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【33】Stellar Explosions and the Heavy Elements

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The build-up of elements up to Fe in stars is governed by fusion reactions in stellar burning stages. The sequence of burning stages is led by the principle that ashes of the previous stage become the fuel of the following one. After the depletion of one fuel, not permitting anymore to make up for the continuing radiation losses which make stars shining, contraction sets in, leading to a temperature increase via the gain of gravitational binding energy. This continues until temperatures pass a threshold, permitting the fusion of reacting charged particles and nuclei via velocities (kinetic energies) which can overcome the repelling Coulomb forces. This stabilizes the star for the next burning stage until its fuel is also depleted. This sequence of events continues until nuclei with the highest binding energy per nucleon are reached, i.e. isotopes of Fe and Ni. What options remain to produce heavier nuclei ? Neutrons do not experience repelling Coulomb forces and neutron capture on nuclei can take place for any temperature. With sufficient amounts of neutrons available, heavy nuclei can be produced by a sequence of neutron captures and beta-decays up to the heaviest nuclei known in nature. The question is how such amounts of unstable neutrons can be provided in stellar environments. The answer is, either (a) via neutron-producing reaction in stellar evolution, or (b) in explosive events originating under conditions of highest densities, where capture of electrons (with high Fermi energies) on protons produced ample amounts of free neutrons. We will connect this to He-burning in stars, as well as neutron star mergers (only observed recently) and a rare class of supernovae.

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