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Hydrogen bomb in miniature

Rusi Taleyarkhan, researcher at Purdue University, and his colleagues have created thermonuclear fusion right in the laboratory. S.Ananthanarayanan looks into what this means.

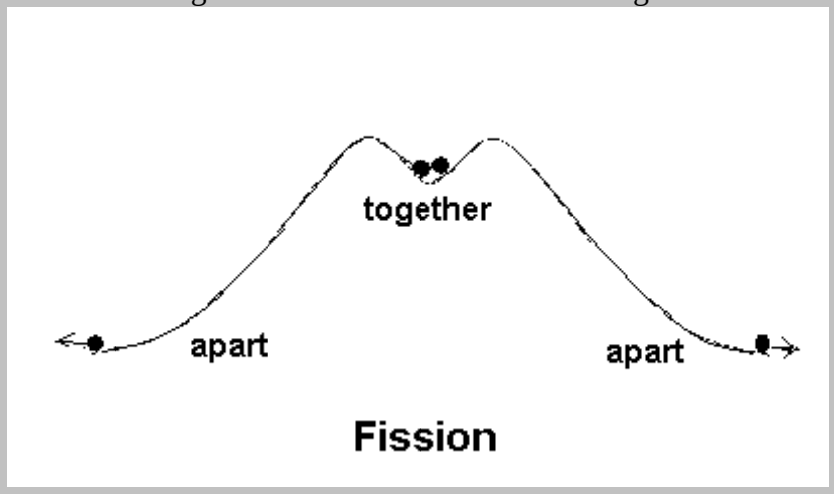
Sources of energy

Nature likes to get to the lowest energy state she can reach. Carbon, in coal, does it by combining with oxygen, when it burns. Going to a lower energy state means giving up the extra energy, which is the heat when we burn coal. A similar thing happens with hydroelectricity. Rivers flow from higher ground down to the sea. The energy they lose shows up as the speed of flowing water, which we can tap and generate power.

Nuclear Power

The simplest of atoms, the hydrogen atom, has a single, positively charged particle, the proton, in its center. This is a pretty low energy state. But the nuclei of very heavy atoms have hundreds of particles, protons and neutrons, and it takes energy to bring them close together. Except that when they are really close together, nuclear particles start *attracting*. If just this low, attracting energy were overcome, the particles would spring apart, and release some of the energy used for bringing them together.

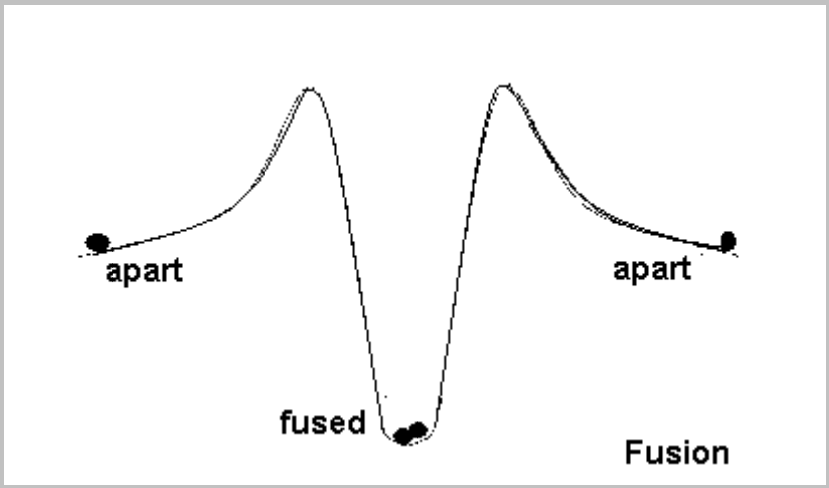
It is something like a golf ball that has been carried to the top of a hill. It could release all that energy by rolling down. But if the ball were in a golf hole at the top of the hill, then it would need to be nudged out of the hole before it could get started!



It the nuclear power plant, heavy atomic nuclei are allowed to split into simpler nuclei, which need less energy to hold them together. This gives off heat, which is used to generate electricity. But it also gives off some ‘extra’ nuclear particles that do not match the composition of the simpler nuclei produced. The simpler nuclei are also only slightly better off and they also decay, to emit nuclear particles for centuries after they are formed and so on. Well, this is a problem with nuclear power, this ‘radioactive waste’, which is dangerous to keep or to throw away!

Nuclear Fusion

Just like heavy nuclei have higher energies than when they are split, some nuclei, like the helium nucleus (which has only 4 particles), have far less energy than even their component parts. This is like the golf hole on top of the hill being so deep that its bottom is well below the fairway! This means just forming such a nucleus from its components, which is called nuclear *fusion*, would release huge energy. Furthermore, apart from some neutrons only at the moment of *fusion*, there is no radioactive waste!



There is also a form of hydrogen whose nucleus has not just one proton, but also a neutron. If two such nuclei are made to *fuse*, to form helium, then all that energy would be released. And there are huge quantities of 'heavy hydrogen in the sea!

The problem is that bringing these 2 nuclei together, which is to say, getting the golf ball to the top of the hill, takes tremendous energy. Doing this practically has been an elusive goal and the only instances are with help of an atom bomb, which is a case of *nuclear fission* proceeding unchecked. The sun and stars get their energy from nuclear fusion reactions, sustained by the energy of the reactions themselves.

Fusion in the lab

What Rusi Taleyarkhan and Co have done is to create local instances of genuine nuclear fusion with simple apparatus, right in the laboratory. This breakthrough may lead to better methods, and then to using nuclear fusion for power generation, or at least as a source of neutrons, which is a useful thing too.

The researchers used a phenomenon of *Sonoluminescence*, an effect where high frequency sound makes tiny bubbles in a liquid expand to hundreds of times their volume. When these bubbles collapse, they get hundreds of times smaller than where they started, and this raises them to tremendous temperatures. At these temperatures, which last a tiny fraction of a second, the bubble gives off flashes of light, even in the ultra violet!

Taleyarkhan *et al* used this method with the substance acetone, where the hydrogen atoms were of the heavy hydrogen kind. Now, with bubbles created by firing neutrons into the liquid, the

high frequency sound was tuned to create moments with temperatures of millions of degrees. During these moments, the heavy hydrogen, or hydrogen nuclei with neutrons, *fused*, to form helium, with flashes of light and emission of neutrons.

Testing the kind of radiation and after-products has proved that this is indeed a case of nuclear fusion.