Summary

Nucleosynthesis of heavy elements: the s-process

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Chapter 1.7.4: γ-ray Transistions in a Stellar Plasma

Excited states are thermally populated. Since the timescale for excitation and de-excitation considerably shorter than the stellar hydrodynamic timescales these excited levels participate in nuclear reactions and β-decay.

The number density N_μ of nuclei in excited state μ divided by the total number density of nuclei N is given by a Boltzmann distrubution:

$$P_\mu = \frac{N_\mu}{N} = \frac{g_\mu e^{-E_\mu/kT}}{\sum_\mu g_\mu e^{-E_\mu/kT}} = \frac{g_\mu e^{-E_\mu/kT}}{G} \tag{1}$$

(Assume nondegenerate plasma in thermodynamic equilibrium.) what is P? the prob that occupies the excited state μ? G is partition function

Thermally excited levels more important (higher prob.) with increasing temperature and lower excitation energy.

Chapter 1.7.5: Isomeric States and the Case of $^{26}_{13}$Al

Half lives (γ)

- Non-isomers: $< 10^{-9}$ s
- Isomeric/metastable states: isomers: sec, min, days

Caused by:

1. Large difference in spins between the states (large multipolarity, M4, E5)
2. Relatively small energy difference between levels (small γ-ray energy)

both tend to reduce the decay probability.

Ex:
$^{26}_{13}$Al have a isomeric state that would recquire M5 rediation to de-excite to the ground state. More likely the isomeric state can decay by β-emission to $^{26}_{12}$Mg. Ground state of $^{26}_{13}$Al is also β-unstable and decays to an excites state of $^{26}_{12}$Mg.

The excited state of $^{26}_{12}$Mg de-excites so quicly that if it is polulated via nuclear reactions in the interiors of stars, the emitted photons would immediately be absorbed by the surrounding matter - would never escape the stellar production site and γ never reach earth.

But if $^{26}_{13}$Al is synthesized via nuclear reactions in the stellar interior the long half-life of the ground state gives good opportunity to be expelled from the star into the interstellar medium before decaying to the excited state of $^{26}_{12}$Mg. Then we would be able to see the decay og $^{26}_{12}$Mg on earth.

We have observed the γ-lines from $^{26}_{12}$Mg $\Rightarrow$ nucleosynthesis is currently active (since the timescale ogf $^{26}_{13}$Al half-life is shorter than galactic chemical evolution $\approx 10^10$ y.

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Chapter 1.8

Chapter 1.8.1

Chapter 1.8.2

Chapter 1.8.3

Chapter 1.8.4

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