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ON POSSIBLE OBSERVATION OF NON-STATISTICAL COLLECTIVE MODES IN COMPOUND NUCLEUS

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Doorway-like states which consist of the collective excitation above the statistical background are assumed to be formed in (n,n')-like reactions (S. Belyaev, B. Rumyantsev. Contribution to this Conference). Here we suggest experiments in which the formation of such states with a rotational or vibrational mode seems to be very probable.

Here the heavy-ion induced single-nucleon transfer-reaction is accompanied by Coulomb excitation. The nucleon, when transfered into high orbitals, heats the nucleus which at the same time is excited into a collective state by the Coulomb field of the heavy ion. The possible show-up of this intermediate state in neutron- and γ-exit channels is discussed below.

Neutron exit channel: If the energy transfer W is fixed, it is distributed between statistical (E) and collective (ω) modes. If W is just above the neutron binding energy B_n, the excitation of the collective mode opens the neutron channel. The number of neutrons emitted per transfer is then

$$N = (\Gamma_n / \Gamma)(1 - P(\omega)) \qquad (1)$$

where $P(\omega)$ is the excitation probability of the collective mode. Eq.(1) can be checked by making use of the dependence of $P(\omega)$ on the ion scattering angles.

Gamma exit channel: If $W \lesssim B_n$, only the γ-channel is open. In the absence of collective excitations the γ-spectrum is similar to that of α (n,γ)-reaction for slow neutrons. Excitation of the collective mode results in an increase of the corresponding γ-line.

The most suitable projectile (apart from ^{9}Be) is ^{17}O due to its relatively weak odd-neutron binding-energy B_n (h.i.) and large Z. The optimal ion energy is near the Coulomb barrier E_{CB} because n - transfer as well as Coulomb-excitation probabilities are high enough and those of harmful processes (fusion reaction, excitation of the projectile) are comparatively low. The cross-section of n-transfer is known to have a maximum for Q=O. For heavy targets it is of the order of 1 mb/ster (for $E \lesssim E_{CB}$). In our case ($E^* \approx B_n$) the Q-value is less favourable, Q = B_n(h.i.). It diminishes the cross-section by a factor of 50 for ^{17}O (5-10 for ^{9}Be). The energy increase ($E > E_{CB}$) results in a rise of the cross-section for n-transfer reaction keeping the probability of Coulomb excitation on the level of tens of per cent.

The crucial assumption of the idea discussed is the long life-time of the collective state in the "heated" nucleus. The experiments proposed can provide a comparative estimate of τ and the inverse values of Γ_n and Γ_γ of the compound nucleus.

A NEW MECHANISM OF PRE-EQUILIBRIUM EMISSION

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The statistical process of compound-nucleus formation is inevitably accompanied by the rearrangement of the selfconsistent (S-C) field which may in its turn create dynamically a hole and a particle and "splash out" the latter from states in the continuum. Such a non-statistical selective population of particle states (in contrast to the model of Griffin (Phys.Rev.Lett.17(1966)478) results in correlation effects in secondary particle spectra.

We assume that the capture of a projectile (in the Mev region) results in an almost instantaneous ($\tau_0^{-1} \sim v_F/R \sim \varepsilon_F A^{-1/3}$) rise of S-C potential δU and then a gradual ($\tau^{-1} \sim \Gamma_{s.p.} \sim \varepsilon_F A^{-2/3}$) relaxation ($\varepsilon_F$, v_F are energy and velocity at the Fermi-surface). Such a variation of the S-C potential can create a particle-hole state with the energies $\omega = E_p + E_h \lesssim \tau_0^{-1} \sim \varepsilon_F A^{-1/3}$. The cross section (say, for (n,n') or (n,p) - reaction) may be written as a product of the n-capture cross section σ_c and the probability to excite a nucleon from the Fermi sea into the continuum with kinetic energy $\varepsilon = E_p - B$

$$\sigma(\varepsilon)d\varepsilon \simeq \sigma_c \sum_h \frac{K_{ph}|\langle \delta U|0\rangle|^2}{(E_p+E_h)^2+\tau^{-2}} \varphi((E_p+E_h)\tau_0)\rho(\varepsilon)d\varepsilon \qquad (1)$$

where the function $\varphi(x) \simeq 1$ for $x \lesssim 1$ and decreases sharply when $x > 1$. Although eq.(1) is valid when the particle-hole dynamical mode exhausts only a small fraction of the total excitation energy we shall use it for the general case as an order of magnitude estimate. For this purpose we put $\delta U \sim U/A \sim \varepsilon_F/A$; $E_p + E_h \sim \varepsilon_F A^{-1/3}$; $\sum \longrightarrow * A^{1/3}$; and obtain for the ratio of the (n,n') - reaction cross sections through our ("splash out") and the usual (evaporation) mechanism

$$\frac{\sigma_{spl}}{\sigma_{evap}} \simeq (T/\varepsilon_F)^{3/2}(T/\varepsilon)^{1/2}\exp(\varepsilon/T) \qquad (2)$$

Which gives tens of per cent for $\varepsilon/T \sim 3 \div 5$ (T is the temperature of the compound nucleus).

Specific features of the emission through S-C potential distortion are:

(1) Forward-backward symmetrical anisotropy, caused by angular asymmetry of S-C potential distortion δU. The Q'Q-forces, in particular, pick out the quadrupole harmonic. Asymmetry in the angular distribution may occur only due to the interference of even and odd harmonics of δU.

(2) Specific scaling - the same distortion of S-C potential (irrespective of the projectile etc.) results in the same yield.

(3) Analogous distortion of the pairing potential may result in the "splash out" of two neutrons correlated with each other (equal energies and opposite directions preferred) but not with the projectile.

When the particle in the particle-hole mode is in a bound state we get a compound nucleus in a semi-equilibrium (doorway) state with particle-hole (or collective) excitation above statistical background. Such states with long enough lifetime may show up the experiment (S.T. Belyaev at all. Contribution to this Conference).