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The work is submitted to the International Scientific Conference «Implementation of integrated model of educational institutions, implements educational programs different levels of education», Republic of Singapore, December, 10-17, 2013, came to the editorial office on 18.11.2013.

ONE-NUCLEON SPECTROSCOPY OF NUCLEI WITH A = 7

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One-nucleon spectroscopic *S*-factors and types of nuclei clusterization are discussed. There is carried out a comparative analysis of the spectroscopic proton S_p- and neutron S_n-factors for transition to both the ground and the excited states of the corresponding nuclei-residues ^{6}Li-^{6}He calculated within the two-body α*t*-model of ^{7}Li nucleus with new accurate results of theoretical calculations of the spectroscopic *S*-factors for $^7\text{Li} \rightarrow {}^6\text{He} + p$ channel obtained within the shell model and also by using of variation methods of Monte-Carlo. For construction of the virtual tritium cluster ^{3}H the following models of wave functions have been used: the translational-invariant shell model which corresponds to the symmetric wave function of the relative coordinates, which has a free variable oscillatory parameter r_0, and also «realistic» wave functions which are variation functions the parameters of which are chosen to reproduce the observable form-factor of tritium nucleus ^{3}H.

The important problem in the theoretical analysis of the nuclear-physical processes is the finding of the correct form of the wave functions of the nuclei participating in the interaction being considered. Since it is possible only in the framework of the definite models, then it is preferably to use the model representations reproducing as much as possible wide spectroscopic information about nuclei. Now the many-particle shell model (MSM) is the more complete and developed one for the light nuclei [1]. The experience of MSM use showed that its application was justified when considering the processes covering the interior of nuclei. At investigating of the peripheral processes, particularly, the reactions of nuclei photodisintegration, the disadvantages of the MSM use appear to be obvious and they are connected with an incorrect asymptotics of the wave functions, i.e. with too fast decrease at large distances.

When considering the peripheral processes the more acceptable are the potential cluster models (PCM), the wave functions of which have a correct asymptotics [2]. In addition, exactly the peripheral processes dominate in the range of low and superlow energies of interaction, which are paid still an increasing attention now, for example, the problem of nucleosynthesis of neutron-deficient *p*-nuclei. In a whole, a study of the structure of the light nuclei including low-energetic near-threshold photonucleon (γ, *N*) reactions has a connection to the nuclear astrophysics, and also to the applied thermonuclear physics.

One-nucleon characteristics of nuclei such as the spectroscopic *S*-factors, reduced widths θ^2, partial widths Γ, and impulse distribution of nucleons are the important element for investigation of reactions, where one nucleon's separation or joining to target-nucleus occurs. Such ones are the direct nuclear reactions of stripping and pickup, the reactions of elastic and inelastic scattering of nucleons on the nuclei, the resonance reactions with an excitation of the high levels of the compound nucleus and with their consequent decay by one-nucleon channel.

Nowadays for the nuclei of 1*p*-shell the various experimental data are accumulated. The study of the one-nucleon characteristics in the light nuclei was began with reactions of deuteron stripping and nucleon pickup as (*d, p*), (*d, n*), (*p, d*). The mechanism of these reactions is well established: this is either the nucleon transfer from the slightly bound deuteron to the target-nucleus, i.e. stripping reaction, or a pickup of the proton or neutron by the projectile nucleon from the target-nucleus, for example (*p, d*) and (*n, d*). It was further shown that the similar simple polar mechanism is the dominant on a series of other direct processes as (^{3}He, α), (*d, t*), (α, ^{3}He), (*t, d*) and etc. The fundamental structural characteristic in all these reactions is the spectroscopic *S*-factor establishing a connection between different states of the neighboring nuclei. The similar structural information can be obtained in the reactions of quasi-elastic knockout of nucleons by the projectile protons such as (*p, 2p*) and (*p, pn*), and also by electrons (*e*, *e'p*). The experiments on quasi-elastic knockout of nucleons from nucleus by electrons, carried out on the Holland accelerator NIKHEV last years, are characterized with high energetic resolution ($E \approx 0{,}1$ MeV), that allows to study transitions to the separate levels of the nuclei-residues (see, for example, review [3] and the literature cited in this ref.).

During the 80–90th a group of theorists created the dynamic model of the light nuclei [4–8], which the first time allowed to describe the structure of ^{6,7}Li, ^{6}He, ^{7,9}Be, ^{9}B nuclei, and properties of their excited states and probabilities of the different processes on them. For the first time the characteristic geometric forms were predicted, and these

forms were subsequently discovered in the experiments in Kurchatov Institute of Atomic Energy.

According to the multicluster dynamic model with Pauli projection (MDMP) a nucleus consists of a few clusters, in each of which there are no more than 4 nucleons. The Pauli principle is taken into account effectively via introduction of the deep attractive cluster-cluster potentials with forbidden states or via introduction of the repulsive core [4–8].

Let's note, that in the case of describing of ^{7}Li nucleus in αt-representation on the base of the simple binary models with using of the deep attractive cluster-cluster potentials with the forbidden states (PFS) practically all statistical characteristics of this nucleus such as the binding energy, charge and magnet radii, quadrupole moment and etc. can be successfully reproduced [3].

In work [9] there was suggested to distinguish the static and dynamic clusterizations of nuclei. Such an approach, from our point of view, is the most effective and further in the process of work in this direction this suggestion can be considered as a conception.

Let us consider the types of clusterization. For example, $^7\mathrm{Li}\{\alpha t\} \rightarrow \alpha + t$ fragmentation channel corresponds to the static type of clusterization when the initial cluster configuration does not differ from the clusterization of the final channel. In the case of consideration of decays into $^7\mathrm{Li}\{\alpha t\} \rightarrow {}^6\mathrm{He}\{\alpha nn\} + p$, $^7\mathrm{Li}\{\alpha t\} \rightarrow {}^6\mathrm{Li}\{\alpha d\} + n$ channels, which are associated to destroying (or «reconfiguration») of the tritium cluster, then one talks about the dynamic clusterization. In this case the situation, from one hand, gets significantly complex, and from the other hand the new possibilities for the investigation of the spectroscopy of these channels, peculiarities of the dynamic and static characteristics of the constituent cluster t, which, in principle, can differ from the corresponding characteristics of the free tritium nucleus ^{3}H, are appeared. It is worth to note, that a study of the dynamic type of clusterization [9] require new theoretical approaches as well as search for possibilities of the experimental test of the conception being developed. Exactly in this context there is a detailed discussion of the results of the experimental measurements of the process of quasi-elastic knockout of protons $^7\mathrm{Li}(e, e', p)^6\mathrm{He}$ on the apparatus NIKHEF [10].

An example of the intermediate clusterization is a decay into the channel $^8\mathrm{Li}\{\alpha tn\} \rightarrow {}^7\mathrm{Li}\{\alpha t\} + n$, when the constituent cluster does not destroy (as in the case of the static clusterization), but in the process of fragmentation only one degree of freedom is involved but not all of its as it were in the case of the dynamic clusterization.

In works [2, 3] there was considered a mathematical method of construction of wave functions (WF) of the relative motion in the channels of fragmentation, in which the initial cluster function does not coincide with the type of clusterization in the final channel, i.e., the projecting method. For $^6\mathrm{Li}\{\alpha t\} \rightarrow {}^7\mathrm{He} + p$ channel the proton spectroscopic factors $S_{0^+,1}$ and $S_{2^+,1}$ for the transition to the ground and the first excited states of the nucleus ^{6}He have been calculated. At this the following variants of construction of the virtual tritium cluster ^{3}H were considered: the translational-invariant shell model (TISM), which corresponds to the symmetric WF of the relative coordinates and has a free variable oscillatory parameter r_0, and also «realistic» WF, which are the variation functions the parameters of which are chosen to reproduce the observable form-factor of ^{3}H nucleus. In case of TISM the sizes of ^{3}H cluster can be varied using the parameter r_0, simulating the «diffuse» or «compressed» cluster. In the second case the root-mean-square sizes of ^{3}H are fixed and correspond to the parameters of free tritium.

In Table there is a comparison of the results on the proton spectroscopic S-factors obtained by using the shell model (SM) [1] and the variation method of Monte-Carlo [10] with the available experimental data on neutron S-factors, which have been recalculated into the proton spectroscopic factors using the model-free relation $S_p/S_n = 2$ obtained and justified in [3].

In Table there are also theoretical and experimental values on neutron spectroscopic S-factors for $^7\mathrm{Li} \rightarrow {}^6\mathrm{Li} + n$ channel with the transitions to the ground (1^+, 0) and the first excited state (3^+, 0) of ^{6}Li nucleus. A comparison of the experimental spectroscopic S-factors for $^7\mathrm{Li} \rightarrow {}^6\mathrm{He} + p$ channel shows that the data [13, 14, 20] are in good agreement with each other, but they contradict to the experimental results of NIKHEV [10], and also to values of [12, 18]. The reason of such a difference of the experimental measurements results is quite the difference of the methodology of extracting of S-factors from the experimental cross sections.

In Table there are also the defined more exactly results of theoretical calculations of the spectroscopic S-factors for $^7\mathrm{Li} \rightarrow {}^6\mathrm{He} + p$ channel obtained within the shell model [17], and also by using of two variation methods of Monte-Carlo: VMC and GFMC (Green Function Monte Carlo) [16]. As it is seen, in this case the model calculations also differ from each other. So, for example, the results of theoretical calculations of S_p-factors [10, 15, 16] are in good agreement with the experimental data of NIKHEV [10] and [12, 18], while the theoretical values [1, 11, 17] agree with the experimental results of [13, 14, 20]. From Table 1 it is also seen, that in calculations [3] in a whole one can achieve an agreement with those or other data at the expense of variation of the oscillatory parameter r_0.

Thus, to ascertain the differences between the available values on the spectroscopic S-factors it is necessary to carry out the systematic analysis of the available experimental data.

Spectroscopic neutron and proton factors in isobar-analogous channels $^{7}Li_{g.s} \rightarrow {}^{6}Li + n$ and $^{7}Li_{g.s} \rightarrow {}^{6}He + p$

j^{π}, T	0^{+}, 1		2^{+}, 1		1^{+}, 0	3^{+}, 0
A = 6	^{6}Li	^{6}He	^{6}Li	^{6}He	^{6}Li	^{6}Li
E_x, MeV	3,563	g.s.	5,37	1,797	g.s.	2,186
S^{theor} [1]	0,285	0,571	0,208	0,416	0,804	0,593
S^{theor} [11]		0,56		0,34		
S^{exp} [12]	0,24	0,48*	0,14	0,28*	0,87	0,67
S^{exp} [13]	0,31*	0,62	0,165(0,16)*	0,37 (0,32)		
S^{exp} [10] NIKHEF	0,21*	0,42(4)	0,08*	0,16(2)		
S^{exp} [14]	0,3*	0,6	0,2*	0,4		
S^{theor}_{VMC} [10; 15]		0,41		0,19		
S^{theor}_{VMC} [15]	0,221 (I)** 0,183 (II)**	0,442 (I)** 0,365 (II)**		0,274 (I)**	0,709 (I)** 0,612 (II)**	0,500 (I)** 0,436 (II)**
S^{theor}_{SM} [17]	0,345	0,691		0,466	0,841	0,646
S^{theor}_{GFMC} [16]	0,203 (I)** 0,204 (II)**	0,406 (I)** 0,409 (II)**			0,668 (I)** 0,657 (II)**	0,435 (I)** 0,447 (II)**
S^{exp} [18]	0,19(3)	0,44(6)			0,74(11)	
S^{exp} [19]					0,73 ± 0,05	
S^{exp} [20]			0,231		0,43	0,72 (14)
S^{exp} [21]						0,58 (13)
S^{theor}, r_0 = 1,3	0,224	0,461	0,146	0,291		
S^{theor}, r_0 = 1,67	0,286	0,581	0,168	0,334		
S^{theor}, r_0 = 2,36	0,228	0,456	0,111	0,219		

Notes: * Experimental data recalculated with regard to the relation $S_p/S_n = 2$ [3];
** I – calculations with the shell model WF; II – calculations with cluster WF [16].

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The work is submitted to the International Scientific Conference «Implementation of integrated model of educational institutions, implements educational programs different levels of education», Republic of Singapore, December, 10-17, 2013, came to the editorial office on 18.11.2013.

METHODS FOR STUDYING MODES OF SELF-OSCILLATING SYSTEMS

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This article describes the results of the simulation of the generator oscillations in the Advanced Design System (ADS). ADS system contains all the functions that are necessary for the development and design of analog and digital radio devices, only the signal chain devices, wired or wireless, design and routing of printed circuit boards, the development of monolithic integrated circuits and three-dimensional electromagnetic structures. This system is good to use when organizing specialized labs on computer modeling of the technical subjects. We use ADS for simulation of chaos generators.

Introduction. Chaotic signals have the most information capacity, that is, their information entropy is maximized. This property of chaotic signals making them the most promising for the broadband wireless communication [1, 2]. As the systems that produce chaotic oscillations using nonlinear dynamic circuits, such as a generator Chua, the generator Pikovsky-Rabinovich [3], a generator with inertial nonlinearity Anischenko-Astakhov [4] and many other schemes. In this paper we present some results on the construction of the electronic circuit of the generator dynamic chaos (GDH) in the specialized program Advanced Design System (ADS) [5].

Advanced Design System

Advanced Design System is the world's leading electronic design automation software for RF, microwave, and high speed digital applications. Here are some of ADS analysis:

– DC analysis: is used for determining the bias point of the circuit.

– Transient analysis: runs the time domain analysis on the circuits and considers the nonlinearity of the elements.

– AC analysis: runs the small signal analysis and use the linear model of elements on their bias point.

So the nonlinear elements like transistor are replaced by a linear model (small signal circuit) which includes resistors, capacitors, inductors and voltage & current sources.

– S_parameters analysis: calculates the Scattering parameters of the components, and shows the variation of the S_parameters over different frequencies. It is also used for calculating noise figure and group delay.

Fig. 1 shows the structure of the system ADS.

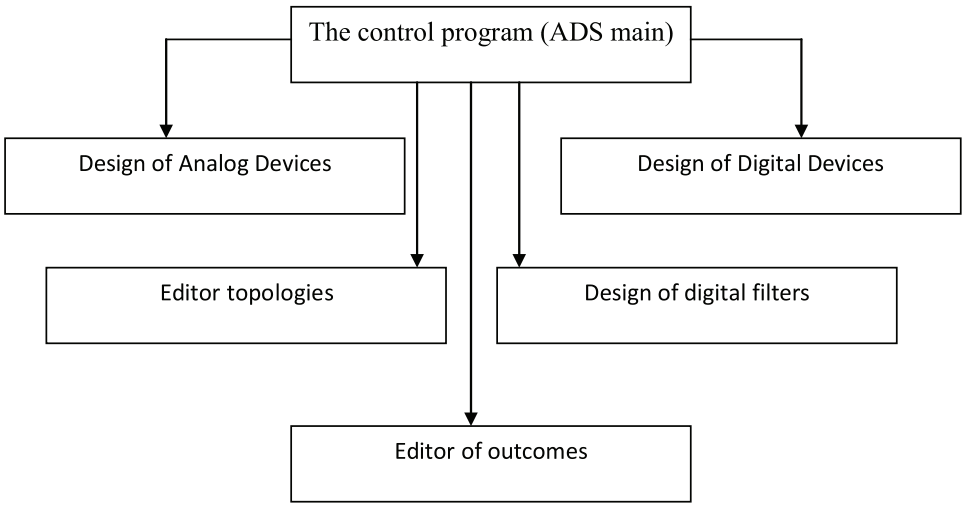

Fig. 1. Structure of the system ADS