

# Nuclear isomer energy storage

What is a nuclear isomer?

Curie A nuclear isomer is a metastable state of an atomic nucleus, in which one or more nucleons (protons or neutrons) occupy excited state (higher energy) levels.

Why do nuclear isomers have a longer life?

The longer lives of nuclear isomers' metastable states are often due to the larger degree of nuclear spin change which must be involved in their gamma emission to reach the ground state. This high spin change causes these decays to be forbidden transitions and delayed. Delays in emission are caused by low or high available decay energy.

What is the difference between a ground state and a nuclear isomer?

The nucleus of a nuclear isomer occupies a higher energy state than the non-excited nucleus existing in the ground state. In an excited state, one or more of the protons or neutrons in a nucleus occupy a nuclear orbital of higher energy than an available nuclear orbital. These states are analogous to excited states of electrons in atoms.

Is isomer depletion possible in nuclear energy storage solutions?

Isomer depletion has often been mentioned in the context of potential nuclear energy storage solutions without involving fission or fusion [1,4 -6]. One of the most intriguing means to externally drive the transition to the gateway state is via coupling to the atomic shell.

How long does a nuclear isomer last?

For example, the  $^{180\text{m}}\text{Ta}$  nuclear isomer survives so long (at least 10<sup>15</sup> years) that it has never been observed to decay spontaneously. The half-life of a nuclear isomer can even exceed that of the ground state of the same nuclide, as shown by  $^{180\text{m}}\text{Ta}$  as well as  $^{186\text{m}}\text{Re}$ ,  $^{192\text{m}}\text{Ir}$ ,  $^{210\text{m}}\text{Bi}$ ,  $^{212\text{m}}\text{Po}$ ,  $^{242\text{m}}\text{Am}$  and multiple holmium isomers.

What is a metastable nuclear state (isomer)?

A different kind of metastable nuclear state (isomer) is the fission isomer or shape isomer. Most actinide nuclei in their ground states are not spherical, but rather prolate spheroidal, with an axis of symmetry longer than the other axes, similar to an American football or rugby ball.

$\text{Th } 229$  with a low-lying nuclear isomeric state is an essential candidate for a nuclear clock as well as many other applications. Laser excitation of the isomeric state has been a long-standing goal. With relativistic  $\text{Th } 229$  ions in storage rings, high-power lasers with wavelengths in the visible range or longer can be used to achieve high excitation rates of  $\text{Th } \dots$

Active optical pumping is presented using narrow-band 29-kiloelectronvolt synchrotron radiation to

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resonantly excite the second excited state of  $^{229}\text{Th}$ , which then decays predominantly into the isomer, enabling accurate determination of the  $^{229\text{m}}\text{Th}$  isomer's energy, half-life and excitation linewidth. The metastable first excited state of thorium-229,  $^{229\text{m}}\text{Th}$ , is ...

A nuclear isomer is a metastable state of an atomic nucleus, in which one or more nucleons (protons or neutrons) occupy excited state (higher energy) levels. "Metastable" describes nuclei whose excited states have half-lives 100 to 1000 times longer than the half-lives of the excited nuclear states that decay with a "prompt" half life (ordinarily on the order of 10<sup>-12</sup> seconds).

triggered to release their energy on demand. 1. What are Isomers? Isomers are excited-states of the nuclei that emit gamma radiations when de-excited. The energy stored in the individual nucleus can contain 100,000 times the energy of an individual chemical atom. [1] By analogy with chemical isomers, nuclear isomers

Isomers are metastable nuclear excitations with long half-lives, ranging from nanoseconds to years. In general, an isomer's decay is inhibited by at least one of three physical constraints: spin isomers involve a large change in the magnitude of the angular momentum, often combined with low transition energy; K isomers require a large change in the direction of the angular ...

Classification of nuclear isomers. Nuclear potential energy as a function of spin variation, spin projections, and shape deformation. The blue arrows denote ... For decades, isomers have held promise as a more compact ( $10^4$ ) denser than chemical batteries) and longer-lasting energy storage solution [31, 63,64,65]. Long-duration energy ...

Stars are fueled by the energy released during nuclear reactions. Since isomers are present in stars, nuclear reactions are different than if a material were in its ground state. This makes the ...

Some nuclear isomers are known to store a large amount of energy over long periods of time, with a very high energy-to-mass ratio. Here, we describe a protocol to achieve the external control ...

The results provide a standard for the assessment of theoretical models relevant to NEEC, which predict cross-sections that span many orders of magnitude and report evidence of NEEC in molybdenum-93 and determine the probability and cross-section for the process in a beam-based experimental scenario. The atomic nucleus and its electrons are often thought of ...

Nuclear isomers are the long-lived excited states of nuclei. Therefore, they constitute the meta-stable landscape of nuclei. The first isomer was probably identified as early as 1921. ... Further, the isomers are beginning to be seen as potential energy storage devices and nuclear clocks with a host of applications. Possible discovery of a ...

OverviewApplicationsNuclei of nuclear isomersMetastable isomersNearly stable isomersHigh-spin suppression of decayDecay processesSee alsoHafnium isomers (mainly Hf) have been considered as weapons

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that could be used to circumvent the Nuclear Non-Proliferation Treaty, since it is claimed that they can be induced to emit very strong gamma radiation. This claim is generally discounted. DARPA had a program to investigate this use of both nuclear isomers. The potential to trigger an abrupt release of energy from nuclear isotopes, a prerequisite to their use in such weapons, is disputed. Nonetheless a 12-member H...

PHYSICAL REVIEW RESEARCH 5, 023134 (2023) Excitation and probing of low-energy nuclear states at high-energy storage rings Junlan Jin,<sup>1,2</sup> \* Hendrik Bekker,<sup>3,4</sup> Tobias Kirschbaum,<sup>5</sup> Yuri A. Litvinov,<sup>6</sup> Adriana Piffy,<sup>5</sup> Jonas Sommerfeldt,<sup>7,8</sup> Andrey Surzhykov,<sup>7,8</sup> Peter G. Thirolf,<sup>9</sup> and Dmitry Budker <sup>3</sup> 4 10 + 1 Department of Electrical and Computer Engineering, ...

associated with harnessing the energy storage capacity of nuclear isomers. They also spotlight the twelve isomer-battery contenders with half-lives in years. Balabanski and Luo [35] go on to describe the role of isomers in nuclear photonics, an emerging field of science, combining the new generation  $\gamma$ -ray sources based on traditional and

nuclear isomer sources such as naturally occurring <sup>180m</sup>Ta, <sup>137</sup>Ba produced in decaying Cesium in nuclear waste, <sup>177m</sup>Lu from medical waste, and <sup>178m2</sup>Hf from the Department of Energy storage can be combined with current dark matter detector technology to search for this class of dark matter. I. INTRODUCTION The nature of dark matter (DM) is ...

The hafnium controversy was a debate over the possibility of “triggering” rapid energy releases, via gamma-ray emission, from <sup>178m2</sup>Hf, a nuclear isomer of hafnium. The energy release per event is 5 orders of magnitude (100,000 times) higher than in a typical chemical reaction, but 2 orders of magnitude less than a nuclear fission reaction. In 1998, a group led by Carl Collins in ...

Nuclear Isomer Energy Storage. Nuclear isomer energy storage involves absorption and release of energy during transitions in the quantum energy state of atomic nuclei. Some researchers ...

Consequently, any nuclear energy storage will involve radiation hazards. Depending on the method used these can be minimized or mitigated with proper procedures and design, but it will always be a factor to consider. ... Nuclear isomer. An isomer is a certain configuration of protons and neutrons in a nucleus. Different isomers of the same ...

One promising area of future research involves the use of nuclear isomers in energy storage. Certain isomers, due to their ability to store significant amounts of energy over long durations, have potential applications in creating long-lasting energy storage systems. This could lead to breakthroughs in how energy is stored and released on ...

A 4.85 keV excitation from the isomer to the gateway state at 2430 keV [3] should release the entire stored energy within only 4 ns. Isomer depletion has often been mentioned in the context of potential nuclear energy storage solutions without involving fission or fusion [1,4-6]. One of the most intriguing means to externally

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drive

$^{229}\text{Th}$  has a low-energy transition between the nuclear ground state and a long-lived isomer,  $^{229\text{m}}\text{Th}$ , at an excitation energy of about 7.8 eV. This enables the application of precision laser ...

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The focus is on the nuclear isomer  $^{178\text{m2}}\text{Hf}$  which has been most widely suggested for energy storage applications. However, the science issues apply to all nuclear isomer. The assessment addresses the production of the nuclear isomer, and inducing the release of the isomer.

Nuclear Isomers have been suggested as a potential high energy density medium that might be used to store energy. This talk assesses the state of the science supporting key elements of using nuclear isomers in energy storage applications.

Nuclear Isomers are an exciting new development in the field of Nuclear physics. They are, essentially, a nuclear storage battery. ... These would amount immensely dense energy storage devices, with power densities per unit weight reaching a theoretical limit near that of low end fusion reactions! Best Batteries - 300 Wh/Kg Fuel Cells ...

Owing to its low excitation energy and long radiative lifetime, the first excited isomeric state of thorium-229,  $^{229\text{m}}\text{Th}$ , can be optically controlled by a laser<sup>1,2</sup> and is an ideal candidate for the ...

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