PLUTUS IAS

CURRENT AFFAIRS

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LASER COOLING OF POSITRONIUM BY CERN

THIS ARTICLE COVERS 'DAILY CURRENT AFFAIRS' AND THE TOPIC DETAILS OF "LASER COOLING OF POSITRONIUM BY CERN".THIS TOPIC IS RELEVANT IN THE "SCIENCE & TECHNOLOGY" SECTION OF THE UPSC CSE EXAM.

WHY IN THE NEWS?

A multinational team of scientists has successfully demonstrated laser cooling of positronium for the very first time, marking a significant scientific milestone. The Antihydrogen Experiment: Gravity, Interferometry, Spectroscopy (AEgIS) team at the European Organisation for Nuclear Research (CERN) conducted the ground-breaking experiment.

WHAT IS POSITRONIUM?

Positronium can be defined as a composite system comprising an electron and its corresponding antiparticle, the positron. Classified as an exotic atom or pseudo-atom, it mimics the behaviour of a hydrogen atom while possessing a reduced mass.

PROPERTIES OF POSITRONIUM:

Positronium exists in two distinct forms known as **ortho-positronium (o-Ps) and para-positronium (p-Ps),** differentiated by their spin configurations.

- **Spin States:**

1. **Ortho-positronium**: In this state, the spins of the electron and positron are parallel, resulting in a triplet state.
2. **Para-positronium**: Here, the spins are anti-parallel, leading to a singlet state.

- **Lifetime**: The lifespan of positronium is notably brief, typically lasting on the order of nanoseconds, culminating in its annihilation.

- **Annihilation**: During the annihilation process, positronium emits two or three gamma-ray photons, each possessing an energy of 511 keV. This emission occurs as the entire rest of the energy of the electron-positron pair transforms into photons.

ANTIHYDROGEN EXPERIMENT: GRAVITY, INTERFEROMETRY, SPECTROSCOPY (AEGIS)

- The **Antihydrogen Experiment: Gravity, Interferometry, Spectroscopy (AEgIS)** is a groundbreaking scientific initiative aimed at unravelling the mysteries surrounding antimatter and its interaction with gravity. Launched to explore the fundamental forces governing antimatter, **AEgIS combines gravity measurements, interferometry techniques, and spectroscopy methods in a comprehensive approach.**
- One of the **primary objectives** of the AEgIS experiment is to examine how antimatter, specifically antihydrogen, responds to gravitational forces. By subjecting antihydrogen atoms to precise gravitational measurements, **scientists aim to gain insights into the gravitational behaviour of antimatter, a critical aspect of our understanding of the universe's fundamental forces.**
- Interferometry, a technique commonly employed in quantum physics, is a key component of AEgIS. This method involves combining and analysing multiple beams of antihydrogen particles to create interference patterns. The resulting interference fringes provide valuable data on the properties and behaviour of antihydrogen, offering a deeper understanding of antimatter physics.
- Spectroscopy, another integral aspect of the AEgIS experiment, involves the **study of the interaction between antihydrogen and electromagnetic radiation.** By analysing the spectral lines produced during these interactions, scientists can gather essential information about the energy levels and characteristics of antihydrogen atoms. This spectroscopic analysis contributes to refining our knowledge of the properties and dynamics of antimatter.
- The AEgIS experiment operates at the Antiproton Decelerator facility at CERN (European Organization for Nuclear Research). This **cutting-edge facility allows scientists to produce and trap antihydrogen atoms, enabling meticulous experimentation and observation.**
- The **significance of AEgIS extends beyond the realm of antimatter physics.** It plays a pivotal role in addressing fundamental questions about the symmetry between matter and antimatter, the nature of gravity's influence on antimatter, and potential disparities in their behaviours.

ABOUT LASER COOLING

Laser cooling emerged as a revolutionary technique in the realms of atomic physics and quantum optics, showcasing the ability to decelerate and confine atomic and molecular particles. The core principle of this method lies in the interaction between light and charged matter, capitalising on the momentum transfer from photons to atoms.

WORKING PRINCIPLE OF LASER COOLING

- The mechanism hinges on the absorption and re-emission of photons. As an atom absorbs a photon, it ascends to a higher energy level, subsequently descending to a lower energy level upon re-emitting the photon. **Laser cooling's effectiveness lies in ensuring that the atom consistently re-emits the photon opposite to its motion.** This meticulous process results in the atom losing more momentum to photons than it gains, leading to a gradual slowdown and eventual capture of atoms in optical traps.
- Typically employing a narrow-band laser with a confined frequency range, the **AEgIS team** has innovatively utilised a broad-band laser (~380 Kelvin to ~170 Kelvin) in their experiment. Employing a **70-nanosecond pulsed alexandrite-based laser system**, this unconventional approach has facilitated the cooling of the positronium sample.
- Remarkably, the AEgIS experiment achieved successful laser cooling without the application of any external electric or magnetic field. This strategic simplification of the experimental setup not

only showcases the versatility of laser cooling but also extends the positronium lifetime, opening new avenues for further exploration in quantum mechanics.

SIGNIFICANCE OF LASER COOLING

- **Building blocks for antimatter research:** Cooling antimatter lays the groundwork for creating antihydrogen and studying its behaviour in Earth's gravity.
- **Unveiling new frontiers:** Laser cooling opens doors to creating a gamma-ray laser, potentially allowing us to peer into atomic nuclei and beyond.
- **Deeper understanding of matter and antimatter**: By meticulously controlling antimatter particles, scientists can probe their interactions with light, revealing the nature of our universe.
- **Unlocking Bose-Einstein condensates and beyond**: Laser cooling enables the creation of a positronium Bose-Einstein condensate, a unique state of matter with the potential for diverse applications. It includes the generation of a revolutionary gamma-ray laser.
- **The groundwork for future discoveries**: It facilitates the formation of ultracold antimatter systems and a degenerate gas of Positronium, crucial for advancing our understanding of the universe.
- **Revolutionising antimatter research**: High-precision manipulation allows detailed study of antimatter properties and behaviour, potentially revealing new physics.

PRELIMS PRACTICE QUESTIONS

Q1. What is the objective of laser cooling in the AEgIS experiment?
(a) Creating a Bose-Einstein condensate
(b) Analyzing dark matter
(c) Studying neutrinos
(d) Slowing down and trapping antihydrogen particles

Answer: d

Q2. What is the primary method used in laser cooling during the AEgIS experiment at CERN?
(a) Magnetic resonance
(b) Radiofrequency heating
(c) Absorption and re-emission of photons
(d) Gravitational acceleration

Answer: c

MAINS PRACTICE QUESTION

Q1. Examine the properties of positronium, specifically ortho-positronium and para-positronium. How their spin configurations contribute to the overall behaviour of this exotic atom. How does the short lifespan of positronium play a role in its annihilation process?

Himanshu Mishra

INDIA MOVING TOWARDS A NEW SUCCESS IN SPACE RESEARCH PROGRAMS

SOURCE – THE HINDU AND PIB.

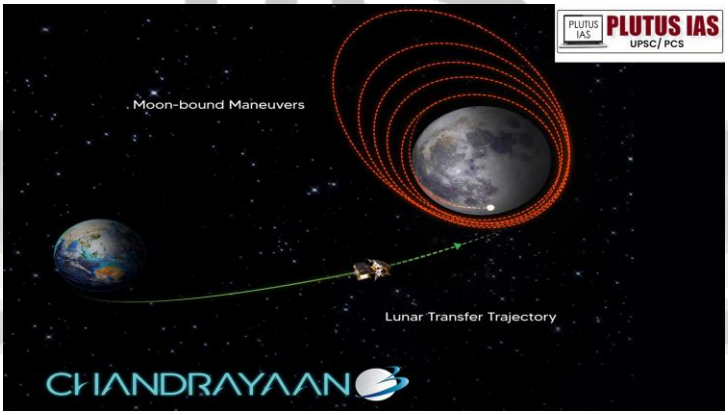
GENERAL STUDIES – SCIENCE AND TECHNOLOGY, CHANDRAYAAN -3, LUNA 25 MISSION, INDIAN SPACE RESEARCH ORGANIZATION (ISRO), ROSCOSMOS OF RUSSIA, CURRENT SPACE POLICY OF INDIA.

WHY IN THE NEWS ?

- For the second time in the history of space research programs, the pace of landing on the Moon is accelerating.
- This time, a new story of success and participation of many countries in the preparation of successfully landing on the Moon is before us.
- The soft-landing of Chandrayaan-3 this time has shown that the Indian Space Research Organization (ISRO), as a space research and flight provider, has an understanding of the technologies and processes involved in space research and all the choices made by it are correct and India Coming out of the colonial mindset, the Indian Space Research Organization (ISRO) has established itself as an influential country.
- The failure of the Luna 25 mission may have opened the way for Russia's Roscosmos to understand its space research technologies and processes and learn a lot from the mistakes made in it, as Russia's Roscosmos is famous as a space agency which has previously had achieved great heights in the field of space research technologies and its failure in the Luna 25 mission is reducing its credibility.
- The success of NASA's space service providers in the United States in its early years is of utmost importance to them. This fact is also true in the case of IM, with some important differences.
- IM launched its Odysseus lander to the Moon as part of NASA's Commercial Lunar Payload Services (CLPS) program. Through this program, NASA is funding instruments aboard commercial missions to the Moon in the hope that their findings will facilitate the agency's possible return to this natural satellite.
- During KIM's journey to Odysseus, as the lander began its descent process, its navigation instruments malfunctioned, forcing IM engineers to quickly resort to a workaround and send instructions to an experimental NASA instrument available on board the spacecraft. . Following the hotfix, Odysseus' soft landing was completed but could not be confirmed due to the weak data link between the spacecraft and the antenna on Earth.

- According to the IM, the Odyssey spacecraft may have turned upside down, but most of its payloads and solar panels, including six NASA payloads, were unaffected.
- This success of IM for CLPS program may help in expanding it further in future.
- NASA's role in missions involving CLPS is limited to identifying interesting landing sites and providing some payloads.
- By the year 2020, it had roped in 14 different companies to conduct research in this area. Which also included an expenditure budget of approximately 2.6 billion US dollars.
- To make such space program transfers possible in any country, a healthy and diverse private space service, like the one in the United States, is needed.
- This is what the success of the IM means for the US space program throughout the world.

CURRENTLY INDIAN SPACE RESEARCH PROGRAMS AND IMPORTANT INITIATIVES BY ISRO :

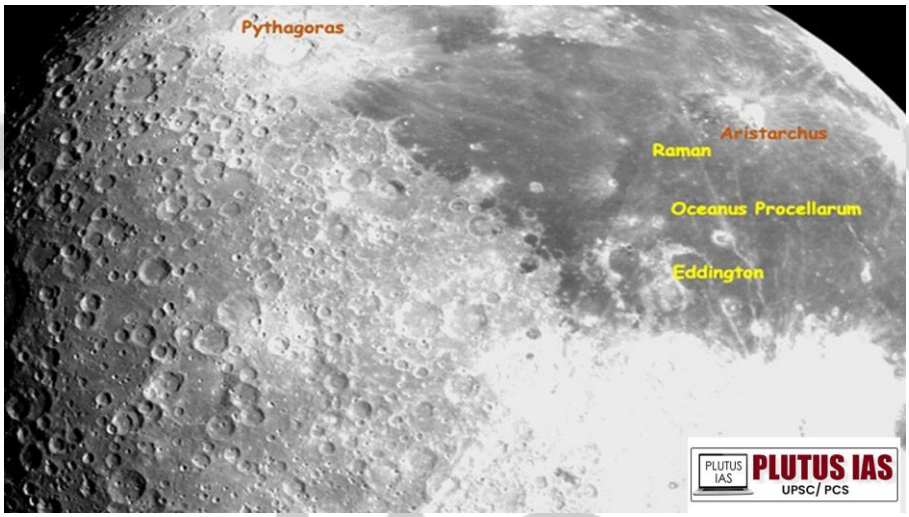


- India has succeeded in moving towards new heights of success in its space research programmes, creating its own unique identity in the global space community.
- The credit for India's success in space research programs goes to the Indian Space Research Organization (ISRO) and its dedicated teams.
- The Indian Space Research Organization (ISRO) continues to support India in achieving the highest standards of space research programs through innovation, efficiency, and innovation.

ISRO ESTABLISHING ITS SPECIAL IDENTITY IN THE FIELD OF SPACE RESEARCH :

- India in the field of space research through ISRO, it has established its special and very important identity in various fields in space. From the earth's surface to the field of space research, India has successfully established its identity.
- India today has played an important role in reaching the Moon and Mars through Chandrayaan, Mangalyaan, and other latest and modern satellites through ISRO.

ISRO TO BE SELF – RELIANT IN THE FIELD OF SPACE RESEARCH AND DEVELOP SCIENTIFIC APPROACH :



- The Indian space research program has made significant changes towards self-reliance. With indigenous satellites, manufacturing and good technological prospects, India has made its place in the world market.

UTILIZATION OF RICH TECHNOLOGY AND NEW ENERGY SYSTEMS BY ISRO IN INDIA :

- Indian space missions have set many benchmarks in the field of innovative energy systems, technological prosperity, and self-reliance to reach new heights in their research every day. It is firmly committed to the field of space, exploring and developing new areas in satellite and rocket technology.

TO DEVELOP INDIA'S MUTUAL COOPERATION AT THE GLOBAL LEVEL :

- India has also shared the success achieved in the field of space research with its global partner countries and every new flight and success by India in the field of space has also helped its global partner countries. India has strengthened cooperation and relations with various countries in international space missions, which is an important step for global development at the international level.

ISRO HAS SET NEW STANDARDS OF SUCCESS IN THE INDIAN SPACE RESEARCH PROGRAMME :

- ISRO has set new standards of success in the Indian space research program and has shown the world in detail its unique capabilities in the field of space research program. This proves that India is continuously moving forward to seriously study and achieve success not only in the space sector but also in the field of science and technology. This is why India is an important and respected name in the space sector today and India's ISRO is continuously moving towards the next heights in the field of research.

CONCLUSION / PATH TO SOLUTION :

- India has recently approved 100% automatic foreign direct investment for its national space programme, thereby creating healthy competition among Indian start-ups to find solutions to the challenges faced by ISRO in India in the coming future. The path will be paved.
- Research in the field of space is a task that requires extensive and mutual cooperation between different nations/countries.
- With the increase in India's stature for research in the field of space, ISRO is also establishing an important identity at the international level. This means that today India is completely dedicated to reaching new heights in science and technology, at the same time it is making a significant contribution towards making India self-reliant in research in the field of space. Is.
- Today India's space research program is touching its heights, taking important steps towards creating important technologies in the future, and today India is establishing its ideal identity in the field of space across the world. In the future, the new and advanced research associated with

this endeavor will strengthen India's position in space and share its liberal vision with the international community.

- ISRO, through its unprecedented plans and successful efforts, has shown that India is playing its role as an important country in the space research sector, moving towards a new success at the global level under the space research programme. This is not only leading to advancement in the field of science and technology in India, but also India is committed to its presence at the global level with the highest standards in the field of space research.

PRACTICE QUESTIONS FOR PRELIMINARY EXAM :

Q.1. Consider the following statements regarding India's space research programme.

1. The Indian Space Research Organization has played an important role in the success achieved by India in its space research programmes.
2. Russia's Roscosmos is known for its space research technologies and processes.
3. The lander landing process began during IM's Odysseus journey.
4. IM launched its Odysseus lander to the Moon as part of NASA's Commercial Lunar Payload Services (CLPS) program.

Which of the above statement / statements is/ are correct ?

(A) Only 1 and 4
(B) Only 2 and 3
(C) None of these.
(D) All of these.

Answer – (D)

PRACTICE QUESTIONS FOR THE MAIN EXAM :

Q.1. Highlighting the major challenges coming in the way of India's National Space Research Programme, also discuss in detail the benefits to various sectors of India under India's National Space Research Programme.

Akhilesh Kumar Shrivastava