor, International Journal of Pure and Applied Mathematics, V-116, I-18 Special Issue, PP-209-212, 2017
30. Shanthi, E., Nalini, C., Rama, A., The effect of highly-available epistemologies on hardware and architecture, International Journal of Pharmacy and Technology, V-8, I-3, PP-17082-17086, 2016
31. Shanthi, E., Nalini, C., Rama, A., Drith: Autonomous, random communication, International Journal of Pharmacy and Technology, V-8, I-3, PP-17002-17006, 2016
32. Shanthi, E., Nalini, C., Rama, A., A case for replication, International Journal of Pharmacy and Technology, V-8, I-3, PP-17234-17238, 2016
33. Shanthi, E., Nalini, C., Rama, A., Elve: A methodology for the emulation of robots, International Journal of Pharmacy and Technology, V-8, I-3, PP-17182-17187, 2016
34. Shanthi, E., Nalini, C., Rama, A., Autonomous epistemologies for 802.11 mesh networks, International Journal of Pharmacy and Technology, V-8, I-3, PP-17087-17093, 2016
35. Sharavanan, R., Golden Renjith, R.J., Design and analysis of fuel flow in bend pipes, International Journal of Pure and Applied Mathematics, V-116, I-15 Special Issue, PP-59-64, 2017
36. Sharavanan, R., Jose Ananth Vino, V., Emission analysis of C.I engine run by diesel, sunflower oil, 2 ethyl hexyl nitrate blends, International Journal of Pure and Applied Mathematics, V-116, I-14 Special Issue, PP-403-408, 2017
37. Sharavanan, R., Sabarish, R., Design of built-in hydraulic jack for light motor vehicles, International Journal of Pure and Applied Mathematics, V-116, I-17 Special Issue, PP-457-460, 2017
38. Sharavanan, R., Sabarish, R., Design and fabrication of aqua silencer using charcoal and lime stone, International Journal of Pure and Applied Mathematics, V-116, I-14 Special Issue, PP-513-516, 2017
39. Sharmila, G., Thooyamani, K.P., Kausalya, R., A schoolwork on customer relationship management with special reference to domain 2 host, International Journal of Pure and Applied Mathematics, V-116, I-20 Special Issue, PP-199-203, 2017

40. Sharmila, S., Jeyanthi Rebecca, L., Anbuselvi, S., Kowsalya, E., Kripanand, N.R., Tanty, D.S., Choudhary, P., SwathyPriya, L., GC-MS analysis of biofuel extracted from marine algae, *Der Pharmacia Lettre*, V-8, I-3, PP-204-214, 2016
41. Sidharth Raj, R.S., Sangeetha, M., Data embedding method using adaptive pixel pair matching method, *International Journal of Pure and Applied Mathematics*, V-116, I-15 Special Issue, PP-417-421, 2017
42. Sidharth Raj, R.S., Sangeetha, M., Android based industrial fault monitoring, *International Journal of Pure and Applied Mathematics*, V-116, I-15 Special Issue, PP-423-427, 2017
43. Sidharth Raj, R.S., Sangeetha, M., Mobile robot system control through an brain computer interface, *International Journal of Pure and Applied Mathematics*, V-116, I-15 Special Issue, PP-413-415, 2017
44. Sivaraman, K., Sundarraj, B., Decisive lesion detection in digital fundus image, *International Journal of Pure and Applied Mathematics*, V-116, I-10 Special Issue, PP-161-164, 2017
45. Sridhar, J., Sriram, M., Cloud privacy preserving for dynamic groups, *International Journal of Pure and Applied Mathematics*, V-116, I-8 Special Issue, PP-117-120, 2017

