EMISSION OF LIGHT CHARGED PARTICLES AT 0^o IN HEAVY ION - INDUCED REACTIONS

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Abstract

Spectra of light particles emitted at 0^o were measured in reactions induced by ^{18}O, ^{20}Ne, ^{22}Ne and ^{40}Ar ions on ^{48}Ti, ^{197}Au, ^{181}Ta and ^{232}Th targets. Incident energies were in the range 5-10 MeV/A. Almost all the spectra extend in energy to the vicinity of the two-body kinematic limit.

Heavy ion reactions involving light charged particle emission have recently attracted the attention of both experimenters and theoreticians. Among these reactions, the process involving the emission of energetic light charged particles is of special interest.

As shown earlier[1,2], the interaction of two complex nuclei can be accompanied by emission of a large number of α -particles whose formation cross section makes up a considerable part of the total reaction cross section. It has been observed experimentally that the yield of energetic α -particles increases significantly compared with that expected from calculations using the evaporation model of compound nucleus decay[3]. In this case most of the projectile energy is carried away by α -particles whose angular distribution is observed to be strongly forward peaked.

The α -particle energy spectra measured at an angle of 0^o in different reactions induced by the ^{22}Ne ions are presented in fig. 1. From the data obtained it follows that the α -particles having velocities above the projectile velocity are formed with a noticeable cross section. The estimate of "nuclear temperature" T_{exp} made assuming that the dependence of the cross section on the emitted particle energy E is describable by the relation $P(E) = (E-B)\exp(-E/T)$, where B is the effective barrier and T is the temperature, shows that T_{exp} is a factor of about 3 higher than the compound nucleus temperature. This difference increases with increasing projectile energy. It should be noted that almost in all cases the maximum α -particle energy is only by several MeV lower than the maximum possible energy which can be carried away by the ^4He nucleus and which is determined by conservation laws under the assumption of the two-body nature of the process. The emission of the heavier particles ($^{6,8}He$, $^{6,7,8}Li$, $^{7,9}Be$) with relatively high probability has been observed in all the reactions investigated. To study the process involving the emission of light charged particles we used targets made of various elements (^{48}Ti, ^{197}Au, ^{181}Ta, ^{232}Th) and the ^{18}O, ^{20}Ne, ^{22}Ne and ^{40}Ar ion beams with an energy of 5-10 MeV/nucl. Energy spectrum measurements were carried out at 0^o by using a magnetic spectrometer. Light particles were detected and identified by means of a semiconductor ΔE-E telescope placed in the focal plane of a magnet. The energy spectra of light charged particles for the reaction $^{232}Th+^{22}Ne$ are shown in fig. 2. These spectra have well pronounced maxima in the exit channel. It is also seen that the cross section for forming the isotopes of a given element increases as their binding energy grows. Another important peculiarity of these spectra is the fact that almost all of them reach the maximum possible energy calculated on the basis of the law of conservation of energy and under the assumption of the two-body nature of this process. Apparently an exception is the spectrum of the ^8He nuclei, which has the form of a narrow distribution with a FWHM of not more than 10 MeV. Thus, as shown earlier, in the given case of emission of energetic particles, the fast particle emitted at the initial stage of the reaction carries away practically the entire thermal energy while the residue, foremd at the following stage, with mass $(A_p + A_t - A_e)$, where A_e is the mass of the particle emitted, will possess minimum excitation energy. We shall not consider the mechanism of such a process, which needs a thorough theoretical analysis and would only like to note some aspects of using reactions of this type to produce nuclei with uncommon properties.

First, as noted above, we have shown earlier for reactions involving fast α-particles[3] that these reactions can lead to the production of nuclei with almost zero excitation energy. The cross sections of such processes, as follows from the spectra measured for non-fissioning nuclei, can amount to 10^{-31} -10^{-32} cm^2. Therefore it is evident that the reactions involving the emission of energetic charged particles, especially ^4He and ^9Be, are a promising method for synthesizing new heavy and superheavy nuclei. In certain cases the energy spectra are cut off 5-8 MeV before the kinematic limit. This difference can be determined by the residue rotational energy, which may produce a few dozens of the $\hbar$ units in the grazing collision of nuclei. This problem needs a detailed consideration too, and experiments are currently underway to measure the angular momentum of the residual nuclei after the emission of fast charged particles. The availability of rotational energy in residual nuclei can lead to another important trend -- the production of rapidly rotating "cold" nuclei. In this respect reactions involving the emission of energetic protons may prove to be the most advantageous ones. Finally, the relatively high yield of different isotopes in these reactions can lead to the formation of various neutron-rich nuclei, e.g. the ^{10}He nuclei, the problem of synthesizing which has recently been raised in nuclear physics again. Extrapolations of formation cross sections for He isotopes according to the Q_{gg}-systematics which describe well the yield of all isotopes of these reactions, give values of $10^{-33}cm^2$ for the formation of the ^{10}He nuclei in the most favorable reaction ^{48}Ti +^{22}Ne.

Thus reactions involving the emission of energetic light particles in the interaction of two complex nuclei with moderate energies constitute a new type of nuclear reactions, which, in all likelihood, reflect the cumulative effect and should be elucidated theoretically. The use of these reactions may prove efficient in synthesizing nuclei in uncommon states.

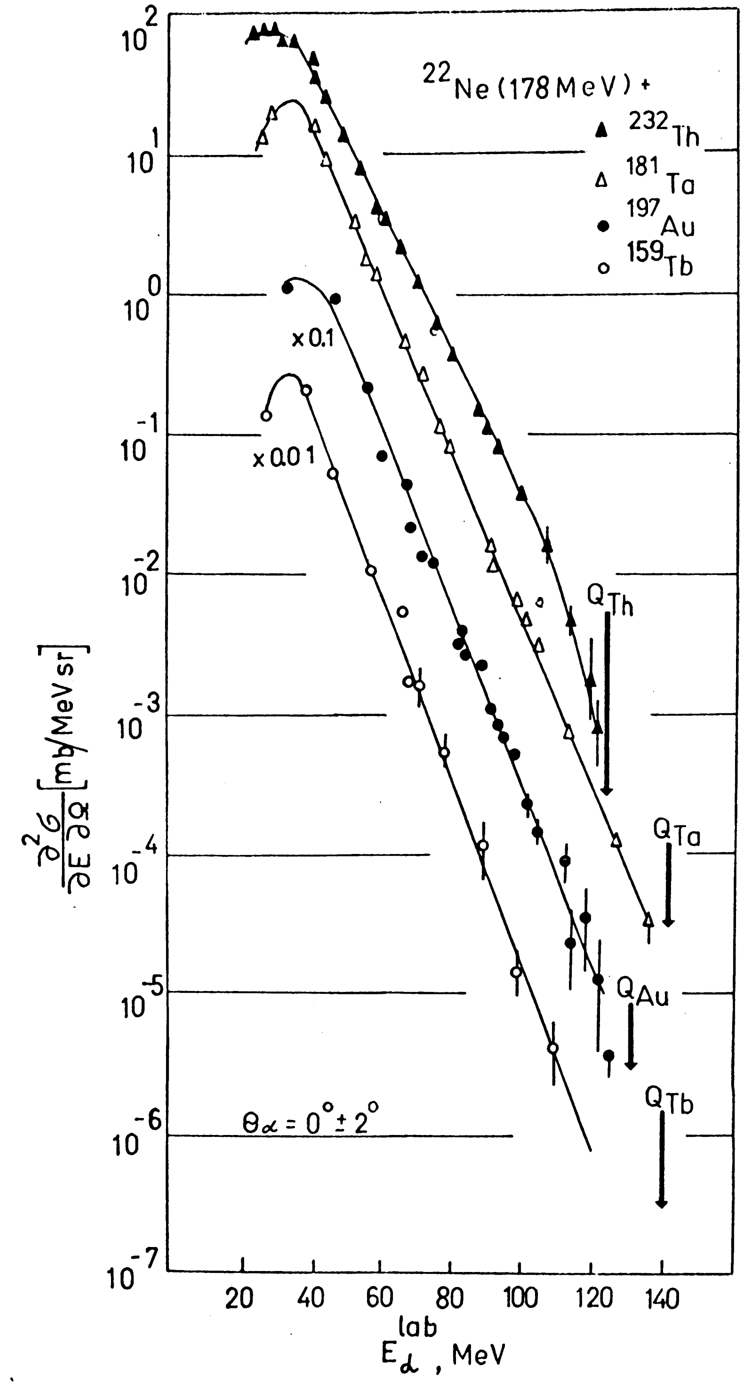

Fig. 1. Spectra of α-particles at 0^o obtained from reactions induced by ^{22}Ne (178 MeV) on different targets.

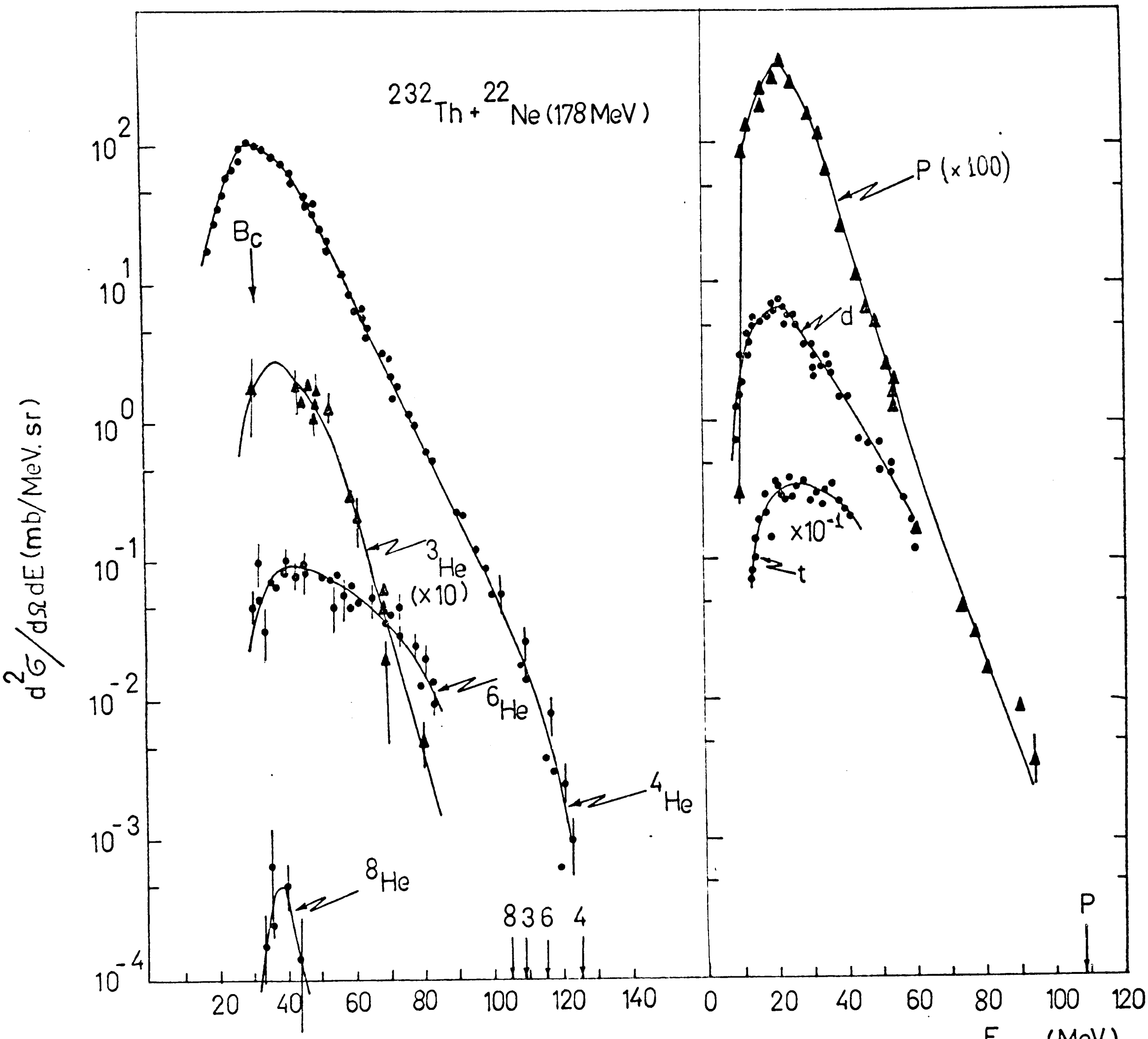

Fig. 2. Spectra of different light isotopes emitted at 0^o in the reaction ^{22}Ne(178 MeV)+^{232}Th. The arrows indicate the maximum energy allowed for these ions if the process is a two-body one. For α-particles the Coulomb barrier is also indicated by an arrow.

<u>References</u>

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2) V.V.Volkov et al., JINR E7-12411 Dubna, 1979
3) C.Borcea et al., Nucl.Phys. <u>A351</u> (1981) 312.