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THE ROLE OF NUCLEAR REACTIONS FOR THE STUDY OF THE EXCITED STATE STRUCTURE

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1. Introduction

In addition to the data on the structure of excited states obtained from α - and β -decays, the study of nuclear reactions: the inelastic scattering, one- and two-nucleon transfer reactions, the (n,γ) reactions on thermal and resonance neutrons and others, has made our knowledge on nuclear structure more profound. With increasing excitation energy the density of levels increases and their structure becomes more complicated. The regularities of this complication can be understood by studying the fragmentation of one-, two- and many-quasiparticle states over nuclear levels. The study of deep hole states in spherical nuclei provided interesting information on the fragmentation of one-quasiparticle states. There are first indications of the fragmentation of two-quasiparticle states; some of these data have been obtained from the two-nucleon reactions. Important data have been obtained for the neutron and radiative strength functions. The nuclear reactions play an important role in the study of multipole, spin-multipole and charge-exchange giant resonances. A large contribution to the study of nuclear reactions has been made by the investigations of the Kharkov Physical Technical Institute /1/.

Many properties of atomic nuclei as systems of interacting protons and neutrons, are exhibited in their excited states. The average field of the nucleus, reflecting its fundamental properties, serves as a basis for describing the excited state properties (see ref. /2/). The aim of the nuclear theory is not so much a rigorous solution of the many-body problem in the general form as the most correct description of those nuclear properties which can be measured experimentally at present and will be measured in future.

In this report we treat the nuclear state properties which are studied in the nuclear reactions. The basic assumptions of the quasiparticle-phonon nuclear model are presented. The excited state properties caloulted in the quasiparticle-phonon nuclear model are compared with the experimental data from nuclear reactions.

2. Excited state properties investigated in nuclear reactions

An enormous and important information on nuclear structure, obtained from the investigation of α -, β - and γ-spectra and nuclear reactions allows one to reproduce the general picture of the low-lying excited states of complex nuclei/3-5/. The experimental study and theoretical description of the nuclear states at intermediate and high excitation energies encounter great difficulties. They can be overcome owing to an extended front of experimental investigations and variety of theoretical methods.

Based on the study of the nuclear state structure, we divide the nuclear reactions into four groups.

Group I. Reactions with excitation of collective states. There are rotational bands and high-spin states, low-lying vibrational states and giant resonances. They include the Coulomb excitation, inelastic scattering of electrons, protons, α -particle, heavy ions and π -mesons, and the reactions of type (p,n), (γ,n) and (γ,γ').

Group II. Direct nuclear reactions which are used to extract the spectroscopic factors. They provide information on the components of the excited state wave functions. These are the one-nucleon transfer reactions. It is hoped that alongside with the two-nucleon transfer reactions they will be added by the many-nucleon transfer reactions. These are also the reactions with slow neutrons of the type (n,n) and (n, γ), which are used to determine the neutron and partial radiative strength functions defining the neutron resonances.

Group III. Reactions (n,γ) on thermal and resonance neutrons, and the technique of average resonance neutron capture (ARC). These reactions guarantee observation of all nuclear levels for fixed spins and parities in a certain excitation energy interval /6-8/.

Group IV. Reactions of the type (p,xn), (n,xn), (H.I.,xn,xp) and others, with excitation of numerous levels of complex nuclei. These reactions do not provide unambiguously the quantum numbers, differential and integral characteristics of excited states and do not guarantee excitation of all states of a definite type in a certain excitation energy region.

Excitation of the states of groups I, II and III is schematically represented in fig. 1. The direct nuclear reactions, β - and γ -decays concern the relationships between the initial and final states, i.e.,provide information on the final state with respect to the initial one. In the inelastic scattering or γ -decays different states of one nucleus are related. In the one-nucleon reactions there are relationships between pairs of states. in which one nucleon is added to or subtracted from the target-nucleus ground state to form various states of a residual nucleus.

The theory should take into account this relationship between the initial and final states for the description of the nuclear properties. The operator form of the excited state wave functions as an expansion over a number of quasiparticles and phonons/9/ turned out to be useful under such a statement of the problem. This wave function is constructed in the representation where the density matrix is diagonal for the ground nuclear state. In this representation the wave function of highly excited state contains thousands of different components. In many cases a highly excited state is produced due to the capture of a nucleon or high-energy γ-ray by the target-nucleus in the ground zero-quasiparticle or one-quasiparticle state. The expansion of the wave func-

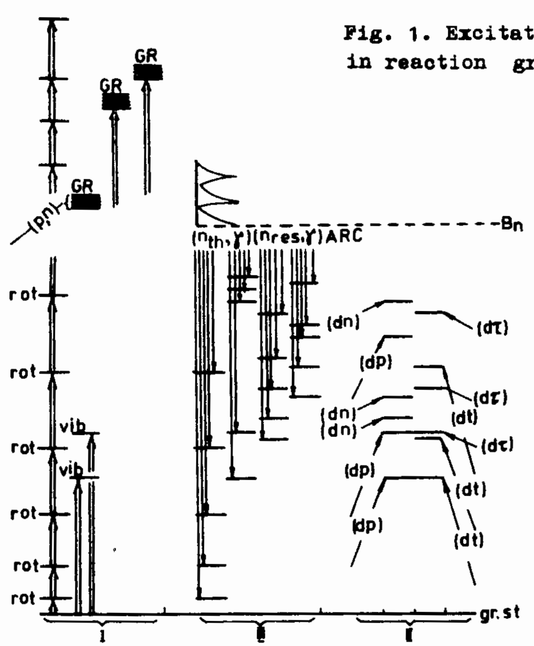

Fig. 1. Excitation of nuclear states in reaction groups I, II and III.

tion over a number of quasiparticles and phonons seems to be performed on the basis of the function of the target-nucleus. The square of each coefficient of this expansion determines a fraction of time of the nucleus in this configuration. The fraction of time of the nucleus in the one-quasiparticle or one-phonon configuration decreases exponentially with increasing excitation energy. The wave function, for inctance, of the highly excited state of an odd-A spherical nucleus is:

$$\Psi_i(I^{\pi}M) = b_I^i \alpha_{IM}^+ \Psi_0 + \sum_{\substack{j_1 j_2 j_3 \\ m_1 m_2 m_3}} b_I^i(j_1m_1 j_2m_2 j_3m_3)\, \alpha_{j_1m_1}^+ \alpha_{j_2m_2}^+ \alpha_{j_3m_3}^+ \Psi_0 + \sum_{\substack{j_1j_2j_3j_4j_5 \\ m_1m_2m_3m_4m_5}} b^i(j_1m_1 j_2m_2 j_3m_3 j_4m_4 j_5m_5)\, \alpha_{j_1m_1}^+ \alpha_{j_2m_2}^+ \alpha_{j_3m_3}^+ \alpha_{j_4m_4}^+ \alpha_{j_5m_5}^+ \Psi_0 + \ldots \quad (1)$$

This expression should be added by the terms with the pair-vibrational phonon operators which substitute the operators $\left(\alpha_{jm}^+ \alpha_{j-m}^+\right)_{I=0}$. Besides, the operators of any phonons can be introduoes explicitly in (1).

With increasing excitation energy the level density increases exponentially and the contribution of few-quasiparticle components to the wave function normalization exponentially decreases. According to the estimates of refs./9,10/ the contribution of one-quasiparticle components to the normalization of the neutron resonance wave functions is 10^{-4}-10^{-7} in the nonmagic nuclei with A>100. The regularities of the statistical nuclear model are valid for these small components of the wave functions. The experimental information on the many-quasiparticle components of the wave functions is very scarce.

The most complete and accurate data are available on the few-quasiparticle components of the nuclear wave functions at low, intermediate and high excitation energies. We shall discuss the few-quasiparticle components of the wave functions. It should be noted that the difficulties of describing the low- and high-lying states of complex nuclei are different. The results of calculation for the low-lying nonrotational states depend strongly on the behaviour of single-particle levels near the Fermi surface. The most difficulties are encountered in the microscopic and semi-microsoopic description of the first most collective vibrational states. The corrections to the RPA due to the Pauli principle and to the ground state correlations are large. For the description of the low-lying states it is desirable to project over the number of particles and angular momentum, that complicates the calculations. There are no such difficulties when describing the collective states of the type of giant resonances. The difficulties in describing the highly excited states are caused by the necessity to take into account a) a large phonon space, b) the components of the wave functions with a large number of quasiparticles and phonons, c) single-particle continuum.

3. Basic assumptions of the quasiparticle-phonon nuclear model

The model Hamiltonian includes an average field as the Saxon-Woods potential, the superconducting pairing interactions and multipole-multipole and spin-multipole - spin-multipole isoscalar and isovector forces. The study of the low-lying states allowed one to fix the parameters of the Saxon-Woods potential. The second quantization method is used for obtaining the secular equations the solutions of which give the energies of one-phonon states. For each multipolarity several hundreds of roots of the secular equations and the corresponding wave functions are calculated. To describe the one-phonon states with any K^{π} in deformed nuclei and any I^{π} in spherical nuclei, the multipole-multipole and spin-multipole - spin-multipole forces with any λ as well as with large multipolarities are introduced. The quasiparticle-phonon interaction is taken into account. If phonons are fixed, the corresponding parts of the multipole and spin-multipole forces describing the quasiparticle-phonon interactions are uniquely determined. If the secular equations for phonons are solved, all model parameters turn out to be fixed.

The advantage of the model is that the one-phonon rather than single-particle states are used as the basis of the model. This means that the basis includes the collective vibrational, weakly collective and two-quasiparticle states. The calculations of the nuclear state density indicate a full phonon space/11/.

After some transformations the model Hamiltonian is of the form/12,13/

$$H_M = H_v + H_{vq}, \qquad (2)$$

where H_v discribes noninteracting quasiparticles and phonons, and H_{vq} describes the quasiparticle-phonon interaction.

The excited state wave functions for an odd-A nucleus are

$$\Psi_\nu = \Big\{ \sum_\rho C_\nu^\rho \alpha_\rho^+ + \sum_\sigma D_\nu^\sigma (\alpha^+ Q^+)_\sigma + \sum_g F_\nu^g (\alpha^+ Q^+ Q^+) \Big\} \Psi_0 , \qquad (3)$$

and for a doubly even nucleus are

$$\Psi_\nu = \Big\{ \sum_\rho C_\nu^\rho Q_\rho^+ + \sum_\sigma D_\nu^\sigma (Q^+ Q^+)_\sigma + \sum_g F_\nu^g (Q^+ Q^+ Q^+)_g \Big\} \Psi_0 . \qquad (4)$$

Here Ψ_0 is the ground state wave function of a doubly even nucleus, ν is the excited state number with a definite value of J^{π} for spherical nuclei and of K^{π} for deformed nuclei. The quantum numbers ρ, σ and g are specified for spherical and deformed nuclei in refs./12-14/. The normalization condition has the form

$$\sum_\rho (C_\nu^\rho)^2 + \sum_\sigma (D_\nu^\sigma)^2 + \sum_g (F_\nu^g)^2 = 1 . \qquad (5)$$

In constructing the function (3) we have restricted ourlelves in (1) to the five-quasiparticle terms, and all two-quasiparticle states have been written through the phonon operators Q_g^+.

Then we calculate the avarage value of H_M over the wave functions (3) and (4), and then using the variational principle and taking into account the condition (5), we get the system of basic equations

$$\begin{aligned} &(\mathcal{P}_\rho - \eta_\nu) C_\nu^\rho - \sum_\sigma U_{\rho\sigma} D_\nu^\sigma = 0 , \\ &(\mathcal{P}_\sigma - \eta_\nu) D_\nu^\sigma - \sum_{\rho'} U_{\rho'\sigma} C_\nu^{\rho'} - \sum_{g'} U_{\sigma g'} F_\nu^{g'} = 0 , \\ &(\mathcal{P}_g - \eta_\nu) F_\nu^g - \sum_{\sigma'} U_{\sigma' g} D_\nu^{\sigma'} = 0 . \end{aligned} \qquad (6)$$

The matrix elements $U_{\rho\sigma}$ and $U_{\sigma g}$ are determined by the quasiparticle-phonon interaction. For an odd-A nucleus $\mathcal{P}_\rho = \varepsilon_\rho$,

$p_G = \varepsilon_p + \omega_g$ and $p_{\mathcal{G}} = \varepsilon_p + \omega_{g_1} + \omega_{g_2}$; for a doubly even nucleus $p_p = \omega_{p\equiv g}$, $p_G = \omega_{g_1} + \omega_{g_2}$ and $p_{\mathcal{G}} = \omega_{g_1} + \omega_{g_2} + \omega_{g_3}$, where ε_p and ω_g are the quasiparticle and one-phonon energies, respectively.

To solve the systems of equations (5) and (6), one should diagonalize the matrices of high rank. At intermediate and high excitation energies the state density is large, and therefore, one should find the energies and wave functions for several thousands of states. The wave function contains many thousands of components, and to describe a certain physical process one or several of them are taken. Just a small part of the available information is used. To overcome these difficulties, the strength function method is used in the quasiparticle-phonon nuclear model. Instead of solving the systems of equations (5) and (6) and finding the energies and wave functions for each state, the proper function is calculated immediatly in a certain energy interval. We present schematically the method. Let the value of the physical quantity B_ν be calculated in a certain energy interval. We introduce the strength function

$$b(\eta) = \sum_\nu B_\nu \rho(\eta - \eta_\nu) \; , \; \rho(\eta-\eta_\nu) = \frac{\Delta}{2\pi} \frac{1}{(\eta-\eta_\nu)^2 + \Delta^2/4} \; , \qquad (7)$$

where Δ determines the way of presentation of the results of calculation. Using the theory of residues, we get[12,15]

$$b(\eta) = \frac{1}{\pi} \, \mathrm{Im} \, \frac{P(\eta + i\Delta/2)}{\mathcal{F}(\eta + i\Delta/2)} \; , \qquad (8)$$

Here $P(\eta+i\Delta/2)$ and $\mathcal{F}(\eta+i\Delta/2)$ are the high rank determinants. In many cases these determinants have been transformed into those of a low rank (see ref.[16]). Thus, using the strength function method, one should not diagonalize the matrices of a high rank. One should calculate the imaginary parts of determinants at different energy values. As a result, the computational time has been reduced 10^3–10^4 times, and it turned out that different properties

of many nuclei can be calculated at intermadiate and high excitation energies.

Let us demonstrate some results of calculation within the quasiparticle-phonon nuclear model at low, intermediate and high excitation energies and show what nuclear reactions play a dominating role in these cases.

4. Vibrational states in deformed nuclei

(Coulomb excitation, inelastic scattering of particle and nuclei on nuclei)

According to the generally accepted treatment (see refs.[3,4]), there should exist one-, two- and so on phonon states in doubly even spherical and deformed nuclei. In odd-A nuclei the one-, two-, etc., phonon states should be constructed in the one-quasiparticle states. In spherical nuclei a large number of quadrupole two-phonon states are observed. Many states of the type of quasiparticle plus phonon are know in odd-A nuclei. In recent years there are doubts about the universality of the generally accepted treatment of the vibrational states. A number of states of the spherical nuclei, which has been thought of to be the two-phonon states, has no large two-phonon components. Based on the analysis of the experimental data, it has concluded in ref.[17] that the two-phonon states are absent in the deformed nuclei. It is not clear whether the vibrational state can be constructed on each one-quasiparticle state.

The collective two-phonon states in deformed nuclei are discussed in view of the absence of 0^+ two-phonon octupole states in the Ra, Th and U isotopes and the present unclear situation with the two-phonon vibrational states in ^{168}Er. In ref.[18] the first $K^\pi = 0^-$ states are related with the stable octupole deformation. This treatment is inconsistent with the analysis of ref.[19]. In ^{168}Er the level with $K^\pi = 4^+$ and energy of 2.03 MeV is considered in ref.[20] as the two-phonon vibrational one, and a large anharmonicity of vibrations is explained by the non-axial form of this nucleus. Note that there are no experimental indications that this state is the two-phonon state.

In ref.[21] the centroid energies of the collective two-phonon states in deformed nuclei are calculated taking into account the Pauli principle in the two-phonon components of the wave functions. It is shown that they are shifted by 1-2 MeV to higher energies. A strong fragmentation of the collective two-phonon states over many nuclear levels occurs at the excitation energies of 3-4 MeV. It is concluded that the two-phonon states cannot exist in deformed nuclei. This conclusion about the absence of the collective two-phonon states has an universal nature. It concerns all the deformed nuclei. It differs from the explanations made in refs.[18,20], which are attributed to the specific properties only of the nuclei considered.

It has been shown in ref.[22], if in the quasiparticle plus phonon components of the wave functions the Pauli principle is not violated or is violated slightly, there may exist the corresponding vibrational states in ood-A deformed nuclei. If the Pauli principle is strongly violated, then the centroid energies are shifted up and the corresponding vibrational states should not exist.

To elucidata the situation with the vibrational states, it is necessary to experimentally search for the collective two-phonon states in deformed nuclei, to study them more thoroughly in spherical nuclei, and to investigate comprehensively the vibrational states in odd-A nuclei.

5. Neutron and radiative strength functions ((n,n), (n,γ) and (γ,n) reactions)

A number of characteristics of the neutron resonances are included in the general scheme of nonstatistical calculations within

the quasiparticle-phonon nuclear model. The study of the fragmentation of one-quasiparticle and one-phonon states allowed the calculation of the s-, p- and d-wave neutron strength functions [15,23-25]. The s- and p-wave neutron strength functions in spherical nuclei are calculated using the fragmentation of one-quasiparticle states. A part of the results of calculation is given in the table. The neutron strength functions and their spin splitting in spherical doubly even compound nuclei are calculated using the fragmentation of one-phonon states. It is shown that the spin splitting is not large, that is in agreement with the experimental data.

In ref.[26] the s-, p- and d-wave neutron strength functions have been measured in the reactions ^{206}Pb+n and ^{207}Pb+n in the energy interval from 0 to 1 MeV. Substructures have been observed in the neutron strength functions. The calculations[25] within the quasiparticle-phonon nuclear model have shown that the observed substructures are due to local maxima in the fragmentation of the subshells $4s_{1/2}$, $3p_{1/2}$, $3d_{3/2}$ and $3d_{5/2}$.

Table

s- and p-wave neutron strength function

Compound nucleus	B_n MeV	$S_0\cdot10^4$ exp.	$S_0\cdot10^4$ calc.	$S_1\cdot10^4$ exp.	$S_1\cdot10^4$ calc.
^{55}Fe	9.29	7.8±3.4	8.8	0.18±0.08	0.18
^{57}Fe	7.64	2.6±0.86	3.9	0.4±0.2	0.2
^{59}Ni	9.00	3.1±0.8	2.0	0.04±0.03	0.1
^{61}Ni	7.82	2.4±0.6	3.1	-	0.2
^{117}Sn	6.94	0.26±0.05	0.2	1.35	0.9
^{121}Sn	6.18	0.08±0.06	0.1	1.1±0.4	0.7
^{127}Te	6.35	0.3±0.1	0.15	1.64	1.4
^{207}Pb	6.74	1.06	0.8	1.32	0.2

A simultaneous calculation of the fragmentation of one-quasiparticle and quasiparticle plus phonon states allowed the calculation of the partial radiative strength functions in odd-A spherical nuclei within the quasiparticle-phonon nuclear model. In ref./27/ the strength functions $b(E1,\eta)$ and $b(M1,\eta)$ versus excitation energy η in ^{55}Fe and ^{59,61}Ni have been calculated for the transitions to the low-lying one-quasiparticle states. The strength functions for the transitions between one-quasiparticle components of the wave functions of the initial and final states have been calculated too. These valence transitions comprise a part of the total strength function.

Now we consider the E1 transitions in ^{55}Fe from the s-wave resonances to the ground $3/2^-$ and first excited $1/2^-$ states. A de-

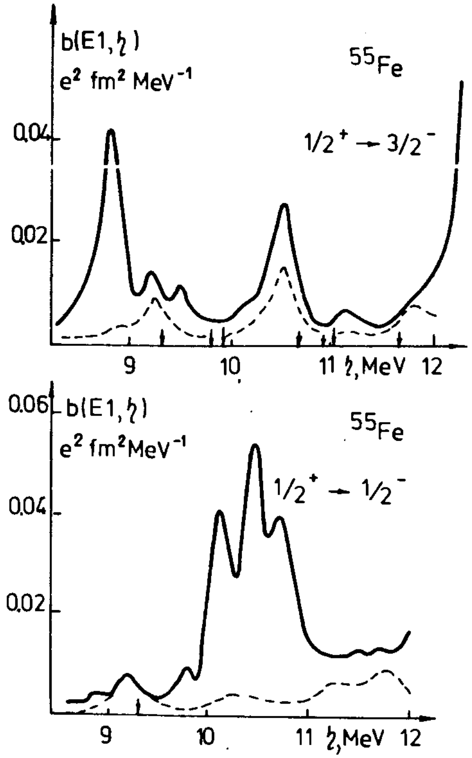

Fig. 2. Strength functions of E1 transitions in ^{55}Fe from s-wave resonances to the states with $I^\pi = 3/2^-$ and $1/2^-$. The solid curve is the total strength function, the dashed curve is for the valence transitions.

tailed investigation of the $^{54}Fe(n,\gamma)^{55}Fe$ reaction has been made in ref./28/; the results of calculation/27/ are shown in fig. 2. In this case the valence model is valid. According to ref./28/ the summed contribution of the valence transitions to the $3/2^-$ and $1/2^-$ states are about 50%. According to the calculations of ref./27/ the contribution of the valence transitions to the $3/2^-$ state is 40% and to $1/2^-$ is 85%. A large difference of the portion of the valence transitions to the $3/2^-$ and $1/2^-$ states is due to the position of the quasiparticle plus phonon poles.

The calculated in ref./27/ absolute values of the E1 and M1 widths in ^{55}Fe and ^{59,61}Ni agree roughly with the corresponding experimental data. A qualitative agreement is obtained with the general picture for the E1 and M1 strength functions, represented in ref./29/. Within the quasiparticle-phonon nuclear model one can calculate the radiative strength functions for the partial γ-transitions from the high-lying to the low-lying states in many odd-A spherical nuclei.

6. Fragmentation of deep hole states
(reactions of the type (^{3}He,α) and (d,^{3}He))

Let us study the fragmentation (strength distribution) of deep hole states in odd-A spherical nuclei. We introduce the strength function

$$C_J^2(\eta) = \sum_\nu \left(C_\nu^\rho\right)^2 \frac{1}{2\pi} \frac{\Delta}{(\eta-\eta_\nu)^2+\Delta^2/4} = \mp\frac{1}{\pi}\, Im\, \mathcal{F}^{-1}(\eta + i\Delta/2) \quad (9)$$

and the spectroscopic factor of the state j

$$S_j = (2j+1)\, v_j^2 \int C_J^2(\eta)\, d\eta . \quad (10)$$

When calculating the fragmentation of the particle state, in eq. (10) the Bogolubov coefficient v_j^2 is substituted by u_j^2.

Within the quasiparticle-phonon nuclear model the fragmentation of the hole neutron state $1g_{9/2}$ in the Sn, Te and Sm isotopes and of the proton $1g_{9/2}$ state in ^{143}Pm has been calculated (see ref./14/). A good description of the experimental data is obtained /30-32/. Our theory has been compared in detail with experiment by Gales/33/. The fragmentation of the hole states $2p_{1/2}$, $2p_{3/2}$, $1f_{5/2}$ and $1f_{7/2}$ in ^{111,115}Sn has been calculated in ref./34/. In ref./35/ the fragmentation of deep hole states in ^{205,207}Pb and ^{203,205,207}Tl has been calculated, and the agreement with the experimental data has been obtained/36-38/. It has been shown in ref./39/ that a rigorous inclusion of the Pauli principle slightly influences the fragmentation of one-quasiparticle states in spherical nuclei. The results of our calculations in ^{207}Pb are in qualitative agreement with the results of ref./40/.

The hole states in spherical nuclei from Ni to Pb lying by 5-10 MeV from the Fermi energy are exhibited in the one-nucleon transfer reactions as pronounced resonance-like structures. They are fragmented in the energy interval from 2 to 5 MeV. The comparison of the results of calculation of the fragmentation of deep hole states in spherical nuclei with the experimental data has shown that the quasiparticle-phonon nuclear model provides a correct description of the fragmentation.

The experimental study of the fragmentation of two-quasiparticle state in spherical nuclei has been undertaken/41/. In reactions of the type (p,d) on odd-N target-nuclei the fragmentation of the valence particle-hole states is studied. It has been shown in refs./33,41/ that the two-nucleon transfer reactions of the type (p,t) may provide a more extended information on the fragmentation of two-quasiparticle states. In ref./42/ the fragmentation of two-quasiparticle states in spherical nuclei has been described within the quasiparticle-phonon nuclear model.

7. Giant resonances

(Reactions of the type (γ,γ'), (e,e'), (p,p') and (α,α'))

In recent years much progress has been achieved in the experimental and theoretical study of the giant resonances (see reviews/43-45/). The position of the giant resonances is determined by the corresponding one-phonon states. The coupling with the two-phonon components results in the fragmentation of one-phonon states thus forming the widths and the regions of location of the giant resonances in spherical nuclei. In the deformed nuclei the giant resonance widths are determined by the one-phonon states. This is caused by the fact that the subshells are splitted due to deformation, and this splitting is more important than the fragmentation of one-phonon states.

Within the quasiparticle-phonon nuclear model the foolowing basic characteristics of the giant resonances are calculated: energies, widths, transitional densities, and the excitation cross sections in spherical/13,25,46/ and deformed/47/ nuclei. Much progress has been achieved in the study of M1 and M2 resonances in spherical nuclei/48/ and of the $T_>$ giant dipole resonances/49/. Within the quasiparticle-phonon nuclear model one can calculate the characteristics of the isobaric analog state, $T_>$ giant resonances of the Gamov-Teller type, 1^- first forbidden, etc.

The fine structure of the giant resonances is studied experimentally and theoretically. Following ref./25/ we consider the isoscalar quadrupole resonance in ^{208}Pb. The calculations are performed with the radial dependence in form $\frac{\partial V(r)}{\partial r}$, where $V(r)$ is the central part of the Saxon-Woods potential. The results of calculation, performed with the wave function (4) with F=0, are given in fig. 3.

The strength of the isoscalar quadrupole resonance is fragmented in the interval from 8 to 11 MeV; there are substructures

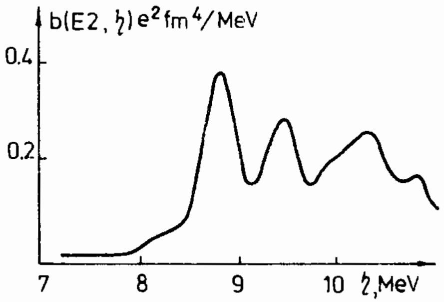

Fig. 3. Giant isoscalar quadrupole resonance in ^{208}Pb.

at the excitation energies of 8.8, 9.5, 10.4 and 10.8 MeV. The experimental data on the fragmentation of E2 strength, measured in the (α,α′), (d,d′) and (e,e′) reactions in ^{208}Pb are in qualitative agreement with the results of our calculations. Our calculations for the fragmentation of the isoscalar quadrupole resonance in ^{208}Pb are close to the results of ref./40/.

8. <u>Conclusion</u>

Within the quasiparticle-phonon nuclear model one can calculate many properties of complex nuclei at low, intermediate and high excitation energies. A part of these calculations has already been perfomed. It is obvious that for futher calculations more complex versions of the model will be used by including new term in the wave functions and by taking into account new forces. In recent years the model is being extended for the calculations of the $T_>$ giant resonances, fragmentation of $T_>$ one-quasiparticle and $T_>$ one-phonon states.

It should be emphasized that the main contribution to the wave functions of highly excited states is given by many-quasiparticle or many-phonon components. There is no yet information on the values and distribution of many-quasipatiole components of the wave functions of highly excited states. In future we shall be aware of the new properties of highly excited states defined by the many-quasiparticle components.

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Соловьев В.Г. E4-82-382

Роль ядерных реакций в изучении структуры возбужденных состояний сложных ядер

Проанализированы возможности извлечения из экспериментальных данных по ядерным реакциям сведений об интегральных и дифференциальных характеристиках возбужденных состояний сложных ядер. В квазичастично-фононной модели ядра вычисляется фрагментация малоквазичастичных состояний и определяемые ею свойства ядер при низких, промежуточных и высоких энергиях возбуждения.

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The Role of Nuclear Reactions for the Study of the Excited State Structure

Possibilities of extracting information about the integral and differential properties of the excited states of complex nuclei from the experimental data on nuclear reactions are analysed. The fragmentation of few-quasiparticle states and the nuclear properties defined by it are calculated at low, intermediate, and high excitation energies within the quasiparticle-phonon nuclear model.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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