THE GROUP-THEORETICAL APPROACH TO THE DESCRIPTION OF NUCLEAR STATES

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1.INTRODUCTION

Study of symmetrical environmental properties, including nuclei, nuclear particles, atoms and molecules has very important, and sometimes determinative meaning. The role of visible symmetry, in other words of the world beauty is generally known, and studied for a long time. The internal symmetry of material world (isotopic, angular, gauge, dynamic etc.), playing vitally important significance for its structure, creation and development has been widely studied for last years.

The development of conception of dynamic symmetry and supersymmetry in the structure of nuclear system condition and their supplement under studies of specific nuclei properties is considered in the present article. The next section includes the summary of the main point of dynamic symmetry and its connection to corresponding Lie algebra and techniques of physical operators construction through generators of chosen algebra and its subalgebra.

Section 3 states the dynamic-symmetric properties of atomic nuclei collective states, which are described by the model of interactive bosons. Section 4 is dedicated to conception of dynamic supersymmetry, its supplement under structure study of quasi-particle and collective states of nuclei and all interactions. In particular, the theory is applied for study of fermion and boson states in the even isotopes Pd, Dy and Er.

2. DYNAMIC SYMMETRY

The dynamic symmetry of considered system we will call that one, where Hamiltonian of the system could be constructed through Lie G algebra generators.

In general case, Lie algebra is created by means of operators set $X_i \in G$, satisfying the following commutation proportions:

$$\left[X_i, X_j\right] = \sum_k C_{ij}^k X_k \tag{1}$$

and to Jacobi identities:

$$\left[\left[X_i, X_j\right], X_k\right] + \left[\left[X_k, X_i\right], X_j\right] + \left[\left[X_j, X_k\right], X_i\right] = 0 \tag{2}$$

System Hamiltonian, in such algebra, is expressed as polynoms from generators X_i of this algebra:

$$H = E_0 + \sum_i e_i X_i + \sum_{i<j} v_{ij} X_i X_j + \ldots \qquad (3)$$

The theory, where Hamiltonian H, describing the system is decomposed on the algebra generators, is called the algebraical theory.

However, system Hamiltonian can not include all generators X_i of algebra G, but contains only special their combinations, where not all X_i .are included in. Such special combinations are called "invariant" operators or Kazimir operators of G algebra and its possible subalgebras $G \supset G' \supset G'' \supset \ldots$. C Kazimir -operators of G algebra always have to commutate with all G generators:

$$[C, X_i] = 0 \qquad \text{for all i} \qquad (4)$$

If in the algebraic theories the system Hamiltonian has polynomial form under generators X_i and their products, then in the theories of dynamic symmetry Hamiltonian, also having polynomial form is expressed only through Kazimir-operators of G algebra and its subalgebras.

$$H = aC(G) + a'C(G') + a''C(G'') + \ldots \qquad (5)$$

As Kazimir-operators are linear combinations of X_i algebra generators and their products, then dynamic -symmetric algebras are represented as specific cases of algebraic theories.

The system Hamiltonian may be constructed as more composite function of the same generators than polynoms. But H is expressed through the small number of symmetry Kazimir-operators.

The main advantage of dynamic-symmetric algebra is the following: when one of the same symmetry takes place, the main properties of considered system may be expressed in closed form through quantum numbers. Such dependence is very useful at the detailed analyze of all structural-spectroscopic properties of microscopic systems.

Since generators of the given group don't connect different irreducible representations between themselves, then Kazimir-operators, which, as it was determined, commute with all algebra generators, have to be diagonal in the basis, describing representations of these groups and therefore they keep all quantum numbers, including quantum numbers of subgroups:

$G \supset G' \supset \ldots$.

Then the proper values H are:

$$E = a\langle C(G)\rangle + a'\langle C(G)\rangle + a''\langle C(G'')\rangle + \ldots, \qquad (6)$$

where $\langle C(G)\rangle$ - - an average value $C(G)$ under proper functions G.

Thus, Hamiltonian, consisting only from Kazimir-operators of groups and subgroups chain, can't mix different representations of any of these chain groups and so the proper values H will be linear combinations of proper values of its chain component-Kazimir-operators.

Therefore all states with the same representations are degenerated on any stage of groups chain and at the same time the operators of transitions between states, composed from generators of given group or subgroups, can't connect states, described by different representations of these groups. It is trivial leads to many well-known rules of transitions selection between states.

For example, let's consider a group of system three-dimensional rotation $O(3) \supset O(2)$, generators of which are operators of angular moments J_x, J_y, J_z. They are submitted to the following commutation proportions:

$$[J_i, J_k] = ie_{ikj}J_j \qquad (7)$$

The set of states $|j, m = j\rangle, |j, m = j-1\rangle, \ldots, |j, m = -j\rangle$ forms an irreducible representations or basis $O(3)$, in which the angular moments j serve as quantum numbers. Basic states are differed in the projections j : m, which denote themselves an irreducible representations of $O(2)$ subgroup .

Operators J^2 and J_z are Kazimir-operators of these groups. Then system Hamiltonian may be represented in the following way:

$$H = aJ^2 + bJ_z \qquad (8)$$

and its corresponding proper value is $E = aj(j+1) + bm$

If system Hamiltonian express only in the group $O(3)$, i.e. consider b=0, then all states in the representation, designated through j are degenerated. This degeneration is removed at the inclusion of subgroup, where energy depends from m.

As we can see, the central task in the development of any group chain and group reduction is determination of quantum number, by means of which an irreducible representation of each

subgroup is determined. Hamiltonian for such any chain is noted down as amount of Kazimir - operators of chain subgroup, and it will be diagonal in the basis, determined an appropriate representation. Thus, each step in the chain introduces one or several free parameters (in this case *a* and *b* parameters) to expression of proper values and so it is required one or several quantum numbers, determining the representations of private groups, which, at the same time, takes away degeneracy. Thus, solution of the problem on the proper value for such reduction chain leads to determination of own value for every Kazimir -operator.

One of elegant aspects of dynamic aspects is that it can describe a complex physical problem, corresponding to complex Hamiltonian. For example, it is easy to write an expected energy spectrum, determining each state by appropriate quantum numbers. Operators of various transitions between states can be written through groups generators, and hence there are determined the rules of transition selection and expressions of acceptable transitions.

3. DYNAMIC SYMMETRY IN THE STRUCTURE OF NUCLEON COLLECTIVE MOTION IN THE NUCLEUS.

The study of dynamic -symmetric properties of collective states on the base of interactive bosons model (IBM) is our main purpose. This model describes of collective excitations of nuclear system with even number of neutrons and protons, generating *N* bosons number with angular moments $l^{\pi} = 0^{+}$ and 2^{+} (s and d - bosons) [1]. In this approach bosons represent the correlated nucleon pairs. For construction of Hamiltonian and others physical operators of iBM it is suitable to enter operators of production and destructuion s^{+} $(l = 0)$ and d_{μ}^{+} $(l = 2)$— of bosons $(\mu = 0, \pm 1, \pm 2)$ and generally denote them as $\hat{b}_{\alpha}^{+}$, $\hat{b}_{\alpha}$ (α = 1, 2, 3, 4, 5, 6). It is possible to make from these 6 types of boson operators 36 their bilinear products $X_{\alpha\beta} = b_{\alpha}^{+} b_{\beta}$, which create the algebra generators *U*(6). All physical operators are constructed from these generators (algebraic theory). Then Hamiltonian will be:

$$H = E_0 + \Sigma \varepsilon_{\alpha\beta} X_{\alpha\beta} + 0.5 \Sigma u_{\alpha\beta\gamma\delta} X_{\alpha\beta} X_{\gamma\delta} . \qquad (9)$$

There are usually exist the following notations $b_2^{+} = d_{2m}^{+}$, $b_0^{+} = s_{00}^{+}$. Then hamiltonain can be written in more suitable form:

$$H = \varepsilon \hat{n}_d + a_0 P^{+} P + a L^2 + a_2 Q^2 + a_3 T_3^2 + a_4 T_4^2 , \qquad (10)$$

where $T_l = (d^{+}\tilde{d})^{(l)}$, l = 0, 1, 2, 3, 4 ; $\hat{n}_d = \sqrt{5}\, T_0$; $\hat{L} = \sqrt{10}\, T_1$; $\hat{P} = 0.5(\hat{d}^2 - s^2)$;

$$Q = (d^{+}s + s^{+}d) - \frac{\sqrt{7}}{2}(d^{+}\tilde{d})^{(2)} = (d^{+}s + s^{+}d) - \frac{\sqrt{7}}{2} T_2 .$$

Linear and quadratic Kazimir-operators of U(6) group, commutating with all its 36 generators are operators of full number of bosons: $C_{1U(6)} = d^{+}\hat{d} + s^{+}s \equiv \hat{N}$, $C_{2U(6)} = \hat{N}(\hat{N}+5)$. Only 25 generators of all 36 generators are formed from operators of production and destruction -of *d*-bosons, namely $(d^{+}\tilde{d})^{(l)}$, which compose the subgroup $U(5)$ by linear and quadratic Kazimir-operators, which are $C_{1U(5)} = d^{+}\hat{d} = n_d$, $C_{2U(5)} = \hat{n}_d(\hat{n}_d+4)$. Other linear and quadratic operators U (6) and its subgroups may be denoted through operators(10) as:

$$C_{2SU(3)} = \frac{4}{3}Q^2 + \frac{1}{2}L^2; \quad C_{2O(6)} = 2\hat{N}(\hat{N}+4) - 8P^{+}P; \tag{11}$$

$$C_{2O(5)} = \frac{3}{5}\hat{L}^2 + 4T_3^2; \qquad C_{2O(3)} = 2L^2.$$

It is easy to show that $U(6)$ - group has solely three group chains which are called asymptotic limits, ending on $O(2)$ - group.

$$U(6) \supset \begin{cases} U(5) \supset O(5) \supset O(3) \supset O(2) \\ SU(3) \supset O(3) \supset O(2) \\ O(6) \supset O(5) \supset O(3) \supset O(2) \end{cases} \tag{12}$$

Let's define the physical structure of the each limit symmetries in order to identify representations of the each chain and basis condition quantum rates and apply them in a concrete system.

a) First chain (12) is called $U(5)$ - mamiltonian-limit of which is recorded through Kazimir-operator of subgroups in the following way:

$$H_I = \alpha C(1U(5)) + \beta C(2U(5)) + \gamma C(2O(5)) + \delta C(2O(3)), \tag{13}$$

Its proper values are expressed in the form of:

$$E = \alpha n_d + \beta n_d(n_d+4) + 2\gamma\nu(\nu+3) + 2\delta L(L+1) \tag{14}$$

There is a number n_d - is the number of d -bosons, ν -quantum number of boson's seniority and L - is the overall angular system moment. We have to note that this limit of cooperative motion conforms to angarmonical vibrator. It is easy to record operators of electromagnetic transitions between conditions, in particular:

$$\left.\begin{aligned} T(E0) &= a\hat{n}_s + b\hat{n}_d = a'\hat{N} + b'\hat{n}d \\ T(E2) &= e_b\hat{Q} = e_b\left[s^+d + d^+s + \lambda(d^+d)^{(2)}\right] \end{aligned}\right\} \qquad (15)$$

This limit is usually applied for description of cooperative excitations of nuclei near the closed shell where the N bosons total number is small.

b) Second chain (12), called $SU(3)$ limit, which Hamiltonian we will record in the form of:

$$H_{II} = \frac{3}{4}a_2C(2SU(3)) + (\frac{a_1}{2} - \frac{3}{16}a_2)C(2O(3))$$

Proper values of this operator are equal to:

$$E = \frac{a_2}{2}(\lambda^2 + \mu^2 + 3(\lambda+\mu)) + (a_1 + \frac{3}{8}a_2)L(L+1) \qquad (16)$$

This asymptotic limit of the boson model is applied for study of rotational condition of deformed nuclei.

c) Hamiltonian of the third chain (12) is recorded in the form of:

$$H_{III} = \alpha_1C(2O(6)) + \alpha_2C(2O(5)) + \alpha_3C(2O(3)).$$

Proper values of such a Hamiltonian are defined through quantum numbers of the depicted sub-algebra:

$$E = \alpha_1\sigma(\sigma+4) + \alpha_2\tau(\tau+3) + \alpha_3L(L+1) \qquad (17)$$

This asymptotic limit respectively describes the so called intermediate nuclei, laying between vibration and rotational areas. On the whole case of overall $U(6)$-symmetry an equation of the cooperative motion of arbitrary quadrupole type is solved numerically. Such a program was carried out in our group by Strygin D.P. and applied for structural study of some nuclei in the so called transition area [2].

Dynamic symmetry theory was further expanded by the other different methods. In particular, bosons space is expanded by addition to s and d bosons the positive parity o the so called p-boson, which of negative internal parity and has angular momentum equal to $l = 1^-$. Then we will get in this system $U(9)$-symmetric algebra [3]. Such expanded algebra has another two complementary limit cases, among which especially significant that $SU(3)$ is asymptotic. Nevertheless this limit due to presence of both parity bosons on its structure and

application range significantly differs from similar asymptotic $U(6)$ - symmetry. Quality and range of the described experimental facts are being much more expanded on the same quantity of free parameters (all in all 2).

As we see, borders of such theory can be further expanded by including to the configuration space new bosons, for example, f, g, ... bosons. However, at that, the number of free parameters will also go up.

4. DYNAMIC SUPER-SYMMETRY IN THE STRUCTURE OF NUCLEI POSITIONS

For the last years the symmetry conception has been further continued by introduction for consideration new dynamic super-symmetries [4], which differs from dynamic symmetry mainly with that super-algebra is operated by two sets of operators: G_α boson and F_i fermion, meeting the following commutating correlation:

$$[G_\alpha, G_\beta] = \sum_\gamma C^\gamma_{\alpha\beta} G_\gamma, \quad [G_\gamma, F_i] = \sum_j C^j_{\alpha i} F_j; \quad \{F_i, F_j\} = \sum_\alpha C^\alpha_{ij} G_\alpha \qquad (18)$$

and respective Jacobian identity. The square brackets denote commutators and braces - anticommutators.

Many asymptotic limits of this supersymmetric algebra are also quite easily and analytically solvable. For instance SU(3)-limit.

In the given work, we will consider the simplest case of super-symmetry when in the system of S,d –bosons one d-boson is ruptured into two pared nucleons. Hamiltonian of such a system is recorded in form of:

$$H = H_b + H_f + H_{\text{int}},$$

in which H_b –boson, H_f –fermion Hamiltonians, H_{int} – Hamiltonian interaction of bosons with fermions. Model space inserts N-1 bosons plus 2 nucleons. Boson hamiltonian is taken in the form of SU(3)-symmetry, a.s. concerned nuclei regard to rotational. (16). The standard shell hamiltonian is regarded as fermion hamiltonian of H_f . It is able to simplify interaction Hamiltonian of partial and collective freedom degree by taking solely two first terms, in the form of:

$$H_{\text{int}} = \frac{1}{2}\sum X^L_{l_1 J_1 l_2 J_2} (b^+_{l_1} A^+_{J_1})^L_M (b_{l_2} A_{J_2})^L_M + \qquad (19)$$
$$+ \frac{1}{2}\sum Y^L_{l_1 l_2 J_1 J_2} \left[(b^+_{l_1} b^+_{l_2})^L_M (b_{l_3} A_J)^L_M + (b^+_{l_3} A^+_J)^L_M (b_{l_2} b_{l_1})^L_M \right]$$

first of which mixes between itself different states, containing one broken pair with the boson, and the second one mixes previous mixed states with the states not containing broken pairs. As a result, in the spectrum of nucleus along with common collective bands there must be observed double-quasi-partial bands, consisting of fixed number of quadrupole bosons and one broken pare. Similar situation will have take place also for broken pares of negative parity independently from their spin value. In order to achieve analytical expressions, we stopped on consideration of only so called "aligned" states with maximally possible spin value $\left|n_\alpha, v = n_\alpha, \Delta = 0, L = 2n_\alpha; j_1 j_2 (J_f) J = 2n_\alpha\right\rangle$. These states will not be mixed with quasi-particle, by means of H_{int}, as they have different value of the overall spin. Exactly «aligned» states posses the minimal energy and consequently first appear in nucleus spectrum in motion through energy scale. In this case for the spectrum of "aligned" state there will be left just first terms in the hamiltonians H_f и H_{int}.

In the such approximation of state with different number of boson and fermion pares they are not being mixed between each other. As a result, in the energy spectrum there will be observed just collective states, peculiar to standard IBM and additional quasi-particle-boson strips in the base of which there are clean quasi-particle states.

5.THEORY APPLICATION IN THE STUDY OF EVEN ISOTOPES PD, DY И ER STRUCTURE.

Theory is applied for investigation of Palladium, Dysprosium and Erbium even isotopes status structure. For radial dependence of paired interaction fermion potential the potential of the Gauss type is used:

$$V = (V_0 + (\sigma_1 \sigma_2) V_\sigma) \exp(-r / r_0)^2,$$

where r_0=0,96$A^{1/3}$. Hamiltonian parameters were chosen from the correct description of nuclei energy spectrum. In calculations, interaction parameters, containing in boson part H_b are preserved for each nucleus for making them similar, for N- boson configuration, and for (N-1) boson plus double-quasi-particle configurations. Interaction depth and single-partial energies for each isotope have become dependent from the mass rate A. In case with isotopes Pd nucleons, appearing in breaking of one boson, may set up on single-partial states $1g_{9/2}, 2p_{1/2}$. They can create pared quasi-particle states of negative parity 4^-, 5^- and positive parity 8^+, 6^+, 4^+, 2^+, 0^+. Interactions of these configurations with bosons may give the source for new strips of negative as well as positive parity. Quasi-particle pairs with configurations $\left(9/2^+\right)^2 . J = 0,2,4,6$ will strongly interact with the pairs of other configurations on account of which they will enter to a collective band and so they will rise to the upper part of the

spectrum. And it occurs that the state energy is equal to $J=8^+$ or less than, or comparable with the state energies of Yrast-strip, having the same spin values. As a result, there is an intersection of the main and quasi-partial spin strips 8^+, with which the back-bending effect in this nuclei can be substantiated.

Moreover, electra-magnetic transitions from quasi-particle strips to the clearly cooperative strips must be heavily hampered due to great difference in the number of quadrupole bosons, generating these states. Thus, all pointed properties fully conform to the frames of considered approximation.

Absolutely the same picture is observed also for isotopes Dy и Er. Solely in this case nucleons, appearing in rupture of one boson, may locate in the states of $h_{11/2}$ и $i_{13/2}$. Values of single-quasi-particle energies are taken being similar for all isotopes of these nuclei.

In the table 1 there given parameters of interaction and single-particle energies for all isotopes of Er. One can see, that the parameter of quasi-particles interaction amplitude V_0 and mixing parameters of fermeon and boson freedom grades X_{J_0} и X_{J_2} can be taken identical for all even-even isotopes of Dysprosium and Erbium. And exchange term amplitude value of paired interaction of the particles V_σ somewhat increase with the extension of nuclei mass rate, while interaction parameters of quadrupole bosons are somewhat decreased with the growth of A.

In the following tables there were given comparisons of calculated values of different bands of energy states with their experimental values for some states of isotopes *Pd: A=100, 102, 104, 106; Er: A=156, 158 160, 162, 164.* As it obvious from the tables, calculated values mainly well reproduce their values, observed in the experiment.

There were also calculated reduced probabilities of *E2*- transitions inside and between the bands. Also it is seen, that calculated *B(E2)* depending on condition spins quite well transfer their experimental values [5].

Table 1. Parameters of interaction and single-particle energies for isotopes of Er.

	V_o	V_σ	K	K^1	X_J	X_J	$\varepsilon_{11/2}$	$\varepsilon_{11/2}$
^{156}Er	26	34	0.1	0.08	0.036	0.027	1.06	1.36
^{158}Er	26	36	0.09	0.08	0.036	0.027	1.06	1.36
^{160}Er	26	37	0.09	0.07	0.036	0.027	1.06	1.36
^{162}Er	26	39	0.08	0.06	0.036	0.027	1.06	1.36
^{164}Er	26	41	0.07	0.08	0.036	0.027	1.06	1.36

Table 2.The state energies of palladium isotopes (MeV)

J^{π}	^{100}Pd		^{102}Pd		^{104}Pd		^{106}Pd	
	exp.	theor.	exp.	theor.	exp.	theor.	exp.	theor.
Y-band								
2+	0.67	0.69	0.56	0.58	0.56	0.58	0.51	0.54
4+	1.42	1.42	1.28	1.28	1.32	1.32	1.23	1.21
6+	2.19	2.19	2.11	2.07	2.25	2.20	2.08	2.02
8+	2.99	3.01	3.01	2.98	3.22	3.24	2.96	2.96
10+	3.87	3.86	3.99	4.00	-	-	3.95	4.04
12+	4.76	4.76	5.26	5.14	-	-	5.11	5.26
14+	5.71	5.70	-	-	-	-	-	-
γ-band								
2+	1.59	1.51	1.53	1.35	1.34	1.21	1.13	1.06
3+	2.33	2.39	2.12	2.34	1.82	1.99	1.56	1.69
4+	-	2.34	2.13	2.19	2.08	2.03	1.93	1.78
β-band								
0+	-	-	1.59	0,85	1,34	0,67	1,13	0,64
2+	-	-	1,94	2,26	1,79	1,98	1,56	1,74
4+	-	-	2,65	4,21	2,44	3,93	2,36	3,37
8+	3,18	3,24	3,34	3,38	3,42	3,46	-	3,11
10+	4,12	4,05	4,33	4,19	4,02	3,97	3,53	3,53
12+	4,93	4,89	5,06	5,12	4,64	4,62	4,09	4,09
14+	5,73	5,78	6,14	6,16	5,43	5,42	4,89	4,78
16+	6,77	6,77	-	-	6,36	6,37	5,89	5,61
18+	7,64	7,69	-	-	7,42	7,47	-	-
20+	8,72	8,71	-	-	-	-	-	-
4-quasiparticle bands								
4-	-	-	2,29	2,35	-	-	2,31	2,31
6-	-	-	2,91	2,88	-	-	2,70	2,67
8-	-	-	3,76	3,52	-	-	3,18	3,18
10-	-	-	4,32	4,26	-	-	3,87	3,81
12-	-	-	5,09	5,11	-	-	4,64	4,59
14-	-	-	5,98	6,08	-	-	-	-
16-	-	-	6,97	7,14	-	-	-	-
5-quasiparticle bands								
5-	2,50	2,56	2,47	2,52	-	-	2,40	2,40
7-	3,23	3,24	3,19	3,07	-	-	2,79	2,84
9-	4,09	3,90	3,73	3,73	-	-	3,46	3,43
11-	-	4,72	4,43	4,49	-	-	4,26	4,15
13-	5,45	5,52	5,33	5,36	-	-	4,99	5,00
15-	5,92	6,36	6,34	6,35	-	-	-	-
17-	-	-	7,46	7,44	-	-	-	-

Table 3 Reduced probabities of E2-transition

J_i	J_f	^{102}Pd		^{104}Pd		^{106}Pd	
		exp.	theor.	exp.	theor.	exp.	theor.
2_1	0_1	0.090	0.109	0.11	0.105	0.14	0.137
4_1	2_1	0.141	0.150	0.15	0.152	0.22	0.214
2_2	2_1	0.100	0.064	0.10	0.099	-	0.149
4_2	2_2	0.013	0.018	0.06	0.064	0.09	0.103
0_2	2_1	0.001	0.046	0.04	0.038	-	0.087
2_3	0_2	0.049	0.010	-	0.026	0.004	0.047
2_2	0_1	0.010	0.012	0.01	0.028	0.22	0.010
0_2	2_2	0.270	0.262	-	0.153	-	0.223
2_3	0_1	0.001	0	0.001	0	-	0
2_3	2_1	0.004	0.004	0.003	0.011	-	0.004
0_3	2_1	0.038	0.021	0.080	0.056	-	0.021
4_2	2_1	0.009	0.011	0.002	0.029	-	0.011

Table 4 Experimental and calculated spectrum of states ^{158}Er

	exp.	theor.		exp.	theor.		exp.	theor.
0+	0	0	0+	0.99	1.0	2+	0.95	0.96
2+	0.10	0.10	2+	1.09	1.11	3+	1.05	1.06
4+	0.32	0.32	4+	1.28	1.30	4+	1.16	1.18
6+	0.64	0.65	6+	1.55	1.58	5+	1.31	1.32
8+	1.04	1.05	8+	1.89	1.92	6+	1.49	1.51
10+	1.52	1.53				7+	1.68	1.70
12+	2.05	2.07				8+	1.89	1.91
14+	2.61	2.63	γ-band 1					
16+	3.19	3.22						
18+	3.78	4.81						
20+	4.41	4.45				γ-band 2		
22+	5.09	5.14						
24+	5.82	5.90						
26+	6.61	6.66						
			^{158}Er					
Yrast-band								

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