

Finding the weight of antimatter

LOOKING FOR SOMETHING YOU CAN SEE ONLY WHEN IT'S GONE CAN TAKE A LONG TIME, WRITES S ANANTHANARAYANAN

Star Trek and Dan Brown's *Angels and Demons* have brought the word *antimatter* into everyday vocabulary. Stated simply, it is a kind of matter that annihilates, or disappears into a flash of energy as soon as it contacts ordinary matter. How, then, can we, who live in an ordinary world, ever learn anything about this kind of stuff? Is it for real?

While all matter is made up, ultimately, of combinations of just three elementary particles, the electron, the proton and the neutron, a class of antiparticles, the positron, the antiproton and the antineutron and also antiparticles of other fundamental particles found in nuclear reactions has been both predicted in theory and detected in the lab, and in cosmic rays. The antiparticle of a particle is exactly like the mother particle, except

Israel, report in the journal *Nature* a further confirmation that atoms of antihydrogen are electrically neutral, just like ordinary hydrogen.

Significance

Now why is this significant and why is it important? It is significant because work of just any kind with antimatter presents problems that do not exist with ordinary matter, the main problem being that antimatter is shortlived and rarely stays around in quantity. For all this, positrons and antiprotons, which are charged antiparticles, can be confined with the help of electric and magnetic fields and studied. Their masses and charges have, thus, been estimated with very high accuracy as being equal to those of electrons and protons. And as the charge on the electron or proton is



The ALPHA facility at CERN, Geneva.

trically neutral antihydrogen atom. Atoms that are not moving too fast can, thus, be confined within a ring of a stronger magnetic field, like a golf ball in a depression. But the trap is not a strong one and it is only a single anti-atom that is generally trapped. And even this atom can be detected only when it gets out of the trap and annihilates.

The best test of neutrality so far was of 2014, where antihydrogen atoms were created and confined within the trap in the ALPHA facility at CERN, near Geneva, and subjected to electric fields as they escaped to see if they deflected. The results, which were published in *Nature Communications*, were that the atoms were neutral to the eighth decimal place, which was a great advance over the previous limit of 1997.

The current advance, whose result is a 20-fold improvement, uses a different method — not of deflecting emerging atoms but testing if electric fields are able to knock atoms out of the weak magnetic trap. Comparatively slow-moving antihydrogen atoms were trapped in a shallow magnetic depression and then subjected to pulses of electric fields. In case the atoms had any electric charge, it was worked out they would gain energy and escape the trap. The experiment was then to apply the field for some time and then switch off the trap to see if any anti-atoms were left!

Importance

The fact that antihydrogen is found to be neutral does not come as any surprise, as all the theory and this is exceedingly successful theory says that this is the way it should be. In fact, finding anything else would be

not just astonishing but would also upset our entire understanding of physics and the nature of things. The reason there is interest in being sure of the charge neutrality of antihydrogen is to eliminate uncertainty in experiments in another area of interest — to test the gravitational properties of antimatter.

For all the success of quantum physics and the General Theory of Relativity, the fact is that there is no bridge between the two areas of study and there are still gaping holes in our understanding of the universe. On the one hand it is not clear why the universe is all ordinary matter and no antimatter. In the field of cosmology, there is no proven mechanism that leads to the expansion of the universe and also the way galaxies are seen to rotate. Unlike the solar system, where the outer planets go round slower than the inner planets, in the case of a galaxy the outermost regions go round much faster than expected. The only way to explain this seems to be by proposing some invisible matter as pervading the galaxy, to show itself only through gravity.

Another difficulty is with the Big Bang Theory of the origin of the universe — the theory says there should be a difference in the level of leftover radiation as seen in different parts of the universe. But what is observed is that the radiation is uniform over distances so large that there could have been no communication from opposite ends, within the known age of the universe. How this is so can be answered only by proposing very fast expansion during the first split seconds, so that places that were once in contact have now been flung so far apart.

Repulsive gravity

Finding devices to fix these deficiencies in the current theory calls for setting the universe free to expand, because of the presence of matter whose gravitational interaction would be repulsive, in place of being attractive. If antimatter were this kind of entity the fact would pave the way to much progress in developing a theory of the nature and origin of the universe. The General Theory of Relativity itself would need refinement but finding candidate samples of dark matter or energy would be an advance indeed.

The force of gravity, however, is so weak that only the presence of a six million billion billion-kilogram earth below us that has made it possible for us to be intuitively aware of gravity. While the measurement of gravitational forces between positrons or antiprotons, whose weight is in billionths of a billionth of the billionth of a gram, is hence hard enough, the fact that these objects are affected by electric fields makes the detection of how gravity affects them simply out of question. Hence the interest in trying our luck with the antihydrogen atom, which may at least be electrically neutral.

But even with the antihydrogen atom, the force of gravity would be so weak that the slightest whisper of electrical effects would wreck the measurements. Experiments to show that the atom is electrically neutral cannot, hence, be accurate enough to push as far back as possible the presence of electric effects that could lead us astray in case we were able to measure gravitational properties of antimatter.

THE WRITER CAN BE CONTACTED AT response@simplescience.in

PLUS POINTS

Alzheimer's transmissible

The controversial theory that the "seeds" of Alzheimer's disease may have been transmitted between patients during surgical procedures involving the use of donated human tissue has been supported by the discovery of new evidence. Scientists have found a link between patients who received nerve-tissue grafts several decades ago and the presence of a protein in the brain that is normally seen in the earliest stages of Alzheimer's.

The study supports findings published last September suggesting that people who had been injected with human growth hormone when they were children were harbouring the same seeds of Alzheimer's at the time of their deaths several decades later. The latest study by scientists from the University Hospital Zurich and the Medical University of Vienna, led by Herbert Budka of the Institute of Neuropathology in Zurich was carried



"This should prompt a critical re-evaluation of the decontamination procedure for surgical instruments."

out on the stored brain samples of eight patients who had undergone tissue grafts in Austria and Switzerland but who had died from another brain ailment.

Creutzfeldt-Jakob Disease (CJD), which is now known to have been transmitted during the operation involving nerve tissue taken from human cadavers.

On 29 January, Professor John Collinge, head of neurodegenerative diseases at University College London, said the latest findings support the hypothesis that protein seeds leading to Alzheimer's disease may be transmissible from one person to another during invasive medical procedures such as tissue grafts and hormone injections. "The find is consistent with our own," he said. "The fact that this is a completely different situation that is nothing to do with growth hormone or growth deficiency, but in people who had to have a surgical procedure and we are seeing the same thing is consistent with our hypothesis that this represents transmission of amyloid-beta seeds to these individuals."

STEVE CONNOR/THE INDEPENDENT

Mosquito protection

The release of Genetically Modified mosquitoes whose offspring die before they become mature adults has slashed their numbers in a Brazilian state troubled by Zika fever. Several million "friendly *Aedes aegypti*"



mosquitoes were released in Piracicaba, in Sao Paulo state, in April 2015. By the end of the year, their numbers in the area had plummeted by 82 per cent, according to Oxitec, the company that developed the mosquito.

The firm announced this month that it would work with Piracicaba municipality to build a local production facility that will continuously rear the GM mosquito for release. This could protect up to 300,000 people — the whole city — from mosquito-borne diseases such as Zika, dengue and chikungunya, according to Oxitec chief executive officer Hadyn Parry.

SVIDEV.NET

Simulating sabotage

Would you poison a competing scientist's tea? Steal another lab's research secrets? You can, in a card game being developed by Caezar Al-Jassar and Kuly Heer: The former, a structural biologist at the MRC Laboratory of Molecular Biology; and Heer, a psychologist at the University of Hertfordshire, enjoy playing



games when they're not in the lab. Inspired by anecdotes told to them by friends and colleagues as well as stories reported in Michael Brooks's 2013 book *Free Radicals: The Secret Anarchy of Science*, the pair decided to create a game of their own while on holiday in Spain.

"Lab Wars", which is suitable for both scientists and otherwise, over-exaggerates the realities of lab life, with a focus on career-building and competition. Players adopt characters and scheme to gain academic prestige.

When Al-Jassar and Heer first demoed the game at a December tabletop gaming convention called Dragonmeet, one man returned to the "Lab Wars" booth twice — first with his son, and then with his daughter. "He wanted to show them what science was like," Al-Jassar said. "Everyone has this notion that scientists are all good people trying to do good for humanity, but there's also this very small minority (who) have a dark side and try to screw each other over."

TRACY VENCE/THE SCIENTIST

THE LAWS OF THERMODYNAMICS

TAPAN KUMAR MAITRA EXPLAINS THE FLOW OF ENERGY IN CELLS

All living systems require an ongoing supply of energy. Usually, energy is defined as the capacity to do work, but that turns out to be a somewhat circular explanation because work is frequently defined in terms of energy changes. A more useful definition is that energy is the ability to cause specific changes. Since life is characterised first and foremost by change, this definition underscores the total dependence of all forms of life on the continuous availability of energy.

The high level of order that exists in cells is possible only because of the availability of energy from the environment. Cells require energy to carry out various kinds of change, including synthesis, movement, concentration, charge separation, the generation of heat and bioluminescence. The energy needed for these processes comes either from the sun or from the bonds of oxidisable organic molecules such as carbohydrates, fats and proteins.

Since chemotrophs feed directly or indirectly

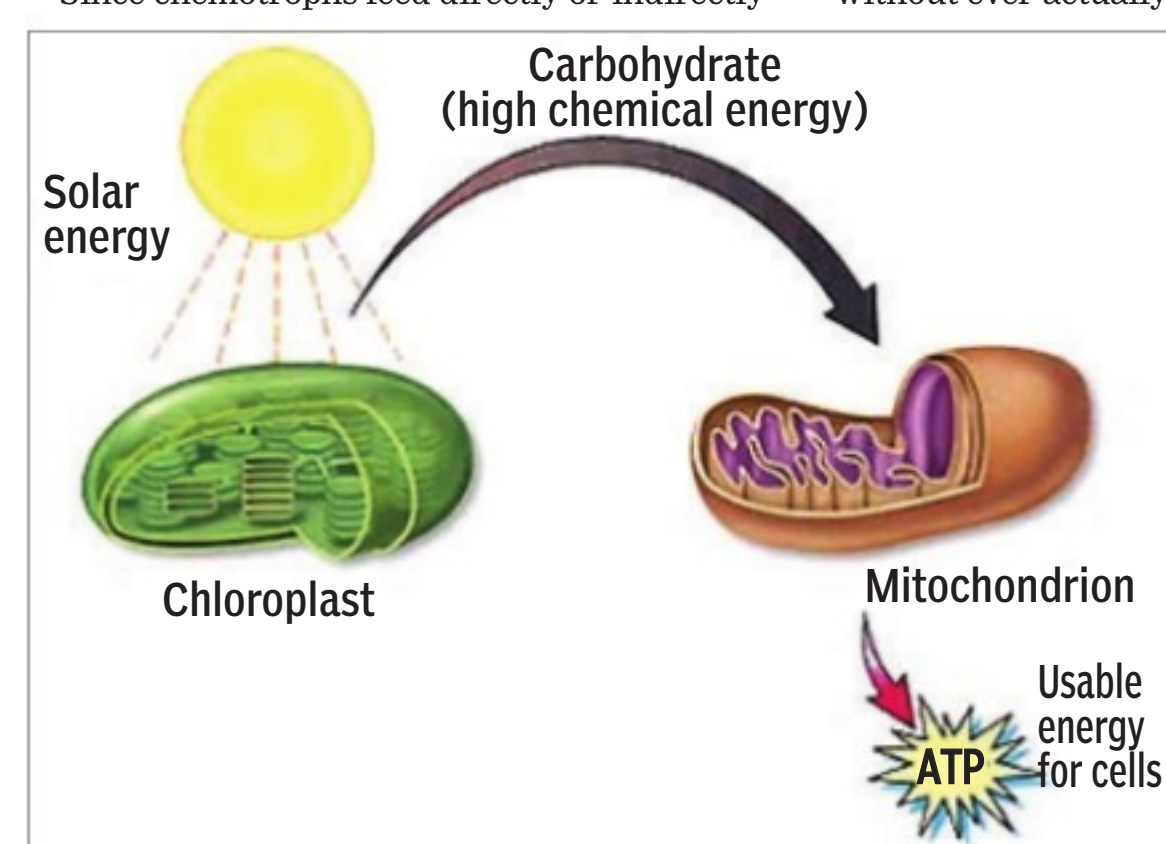
on phototrophs, there is a unidirectional flow of energy through the biosphere, with the sun as the ultimate source and entropy and heat losses as the eventual fate of all the energy that moves through living systems.

The flow of energy through cells is governed by the laws of thermodynamics. The first law specifies that energy can change form but must always be conserved. The second provides a measure of thermodynamic spontaneity, although this means only that a reaction can occur and says nothing about whether it will actually happen or at what rate. Spontaneous processes are always accompanied by an increase in the entropy of the universe and by a decrease in the free energy of the system. The latter is a far more practical indicator of spontaneity because it can be calculated readily from the equilibrium constant, the prevailing concentrations of reactants and products, and the temperature.

Cells obtain the energy they need to carry out their activities by maintaining the many reactants and products of the various reaction sequences at steady-state concentrations far from equilibrium, thereby allowing the reactions to move exergonically toward equilibrium without ever actually reaching it.

A negative DG' is a necessary prerequisite for a reaction to proceed, but it does not guarantee that the reaction will actually occur at a reasonable rate. To assess that, we must know more about the reaction than just its thermodynamic status. We need to know whether an appropriate catalyst is on hand and at what rate the reaction can occur in the presence of the catalyst.

THE WRITER IS ASSOCIATE PROFESSOR, HEAD, DEPARTMENT OF BOTANY, ANANDA MOHAN COLLEGE, KOLKATA, AND ALSO FELLOW, BOTANICAL SOCIETY OF BENGAL, AND CAN BE CONTACTED AT tapanmaitra59@yahoo.co.in



The Theia signature

UCLA SCIENTISTS FIND THAT EARTH WAS MADE UP OF TWO PLANETS AFTER A 'VIOLENT COLLISION' THAT ALSO CREATED THE MOON. KAYLEIGH LEWIS REPORTS

A "violent, head-on collision" created earth as we know it, according to new ground-breaking research. A planetary embryo called Theia, thought to be around the size of Mars or our planet, collided with earth 4.5 billion years ago when it was just 100 million years old.

It was already known that Theia and earth collided, but the new evidence from the Uni-

versity of California, Los Angeles-led scientific team shows it was less of a side swipe, as previously thought, and more of a "head-on assault". The force of the impact resulted in early earth and Theia, together, to form a single planet, with a piece breaking off and entering its gravitational pull to form the moon.

Researchers studied moon rocks from three Apollo missions and compared them with volcanic rocks found in Hawaii and Arizona. To their surprise, no difference was found in the oxygen isotopes and it was established that the rocks from each shared chemical signatures.

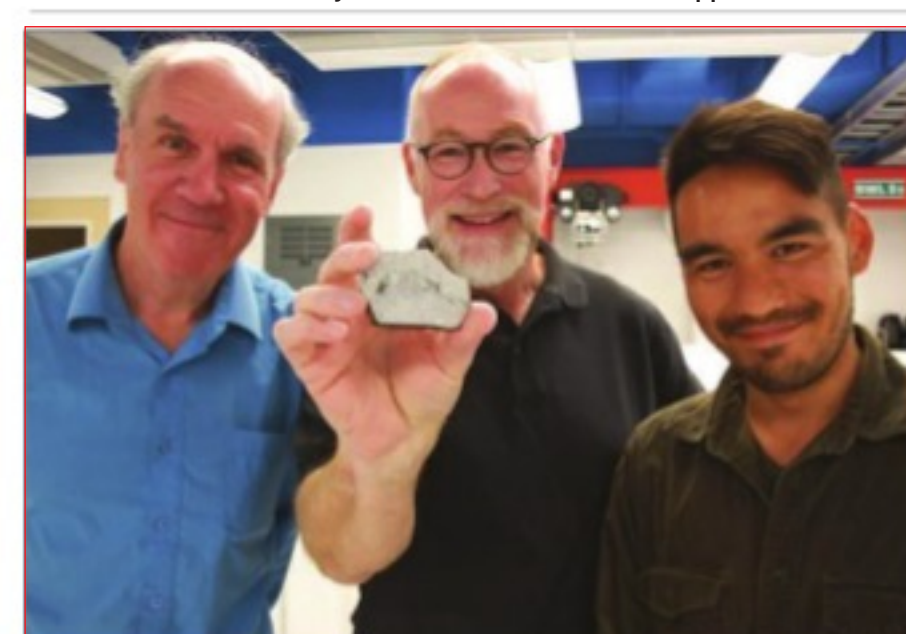
Edward Young, lead author of the new study and a UCLA professor of geochemistry and cosmochemistry, said, "We don't see any difference between the earth's and the moon's oxygen isotopes; they're indistinguishable. Theia was thoroughly mixed into both the earth and the moon, and evenly dispersed between them. This explains why we don't see a different signature of Theia in the moon versus the earth."

According to Professor Young, "Theia was growing and would likely have become a planet, had it not been destroyed in the collision."

The research, funded by the National Aeronautics and Space Administration, the Deep Carbon Observatory and a European Research Council-advanced grant (Accrete) and published in the journal *Science*, also raised questions about earth's origin. These include whether the collision would have removed any water contained by earth — before asteroids rich in water hit our planet tens of millions of years later.



The earth was 100 million years old when the collision happened.



Edward Young and colleagues.

THE INDEPENDENT