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REGULARITIES OF DEEP INELASTIC TRANSFER REACTIONS WITH THE ^{40}Ar PROJECTILE

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From the deep inelastic transfer reaction (DITR) cross section measurements it is known that the so-called Q_{gg} systematics are satisfied[1]. An explanation of this dependence was given in terms of quasistatistical equilibrium established in the Double Nuclear System (DNS)[2,3].

For the ^{40}Ar projectile, this law was experimentally found to hold in the reactions ^{107,109}Ag+ ^{40}Ar (285 MeV), θ_L =40° (ref.[4]) and ^{197}Au+^{40}Ar (292 MeV), θ_L =40 (ref.[5]), where the differential cross sections of light isotopes were measured for Z ranging from 2 to 18. A further example of the validity of the Q_{gg} systematics with the ^{40}Ar projectile is shown in fig. 1, for the ^{58}Ni + ^{40}Ar (280 MeV) DITR integrated cross sections reported by a French group[6]. The temperature parameter of each elemental line for $5 \leq Z \leq 10$ is T=2.3 MeV. For $Z > 11$, the systematics are apparently violated due to the secondary evaporation processes, whose quantitative evaluation can be done according to the technique described in refs.[4,7].

The Q_{gg} systematics were supposed to be, however, valid for the primary reaction products. Results were then obtained which are represented by straight lines in the region of

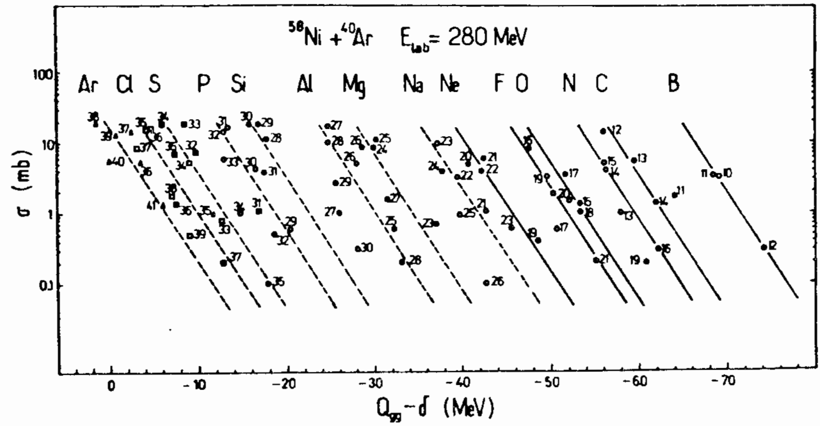

Fig.1. Q_{gg} - systematics for ^{58}Ni + ^{40}Ar (280 MeV) integral cross sections. Experimental data are those reported in[6].

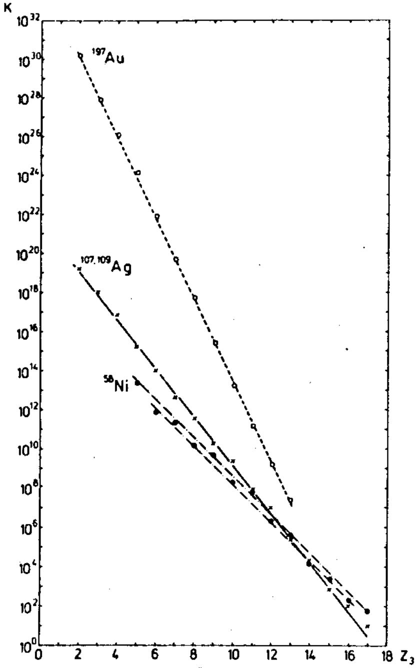

Fig.2. Dependence of the K factors versus Z_3 for Ar projectile and various targets.

$11 \le Z \le 18$ of fig. 1. In the Q_{gg} systematics:

$$\sigma = K \exp[(Q_{gg} - \delta)/T], \qquad (1)$$

where $Q_{gg} = (M_1 + M_2) - (M_3 + M_4)$, δ is the non-pairing energy of transferred nucleons, $\delta = \delta_p + \delta_n$, T denotes the temperature parameter of the DNS, and K is the factor.

For the three above-mentioned sets of experimental data with ^{40}Ar projectile, the factor K was evaluated from eq. (1) and the results were plotted on logarithmic scale versus Z_3 (fig. 2). For a given reaction, the factors are found to lie with surprising accuracy over as many as 22 orders of magnitude, on a straight line, whose characteristics are functions of the target. Moreover, a clear parity effect is observed in the case of Ni. This effect is negligibly small in the case of Ag and is absent for Au.

Therefore we can write the empirical dependence:

$$K(Z_3) = \exp(aZ_3 + b), \qquad (2)$$

where a and b are constants for a given reaction. The largest relative deviations of the original experimental values from those obtained with eq. (2) are smaller than a factor of two. This allows us to use the obtained values of the parameters a and b for cross sections evalution for the isotopes produced in DITR, other than those already measured. In the table the cross section values, which were calculated using eqs. (1) and (2) for Z =0, Z =1 (p, d, t) and Z=2 (^{3}He, ^{4}He, ^{6}He), are reported. These are in good agreement with experimental data /5,8/. The values extrapolated to Z =0 are thought to represent the cross section for the compound nucleus which is formed at the last stage of the deep inelastic transfer reactions in the Double Nuclear System.

Other systematics, which reveal the existence of a striking effect, are obtained by plotting the functional dependence

Table

Cross sections corresponding to Z =0, Z =1, and Z =2 for various reactions with the same projectile ^{40}Ar ($E_L \simeq$ 300 MeV). Data have been calculated using eqs. (1) and (2), with values of the parameters obtained from the experimental data fits.

Target	Z = 0	Z = 1			Z = 2		
		1	2	3	3	4	6
^{58}Ni σ (mb)	2200	3800	260	59	37	5400	0.6
^{nat}Ag $d\sigma/d\Omega$ (mb/sr)	196	235	28	9	1	211	0.2
^{197}Au $d\sigma/d\Omega$ (mb/sr)	152	138	35	3	0.1	50	0.14

$\sigma(T_3, Z_3)$ - isospin Z-systematics - and the functional dependence $\sigma(T_3, Q_{gg} - \delta)$ - isospin Q_{gg}-systematics - where $T_3 = (N_3 - Z_3)/2$ is the third projection of the isospin of the light nucleus. The $\sigma(T_3, Z_3)$ and $\sigma(T_3, Q_{gg} - \delta)$ plots for differential cross sections of the reaction ^{107,109}Ag+^{40}Ar are given in figs. 3a and 3b respectively and for integral cross sections of ^{58}Ni+^{40}Ar in figs. 4a and 4b.

The quite large cross sections observed for He isotopes in fig. 3 are consequences of the structure effects of the projectile and are similar to the relatively large cross sections of light nuclei such as ^{16}O, ^{15}N, ^{12}C and ^{8}Be /4/ .

The data shown in figures 3 and 4 exhibit the following features:

- At constant isospin values, the linear dependence is roughly satisfied (gross structure). The lines shown in the figures were obtained via least-squares fit procedures.
- At integer T_3 a regular fine structure is clearly superimposed on the gross structure, with maximal amplitudes for T_3=0 and a monotonic decrease in amplitude towards increasing T_3 values.
- In isospin Z-systematics, the slopes of the gross structures monotonically increase with T_3, while in the isospin Q_{gg}-systematics the reverse situation occurs.

The variation with T_3 of the slope of the lines which characterize the gross structure in the isospin Z-systematics

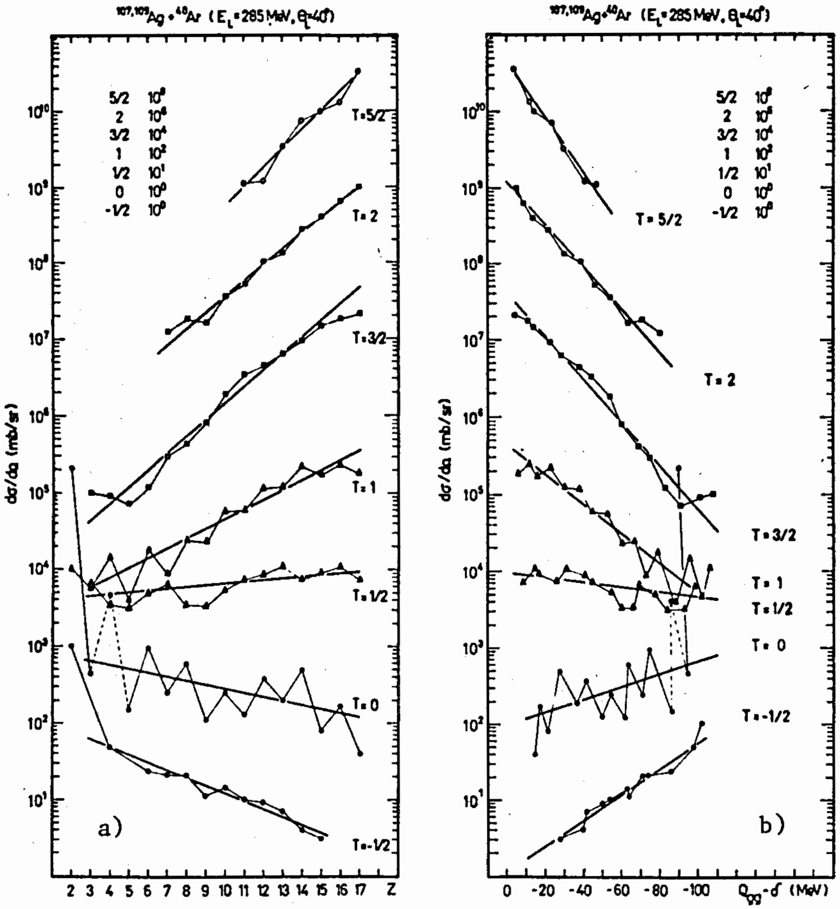

Fig.3. Isospin systematics for $^{nat}Ag+^{40}Ar$. The multiplying factors are indicated in the upper left corners of the figures. a) Isospin Z - systematics; b) Isospin Q_{gg}-systematics.

is shown in fig. 5. Accurate enough linear dependences are obtained whose slopes are independent of the target used in DITR. This suggests that the isospin systematics are mainly determined by the structure of the projectile.

As in eq. (1), two further relations can be written which yield cross sections in terms of the isospin T_3 in the isospin Z and Q_{gg} -systematics, respectively:

$$\sigma \sim \exp[(mT_3 + n)Z_3], \qquad (3)$$

$$\sigma \sim \exp[(pT_3 + q)(Q_{gg} - \delta)], \qquad (4)$$

where m,n,p and q are constants for a given reaction.

A surprising result is shown in fig. 6, where all the above mentioned features of the isospin Z-systematics prove to be valid at high energies for $^{12}C+^{40}Ar$ (213 MeV/A). The data presented on this figure are taken from ref./9/. As in fig. 5, the linear variation with T_3 of the slopes of the gross structures obtained in the isospin Z-systematics of fig. 6, with the same slope m, is found to be valid (fig. 7).

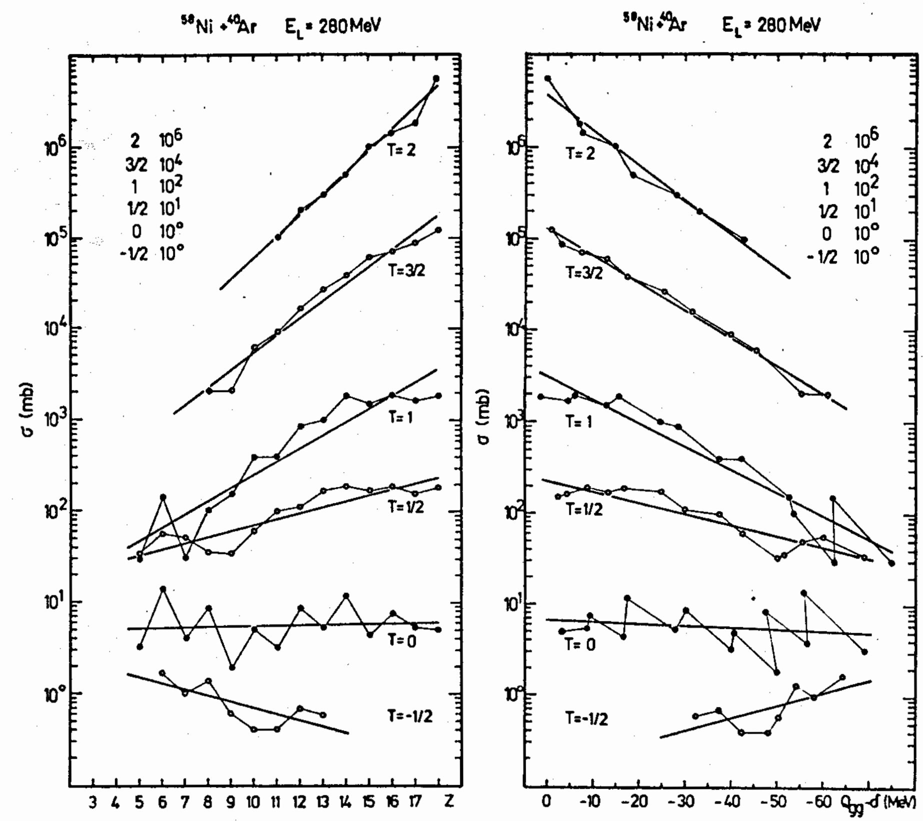

Fig.4. Same as fig. 3, for $^{58}Ni + ^{40}Ar$.

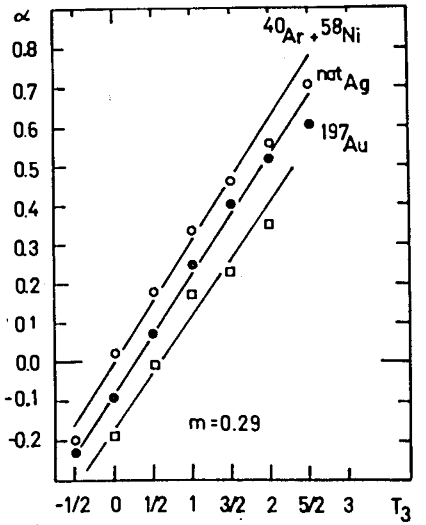

Fig.5. The functional dependence of the slope of the linear gross structure versus T_3 for the three reactions discussed in text. The value is the slope of the lines.

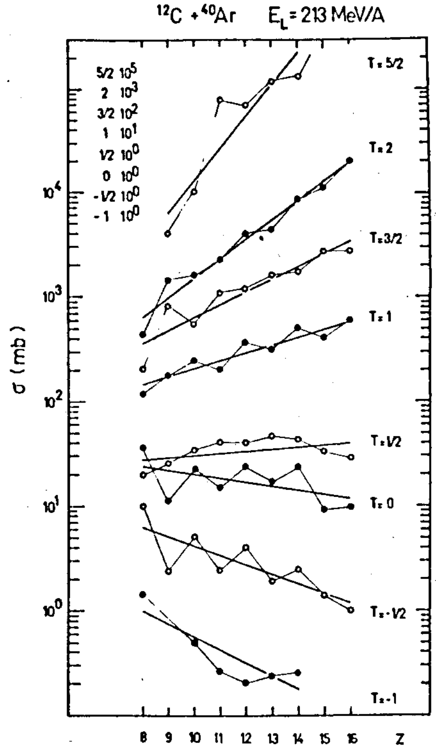

Fig.6. Same as fig.3a, for $^{12}C + ^{40}Ar$ (213 MeV/A).

A theoretical study of the elastic scattering of heavy ions shows that the biparticle isospin-isospin term included in the interaction potential brings nothing more than negligibly small effects. When investigating DITR, however, the situation is radically different. The present data suggest that an isospin term should be significant in the potential which describes deep inelastics processes.

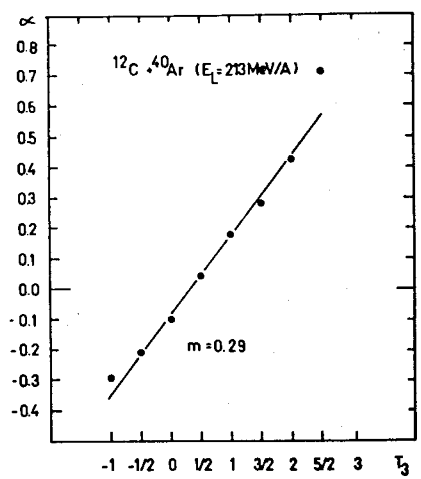

Fig.7. Same as fig. 5, for ^{12}C + ^{40}Ar.

A similar study has been done by V.V.Avdeichikov in ref.[11], where a phenomenological analysis of the fragmentation cross section was presented. Expression (2) in ref.[11] contains the T_3 factor proposed to describe the fragment yield. Our dependences on T_3 explicitly presented in relations (3) and (4) deduced from experimental data are different.

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