COMSATS PHYSICS TODAY

COMSATS Institute of Information Technology
Department of Physics
Defense Road, Lahore, Pakistan

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In this issue

Student's Question of the Day

What is Nuclear Fusion?

Nuclear fusion involves the bringing together of atomic nuclei. The atom's nucleus consists of protons (p) with a single positive charge and neutrons (n) of similar mass and no charge. The strong nuclear force holds these "nucleons" together against the repulsive effect of the proton's charge. As many negatively charged electrons as protons swarm around the nucleus to balance the proton charge and the mass of the atom lies almost totally in the nucleus.

The sum of the individual masses of the nucleons is greater than the mass of the whole nucleus. This is because the strong nuclear force holds the nucleons together - the combined nucleus is a lower energy state than the nucleons separately. The difference, the binding energy ($\Delta E=\Delta mc^2$), varies from one element to another. Because of the possible ways that nucleons can pack together,

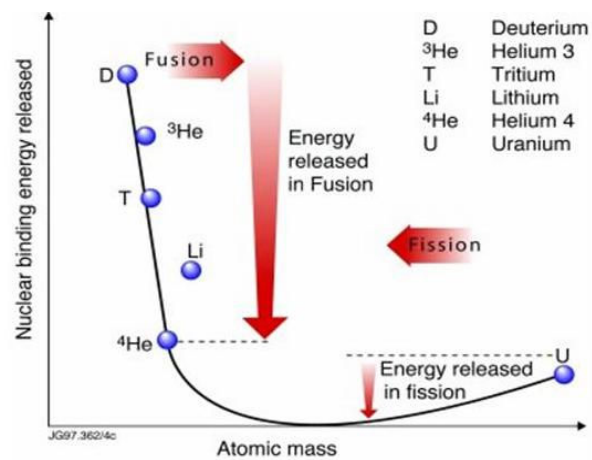

Fig 1: Comparison of Energy released in Fission and Fusion.

when two light atomic nuclei are brought together to make a heavier one, the binding energy of the combined nucleus can be more than the sum of the binding energies of the component nuclei (i.e. it is in an even lower energy state). This energy difference is released in the "fusion" process.

A similar situation occurs when heavy nuclei split. Again the binding energies of the pieces can be more than that of the whole (i.e. they are in a lower energy state), and the excess energy is released in the "fission" process. These alternatives are shown in the Figure 1.

In the Sun and stars a chain of fusion reactions (see Table 1) occur which converts hydrogen to helium. There are two chains, both having the same effective result, and which one dominates depends on the size of the star. For our Sun the proton cycle dominates.

Table1: Proton cycle and Carbon-Nitrogen-Oxygen Cycle.

Proton Cycle (most common reactions)	Carbon-Nitrogen-Oxygen Cycle
Twice: $p + p \to D + e^+ + \nu$ Twice: $p + D \to {}^3He + \gamma$ ${}^3He + {}^3He \to {}^4He + 2p$ Net result: $4p \to {}^4He + 2e^+ + 2\nu + 27\ MeV$	$p + {}^{12}C \to {}^{13}N + \gamma$ ${}^{13}N \to {}^{13}C + e^+ + \nu$ $p + {}^{13}C \to {}^{14}C + \gamma$ $p + {}^{14}C \to {}^{15}O + \gamma$ ${}^{15}O \to {}^{15}N + e^+ + \nu$ $p + {}^{15}N \to {}^{12}C + {}^4He$ Net result: $4p \to {}^4He + 2e^+ + 2\nu + 27\ MeV$

The overall reaction rate is extremely low, but it nevertheless drives the universe due to star sizes and huge masses. The particles are held together by gravity long enough for sufficient reactions to occur. For instance, in the core of the Sun the temperature is 10 - 15 million °C. Along with the extreme pressure (a quarter of a trillion atmospheres) and density (eight times that of gold), this allows matter to be converted into large amounts of energy.

To make fusion on a smaller scale on earth, more probable reactions have to be used. A figure of merit for a reaction is the "reactivity" - the product of the probability of reaction and the energy delivered per reaction as shown in figure 2.

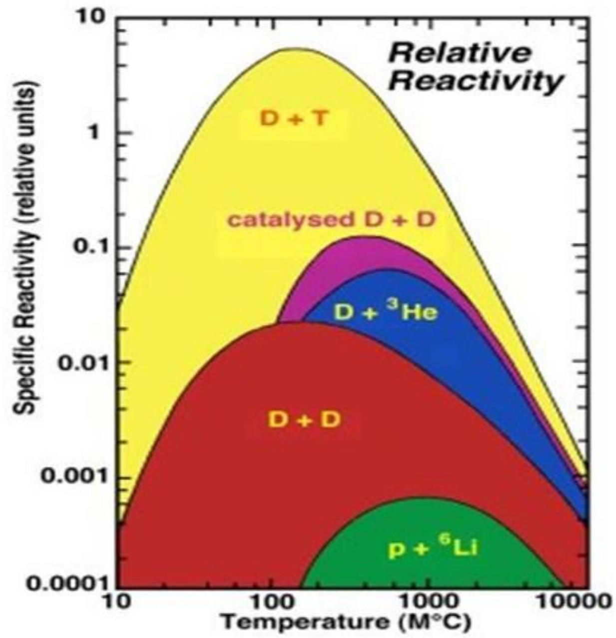

Fig 2: "Reactivity" - the product of the probability of reaction and the energy delivered per reaction.

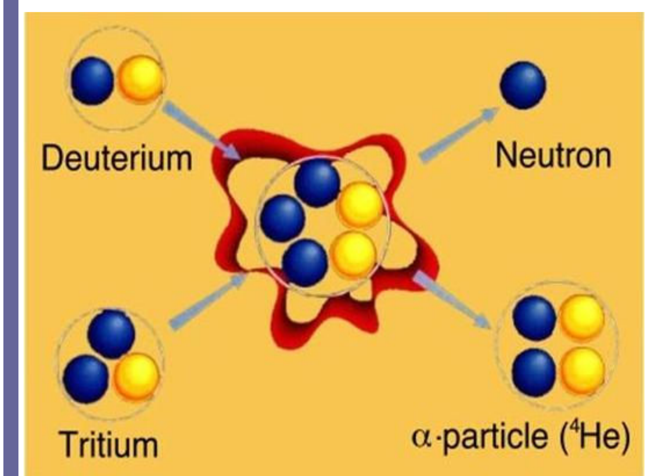

Fig. 3: The fusion reaction between two "isotopes" of hydrogen, deuterium (D) and tritium (T).

In Figure 3 (for a given confinement capability) shows, the fusion reaction between two "isotopes" of hydrogen, deuterium (D) and tritium (T), has maximum reactivity at around 100 million °C (isotopes have the same number of protons, but a different number of neutrons).The next most reactive is D+D, about 40 times smaller, and

$D+^3He$, an isotope of helium, about 85 times smaller. The D+D reactivity value includes "side reactions" between D and the D+D reaction products, namely T and ^3He.

For comparison, the reactivity of stellar reactions is 3×10^{-25} smaller than that for D+T. This large difference allows fusion power to be a possibility on human scales, but the removal of the large mass which allows gravitational confinement to work so well in stars means that different confinement schemes have to be exploited, and these have different conditions for their success.

Dr. Muhammad Asif

(Assistant Professor, Physics, CIIT Lahore)

New Research

A search group in USA has recently designed absorbing left-handed materials having nearly unity absorbance. The design uses the exotic behavior of left- handed elements that individually absorb completely the electric and magnetic field component of the electromagnetic wave impinging on it.

Physical Review Letter 100,207402 (2008)

Not wonder, this is Physics

The energy of empty space is called "zero-point" energy. Its density is same throughout the universe. As the universe expands and space grows larger, the amount of "zero-point" energy also grows ever larger. Hence this "zero-point" energy is being created by the universe constantly thus violating the conservation of energy. So zero-point" energy is contributing to the continuing expansion of the universe

News Bulletin

1. Dr. Samar Mubarak Mand, renowned scientist and member Pakistan Planning Commission visited CIIT, Lahore campus on January 10, 2009. During the visit to Physics Department, Dr. Samar Mubarak Mand appreciated the role of physicists in the scientific advancement of Pakistan, and emphasized on the conceptual learning and active involvement of students in the research activities.
2. Dr. Shabana Nisar of Syracuse University USA delivered a talk titled, “The Subatomic Cosmos and the Tools of Discovery” on January 19, 2009, at 12.10 P.M, in the seminar room of Block A.
3. Dr. Arshad Saleem Bhatti Chairman Department of Physics CIIT, Islamabad delivered a talk titled, “Bio-Sensors: New Avenues for Physicist and Engineers” on February 12, 2009, at 2.00 P.M, in the seminar room of Block A
4. Prof. Dr. Mirko Cvjeticanin, Director Middle East PHYWE had a wonderful interactive session with the faculty and students of CIIT, Lahore on February 24, 2009, at 11.00 A.M, in the seminar room of Block A. The main focus

of the talk was that why we need natural sciences more than ever? Dr. Mirko pointed out that we need the knowledge of Biology, Chemistry and Physics to support all the advancements in the area of science and technology such as Oil and gas, Energy, Soft ware, Entertainment, Pharmaceutical, Textile, Telecom, Agriculture, Material Coating, Chemical Industry, Metal Forging etc

5. A research paper by Dr. Muhammad Asif titled**,** “Relationship between current density and mass density for ohmic tokamak plasmas” has been published in “International Journal of Modern Physics B”**,** 22 (2008) 5329.

Photo Gallery

Some of glimpses of the great moments of the visit of Dr. Samar Mubarak Mand to the Physics Department and Seminars held in the Physics Department are posted below.

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- Arrangement of educational trips
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