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Supernovae and the higher elements

The ‘nova’ is a new star that appears in the sky. A very bright new star is then a ‘supernova’, says S.Ananthanarayanan.

The origin of stars is in vast, light-years-spanning clouds of gas, mostly hydrogen, held together by my mutual attraction by gravity. Over aeons, the gravitational force draws the atoms of the gas closer and closer together, which results in increasing the ‘pressure’ of the gas. And like the air in a bicycle pump gets hot when it is compressed, the cloud of gas also gets hot, to millions of degrees.

Nuclear Fusion

At such temperatures, the nuclei of the hydrogen atoms can separate from the electrons and bang into each other hard enough to be able to ‘fuse’ into helium nuclei, the reaction that takes place in the hydrogen bomb, and this releases immense energy. The core of the cloud of gas is soon blazing with this nuclear fire, which causes the gas to expand. The cooling due to expansion, as well as the reducing supply of hydrogen as fuel, then lets gravity get the upper hand and the cloud begins to get compressed again.

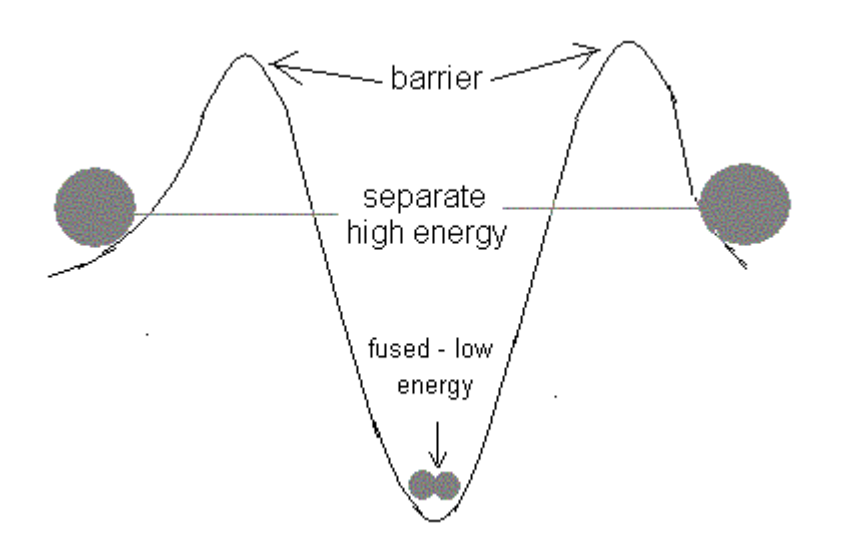
This soon re-ignites the nuclear fire, which again leads to expansion. When the hydrogen fuel is all used up, the compression is able to proceed further, to hit the energies required for helium nuclei to fuse, and form n along the way, up to the element, iron.

Things stop with iron

The way fusion works is that the combined or ‘fused’ nuclei represent a lower energy state than the separate nuclei. But there is a great barrier to be overcome before the separate nuclei can combine. This is why it takes temperatures of millions of degrees to get the ‘fusion’ going. But once started, fusion releases so much of energy that the reaction can continue by itself.

Higher and higher elements get created like this, with increasing doses of energy needed to overcome the ‘barrier’, till we reach iron. The nucleus contains 56 particles, against the single particle in the nucleus of hydrogen, from where we started.

But with iron, we reach a nucleus with a very low energy, and the combination of the iron nucleus with other particles to form elements with even more particles does not generate the energy needed to keep the reaction going. Hence, in stars formed through this process, elements higher than iron are usually not found.



Where do they come from, then?

When the nuclear fuel of a star is completely consumed, there is nothing to stop the compression due to gravity and the matter in the star gets compressed till the electrons of the atoms and very nuclei begin to be squeezed together. The positive protons and negative electrons now merge to form neutrons, again a reaction that gives off energy. This kind of thing happens at the core of the collapsing star and the resulting explosion blows off the outer parts of the star, as a ‘supernova’.

The fantastic energies released are able to support fusion and the formation of higher elements than iron, even without the help of any energy coming from the fusion reaction itself.