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On Some Phenomena, where the Concept of Cluster may Have to be Involved

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Discussions are made on two phenomena, where the concept of cluster formation may have to be taken into account for more physical investigations.

1. Ratios of Proton α Branching from Highly Excited States of ^{40}Ca produced by the Decay of ^{40}Sc.

Due to a very high decay energy (Q_{EC}=14.32 MeV) of ^{40}Sc to ^{40}Ca, very many excited states of ^{40}Ca which can emit both protons and α particles can be reached by β^+ decay of ^{40}Sc. Hokanen et al.[1)] measured for about 60 levels between 9.36 MeV and 12.07 MeV excitation. They found for about 20 emitting states, which are mainly 3^- states, that the ratio of reduced width, $\gamma_\alpha^2 / \gamma_p^2$ is systematically far bigger than 1, ranging from $\sim$ 7 to $\sim$ 7,000, mostly scattering around several hundred.

Why are the α widths always so much bigger than the proton widths? The question seems to be worth while to investigate. The energies of the states are already quite high. The level density, too. The spin values (3^-) are not so high. Therefore, this is the region where one uses statistical treatment without much hesitation.

One can quite simply guess that this experimented fact shows the cluster nature of the states. Then, the natural question is why we do not introduce the effect of clustering into the level density formula. In the gas kinetics it is well known that the specific heat of monoatomic gas is different from that of the diatomic gas and polyatomic gases. Therefore, now that we see a lot of evidences for cluster formation in the low energy spectra of the light nuclei, and even in the statistical state as seen in the investigation of the ^{40}Sc β^+ decay, the use of the Fermi gas level density formula for medium light to light nuclei seems to be a mere unphysical parametrization.

The ratio of γ_α^2 to γ_p^2 may not really reflect the degree of clusterization. The raw data is obtained in the form Γ_α / Γ_p. The converstion factor of Γ to γ^2 involves the barrier penetration. In the case of proton emission, as far as we take the normal statistical model it is known that the expansion of nucleus due to the heating in this energy range is not that serious. Also the change of barrier due to the deformation is again not so serious.

In the case of cluster state, however, the situation is somewhat different. The barrier penetrability goes up when the deformation grows. The defomability of clustered states are considered to be bigger. It is easy to understand the effect physically because the binding energy of par- ticles are smaller than that of proton and neutrons. The surface tension which resist against deformation goes down. One has to examine this point more quantitatively but it is guessed that the mean deformation of the cluster state becomes bigger than that of the Fermi gas nucleus at higher energies.

It looks to me necessary to investigate the cluster structure of the higher excited states. The case of the ^{40}Sc may be used as a very important test case.

2. The Equation of the States at the Point of Carbon Flush

At the end of the α burning the inside of a star suffered the lack of α particles which used to give heat through the Salpeter process. The most reactive element, then, is ^{12}C. The star again contracts raising its temperature until the ^{12}C starts to burn. Then it is believed to undergo the carbon flush. If the star is small it may totally explode and disappear (Supernova type I).

Just before this point is reached, an intriguing possibility exists. It is a possibility of a pattern formation due to the fact, that isolated ^{12}C gas may have nearly the same energy as chains of alpha particles.

Consider a ^{12}C gas. The number of bonds (in the sense of old α-particle model) is the same as the number of the particles. If we line up all the alpha particles in chains, again the number of the bond and of the α-particles is the same. The bond energy is of the order of 7 MeV.

As is well known, examples of chain formation of micro-atomic clusters (ultra fine powder) have been seen in the case of magnetic particles.

More exact calculations of the free energies of chain structures including also the possibility of finite chains and even rings and all possible shapes as function of the density and temperature would be very difficult but an interesting game.

References

1) J. Hokanen, J. Äystö, M. Kortelakti, K. Eskola, K. Vierinen and A. Hautojarvi: Nucl. Phys. A380 (1982) 410