EXCHANGE SPATIAL-ENERGY INTERACTIONS

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The notion of spatial-energy parameter (*P*-parameter) is introduced based on the modified Lagrangian equation for relative motion of two interacting material points, and is a complex characteristic of important atomic values responsible for interatomic interactions and having the direct connection with electron density inside an atom. Wave properties of *P*-parameter are found, its wave equation having a formal analogy with the equation of ψ-function is given. With the help of *P*-parameter technique, numerous calculations of exchange structural interactions have been performed and the applicability of the model for the evaluation of the intensity of fundamental interactions has been demonstrated. Initial theses of quark screw model are also discussed.

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SPATIAL-ENERGY PARAMETER

When oppositely charged heterogeneous systems interact, a certain compensation of the volume energy takes place, which results in the decrease in the resultant energy e.g. during the hybridization of atom orbitals.[1] But this is not a direct algebraic deduction of corresponding energies. The comparison of numerous regularities of physical and chemical processes leads us to assume that in such and similar cases the principle of adding reverse values of volume energies or kinetic parameters of interacting structures are observed. For instance, during the ambipolar diffusion, when joint motion of oppositely charged particles is observed in the given medium (in plasma or electrolyte), the diffusion coefficient (*D*) is found as follows:

$$\frac{\eta}{D} = \frac{1}{a_+} + \frac{1}{a_-}$$

where

a_+ and a_- are the charge mobility of both atoms and η is the constant coefficient.

Total velocity of the topochemical reaction (υ) between the solid and gas is found as follows:

$$\frac{1}{v} = \frac{1}{v_1} + \frac{1}{v_2}$$

where

υ_1 is the diffusion velocity of the reagent and

υ_2 is the velocity of reaction between the gaseous reagent and solid.

Change in the light velocity (Δv) when moving from the vacuum into the given medium is calculated by the principle of algebraic deduction of reverse values of the corresponding velocities:

$$\frac{1}{\Delta v} = \frac{1}{v} - \frac{1}{c}$$

where c is the velocity light in vacuum.

Lagrangian equation for relative motion of the system of two interacting material points with masses m_1 and m_2 in coordinate x is as follows:

$$m_{\text{np}} x'' = \frac{\partial U}{\partial x} \qquad (1)$$

where

$$\frac{1}{m_{\text{r}}} = \frac{1}{m_1} + \frac{1}{m_2} \qquad (1a)$$

here U is the mutual potential energy of material points, m_r is the reduced mass and $x'' = a$ (characteristic of system acceleration).

For elementary interaction areas Δx, $\frac{\partial U}{\partial x} \approx \frac{\Delta U}{\Delta x}$ then

$$m_{\text{r}} a \Delta x = -\Delta U$$

$$\frac{1}{1/(a\Delta x)} \times \frac{1}{(1/m_1 + 1/m_2)} \approx \Delta U$$

or

$$\frac{1}{1/(m_1 a\Delta x) + 1/(m_2 a\Delta x)} \approx \Delta U$$

Since in its physical sense the product $m_i a \Delta x$ equals the potential energy of each material point ($-\Delta U_i$), then

$$\frac{1}{\Delta U} \approx \frac{1}{\Delta U_1} + \frac{1}{\Delta U_2} \qquad (2)$$

Thus the resultant energy characteristic of the interaction system of two material points is found by the principle of adding the reverse values of initial energies of interacting subsystems.

Therefore assuming that the energy of atom valence orbitals (responsible for interatomic interactions) can be calculated by the principle of adding the reverse values of some initial energy components, the introduction of *P*-parameter as the averaged energy characteristic of valence orbitals is postulated based on the following equations.

$$\frac{1}{q^2/r_\mathrm{i}} + \frac{1}{W_\mathrm{i} n_\mathrm{i}} = \frac{1}{P_\mathrm{E}} \tag{3}$$

$$\frac{1}{P_0} = \frac{1}{q^2} + \frac{1}{(Wrn)_\mathrm{i}} \tag{4}$$

$$P_\mathrm{E} = P_0/r_\mathrm{i} \tag{5}$$

here

W_i is the orbital energy of electrons,[2]

r_i is orbital radius of *i*–orbital,[3]

$q=Z^*/n^*$,[4,5]

n_i is the number of electrons of the given orbital,

Z^* and n^* are the effective charge of the nucleus and effective main quantum number, and

r is the bond dimensional characteristics.

The term P_0 will be called spatial-energy parameter (SEP), and e P_E as effective *P*–parameter (effective SEP). Effective SEP has a physical sense of some averaged energy of valence electrons in the atom and is measured in the energy units e.g., in electron-volts (eV).

Values of P_0-parameter are tabulated constant values for the electrons of the atom given orbital.

For the dimensionality, SEP can be written as follows:

$$[P_0] = [q^2] = [E] \times [r] = [h] \times [\upsilon] = \frac{kg\ m^3}{s^2} = Jm$$

where $[E]$, $[h]$ and $[\upsilon]$ are the dimensionalities of energy, Plank's constant and velocity respectively.

The introduction of *P*-parameter should be considered as further development of quasi-classic notions using quantum-mechanical data on the atom structure to obtain the energy conditions criteria of phase-formation. At the same time, for similarly charged systems (e.g. orbitals in the given atom) and homogeneous systems the principle of algebraic addition of these parameters will be preserved.

$$\sum P_\mathrm{E} = \sum (P_0/r_\mathrm{i}) \tag{6}$$

$$\sum P_\mathrm{E} = \frac{\sum P_0}{r} \tag{7}$$

$$\sum P_0 = P_0' + P_0'' + P_0''' + \cdots, \tag{8}$$

$$r \sum P_\mathrm{E} = \sum P_0 \tag{9}$$

Here *P*-parameters are summed for the valence orbitals of all atoms.

To calculate the values of P_E-parameter at the given distance from the nucleus either atomic radius (R) or ionic radius (r_i) can be used instead of r depending on the bond type.

Applying the equation (8) to hydrogen atom we can write down the following

$$K\left(\frac{e}{n}\right)_1^2 = K\left(\frac{e}{n}\right)_2^2 + mc^2\lambda \tag{10}$$

where e is the elementary charge, n_1 and n_2 are the main quantum numbers, m is the electron mass, c is the velocity of electromagnetic wave, λ is the wave length, K is a constant.

Using the known correlations $\nu = c/\lambda$ and $\lambda = h/mc$ (where h is Plank's constant, ν is the wave frequency) from the formula (10), the equation of spectral regularities in hydrogen atom can be obtained, in which $2\pi^2e^2/hc = K$.

EFFECTIVE ENERGY OF VALENCE ELECTRONS IN AN ATOM AND ITS COMPARISON WITH THE STATISTIC MODEL

The modified Thomas-Fermi equation, converted to a simple form by introducing dimensionless variables,[6] can be written as eqn. (11).

$$U = e(V_\mathrm{i} - V_0 + \tau_0^2) \tag{11}$$

where

V_0 is the countdown potential,

e is the elementary charge,

τ_0 is the exchange and correlation corrections,

V_i is the interatomic potential at the distance

r_i from the nucleus and

U is the total energy of valence electrons.

For some elements, the comparisons of the given value U with the values of P_E-parameter are given in Table 1.

As it is seen form the Table 1 the parameter values of U and P_E are practically the same (in most cases with the deviation not exceeding 1-2 %) without any transition coefficients. Multiple corrections introduced into the statistic model are compensated with the application of simple rules of adding reverse values of energy parameters, and SEP quite precisely conveys the known solutions of Thomas-Fermi equation for interatomic potential of atoms at the distance r_i from the nucleus. Namely the following equality takes place:

$$U = P_\mathrm{E} = e(V_\mathrm{i} - V_0 + \tau_0^2) \tag{12}$$

Using the known correlation[6] between the electron density (β_i) and interatomic potential (V_i) we have Eqn. (13).

Table 1. Comparison of total energy of valence electrons in atom calculated in Thomas-Fermi statistic atom model (*U*) and with the help of approximation.

Atom	Valence electrons	r_i (Å)	*X*	φ(X)	*U* (eV)	W_i(eV)	*n*	q^2(eV Å)	P_E (eV)
Ar	$3P^4$	0.639	3.548	0.09-	35.36-	12+	4	73.196	33.45
				0.084	33.02				
	$3S^2$	0.607	3.268	0.122-	47.81	34.8 (*t*)	2	96.107	48.44
				0.105	44.81	29.0	2	96.107	42.45
	$2P^4$	0.146	0.785	0.47	834.25	246	4	706.3	817.12
V	$4S^2$	1.401	8.508	0.0325	7.680	7.5	2	22.33	7.730
			8.23	0.0345	8.151				
Cr	$4S^2$	1.453	8.95	0.0295	7.013	7	2	23.712	7.754
			8.70	0.0313	7.440				
Mn	$4S^2$	1.278	7.76	0.0256	10.89	6.6 (*t*)	2	25.12	7.895
						7.5	2	25.12	10.87
Fe	$4S^2$	1.227	7.562	0.0282	8.598	8.00	2	26.57	9.201
						7.20 (*t*)	2	26.57	8.647
Co	$4S^2$	1.181	7.565	0.02813	9.255	8	2	27.98	10.062
			7.378	0.03075	10.127	7.5 (*t*)	2	27.98	9.187
Ni	$4S^2$	1.139	7.2102	0.02596	9.183	9	2	29.348	10.60
						7.7 (*t*)	2	29.348	9.640
Cu	$4S^2$	1.191	7.633	0.0272	9.530	7.7	2	30.717	9.639
In	$5S^2$	1.093	8.424	0.033	21.30	11.7	2	238.3	21.8
			8.309	0.03415	22.03*				
	$4d^{10}$	0.4805	3.704	0.106	155.6	20	10	258.23	145.8
Te	$5p^4$	1.063	8.654	0.0335	23.59	9.8	4	67.28	24.54
			8.256	0.0346	24.37*				
	$5S^2$	0.920	7.239	0.0326	26.54	19	2	90.577	27.41
			7.146	0.0341	27.72*	17	2	90.537	25.24

Note: (1) Bond energies of electrons W_i are obtained: "*t*" – theoretically (by Hartry-Fock method), "+" – by XPS method, all the rest – by he results of optic measurements; (2) "*" – energy of valence electrons (*U*) calculated without Fermi-Amaldi amendment.

$$\beta^{2/3}{}_i \approx (3e/5) \times (V_i - V_0);$$

$$\beta^{2/3}{}_i \approx Ae \times (V_i - V_0 + \tau^2{}_0) = [Ae \times r_i \times (V_i - V_0 + \tau^2{}_0)]/r_i \quad (13)$$

where A is a constant.

According to the Eqns. (12) and (13) we have the following correlation (Eqn. 14), setting the connection between P_0-parameter and electron density in the atom at the distance r_i from the nucleus.

$$\beta_i^{\frac{2}{3}} = \frac{AP_0}{r_i} \quad (14)$$

Since in the value $e(V_i - V_0 + \tau_0^2)$ in Thomas-Fermi model there is a function of charge density, P_0-parameter is a direct characteristic of electron charge density in atom.

This is confirmed by an additional check of equality correctness (14) using Clementi function.[7] A good correspondence between the values of β_i calculated via the value of P_0 and obtained from atomic functions is observed.

Wave equation of *P*-parameter

For the characteristic of atom spatial-energy properties two types of *P*-parameters with simple correlation between them are introduced, $P_E = P_0/R$, where R is the dimension characteristic of the atom. Taking into account additional quantum characteristics of the sublevels in the atom, this equation in coordinate x can be written down as follows:

$$\Delta P_E \approx \frac{\Delta P_0}{\Delta x}$$

or

$$\partial P_E \approx \frac{\partial P_0}{\partial x}$$

where

the value ΔP equals the difference between P_0-parameter of *i*-orbital and

P_{CD}–countdown parameter (parameter of basic state at the given set of quantum numbers).

According to the established rule[8] of adding *P*-parameters of similarly charged or homogeneous systems for two orbitals in the given atom with different quantum characteristics and in accordance with the law of energy conservation we have

$$\Delta P''_{\mathrm{E}} - \Delta P'_{\mathrm{E}} = P_{\mathrm{E},\lambda}$$

where $P_{E,\lambda}$ is the spatial-energy parameter of quantum transition.

Taking as the dimension characteristic of the interaction $\Delta\lambda=\Delta x$, we have

$$\frac{\Delta P''_0}{\Delta\lambda} - \frac{\Delta P'_0}{\Delta\lambda} = \frac{P_0}{\Delta\lambda} \text{ or } \frac{\Delta P'_0}{\Delta\lambda} - \frac{\Delta P''_0}{\Delta\lambda} = -\frac{P_0\lambda}{\Delta\lambda}$$

If we divide termwise by $\Delta\lambda$, we get

$$\frac{\left(\frac{\Delta P'_0}{\Delta\lambda} - \frac{\Delta P''_0}{\Delta\lambda}\right)}{\Delta\lambda} \sim \frac{d^2P_0}{\Delta\lambda^2}$$

i.e.,

$$\frac{d^2P_0}{d\lambda^2} + \frac{P_0}{\Delta\lambda^2} \approx 0$$

Taking into account the interactions where $2\pi\Delta x = \Delta\lambda$ (closed oscillator), we have the following equation

$$\frac{d^2P_0}{dx^2} + 4\pi^2 \times \frac{P_0}{\Delta\lambda^2} \approx 0$$

then:

, $\Delta\lambda = h/m\upsilon$

$$\frac{d^2P_0}{dx^2} + 4\pi^2 \frac{P_0}{h^2} m^2\nu^2 \approx 0 \text{ or}$$

$$\frac{d^2P_0}{dx^2} + \frac{8\pi^2 m}{h^2} P_0 E_{\mathrm{k}} = 0 \qquad (15)$$

where $E_{\mathrm{k}}=mv^2/2$ electron kinetic energy.

Schrödinger equation for stationary state in coordinate x is

$$\frac{d^2\psi}{dx^2} + \frac{8\pi^2 m}{h^2} \psi E_{\mathrm{k}} = 0 \qquad (16)$$

Comparing the Eqns. (15) and (16) we can see that P_0-parameter correlates numerically with the value of ψ function i.e., $P_0 \approx \psi$ and in general it is proportional to it, $P_0 \propto \psi$. Taking into account wide practical application of *P*-parameter methodology, we can consider this criterion as the materialized analog of ψ-function.

Since P_0-parameters, like ψ-function possess wave properties, the principles of superposition should be executed for them, thus determining the linear character of equations of adding and changing *P*-parameters.

Wave properties of *P*-parameters and principles of their addition

Since *P*-parameter possesses wave properties (by analogy with ψ-function) the regularities of the interference of corresponding waves should be executed mainly with structural interactions.

Minimum interference, oscillation attenuation (in anti-phase), takes place if the difference in wave motion (Δ) equals the odd number of semi-waves:

$$\Delta = (2n+1)\frac{\lambda}{2} = \lambda\left(n + \frac{1}{2}\right),$$

where n = 0, 1, 2, 3, … (17)

As applied to *P*-parameters this rules means that minimum interaction occurs if *P*-parameters of interacting structures are also "in anti-phase" i.e, there is an interaction either between oppositely charged systems or heterogeneous atoms (for example, during the formation of valence-active radicals CH, CH_2, CH_3, NO_2 …, etc).

In this case the summation of *P*-parameters takes place by the principle of adding the reverse values of *P*-parameters as in Eqns. (3) and (4).

The difference in wave motion (Δ) for *P*-parameters can be evaluated via their relative value ($\gamma = P_2/P_1$) or via the relative difference in *P*-parameters (coefficient α), which with the minimum of interactions produce an odd number:

$$\gamma = \frac{P_2}{P_1} = \left(n + \frac{1}{2}\right) = \frac{3}{2}, \frac{5}{2} \ldots \qquad (18)$$

when n = 0 (main state), P_2/P_1 = ½

Let us mention that for stationary levels of one-dimensional harmonic oscillator the energy of these levels $\varepsilon = h\nu(n+½)$, therefore in quantum oscillator, in contrast to a classical one, the minimum possible energy value does not equal zero.

In this model the minimum interaction does not produce the zero energy, corresponding to the principle of adding the reverse values of *P*-parameters (Eqns. 3 and 4). Maximum interference, oscillation amplification (in the phase), takes place if the difference in wave motion equals the even number of semi-waves:

$\Delta = 2n\frac{\lambda}{2} = \lambda n$ or $\Delta=\lambda(n+1)$

As applied to *P*-parameters the maximum amplification of interactions in the phase corresponds to the interactions of similarly charged systems or systems homogeneous in their properties and functions (for example, between the fragments and blocks of complex organic structures, such as CH_2 and NNO_2 in octogen). Then

$$\gamma = \frac{P_2}{P_1} = (n+1) \qquad (19)$$

By the analogy, for "degenerated" systems (with similar values of functions) of two-dimensional harmonic oscillator the energy of stationary states: $\varepsilon = h\nu(n+1)$.

In this model, the maximum interaction corresponds to the principle of algebraic addition of *P*-parameters (Eqns. 6-8). When $n = 0$ (basic state) we have $P_2 = P_1$, or maximum interaction of structures takes place when their *P*-parameters equal. This postulate can be used as the main condition of isomorphic replacements.[8]

STRUCTURAL EXCHANGE SPATIAL-ENERGY INTERACTIONS

In the process of solution formation and other structural interactions the single electron density should be set in the points of atom-component contact. This process is accompanied by the redistribution of electron density between the valence areas of both particles and transition of the part of electrons from some external spheres into the neighbouring ones. Apparently, frame atom electrons do not take part in such exchange.

Obviously, when electron densities in free atom-components are similar, the transfer processes between boundary atoms of particles are minimal, this is favourable for the formation of a new structure. Thus the evaluation of the degree of structural interactions in many cases means the comparative assessment of the electron density of valence electrons in free atoms (on averaged orbitals) participating in the process.

The less is the difference $(P'_0/r'_i - P''_0/r''_i)$, the more favourable is the formation of a new structure or solid solution from the energy point.

In this regard, the maximum total solubility, evaluated via the coefficient of structural interaction, α, is determined by the condition of minimum value α, which represents the relative difference of effective energies of external orbitals of interacting subsystems:

$$\alpha = \frac{P'_0/r'_i - P''_0/r''_i}{(P'_0/r'_i + P''_0/r''_i)/2} 100\ \% \qquad (20)$$

$$\alpha = \frac{P'_S - P''_S}{P'_S + P''_S} 200\ \% \qquad (20a)$$

where P_S, the structural parameter, is found by Eqn. (20).

$$\frac{1}{P_S} = \frac{1}{N_1 P'_E} + \frac{1}{N_1 P''_E} + \cdots \qquad (20b)$$

here N_1 and N_2 are the number of homogeneous atoms in subsystems.

The nomogram of the dependence of structural interaction degree (ρ) on the coefficient α, unified for the wide range of structures was prepared based on all the data obtained. Figure 1 presents such a nomogram obtained using P_E-parameters calculated via the bond energy of electrons (w_i) for structural interactions of isomorphic type.

The mutual solubility of atom-components in many (over a thousand) simple and complex systems have been evaluated earlier using this technique. The calculation results are in compliance with theoretical and experimental data.[8]

Isomorphism as a phenomenon is used to be considered as applicable to crystalline structures. But similar processes can obviously take place between molecular compounds, where their role and importance are not less than those of purely coulomb interactions.

In complex organic structures during the interactions the main role can be played by separate "blocks" or fragments. Therefore, it is necessary to identify these fragments and evaluate their spatial-energy parameters. Based on the wave properties of *P*-parameter, the overall *P*-parameter of each fragment can be found by the principle of adding the reverse values of initial *P*-parameters of all atoms. The resultant *P*-parameter of the fragment block or all the structure is calculated by the rule of algebraic addition of *P*-parameters of the fragments constituting them.

The role of the fragments can be played by valence-active radicals, e.g. CH, CH_2, OH^-, NO, NO_2, SO_4^{2-}, etc. In complex structures the given carbon atom usually has two or three side bonds. During the calculations by the principle of adding the reverse values of *P*-parameters, the priority belongs to those bonds, for which the condition of minimum interference is better performed. Therefore the fragments of the bond C-H (for CH, CH_2, CH_3 …) are calculated first, then separately the fragments N-R, where *R* is the binding radical (for example – for the bond C-N).

Apparently spatial-energy exchange interactions (SEI) based on equalizing electron densities of valence orbitals of atom-components have in nature the same universal value as purely electrostatic coulomb interactions, but they supplement each other. Isomorphism, known from the time of E. Mitscherlich (1820) and D.I. Mendeleev (1856), is only a particular manifestation of this general natural phenomenon. The numerical side of the evaluation of isomorphic replacements of components both in complex and simple systems rationally fit in the frameworks of *P*-parameter methodology. More complicated is to evaluate the degree of structural SEI for molecular, including organic structures. The technique for calculating *P*-parameters of molecules, structures and their fragments has been successfully implemented.

But such structures and their fragments are frequently not completely isomorphic with respect to each other. Nevertheless there is SEI between them, the degree of which in this case can be evaluated only semi-quantitatively or qualitatively. By the degree of isomorphic similarity all the systems can be divided into the following three types.

(1) Systems mainly isomorphic to each other i.e., systems with approximately identical number of dissimilar atoms and nearly similar geometrical shapes of interacting orbitals.

(2) Systems with the limited isomorphic similarity i.e, systems which either (a) differ by the number of dissimilar atoms but have nearly similar geometrical shapes of interacting orbitals, or (b) have definite differences in geometrical shapes of orbitals but have identical number of interacting dissimilar atoms.

(3) Systems not having isomorphic similarity i.e., systems, which differ considerably both by the number of dissimilar atoms and geometric shapes of their orbitals.

Then taking into account the experimental data, all types of SEI can be approximately classified as follows.

Systems (1): (i) α < 0-6 %, ρ = 100 %. Complete isomorphism, there is complete isomorphic replacement of atom-components, (ii) 6 % < α < 25-30 %, ρ = 98 – (0-3) %. There is either a wide or limited isomorphism according to nomogram 1. (iii) α > 25-30 %, no SEI.

Systems (2): (i) α < 0-6 %, (a) there is the reconstruction of chemical bonds, can be accompanied by the formation of a new compound, (b) breakage of chemical bonds can be accompanied by separating a fragment from the initial structure, but without attachments or replacements. (ii) 6 % < α < 25-30 %, limited internal reconstruction of chemical bonds without the formation of a new compound or replacements is possible and (iii) α > 20-30 %, no SEI.

Systems (3): (i) α < 0-6 %, (*a*) limited change in the type of chemical bonds of the given fragment, internal regrouping of atoms without the breakage from the main part of the molecule and without replacements, (*b*) change in some dimensional characteristics of the bond is possible. (ii) 6 % < α < 25-30 %, very limited internal regrouping of atoms is possible and (iii) α > 25-30 %, no SEI.

Nomogram (Figure 1) is obtained for isomorphic interactions for systems of types (1) and (2).

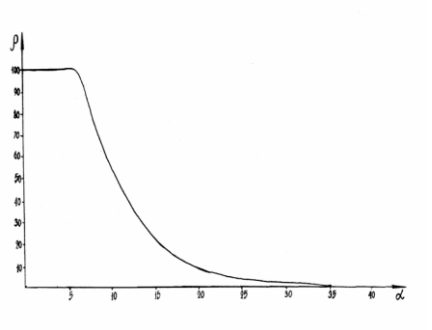

Figure 1. Dependence of the structural interaction degree (ρ) on the coefficient α

In all other cases the calculated values α and ρ refer only to the given interaction type, the nomogram of which can be clarified by reference points of etalon systems. If we take into account the universality of spatial-energy interactions in nature, this evaluation can be significant for the analysis of structural rearrangements in complex biophysical-chemical processes.

Fermentative systems contribute a lot to the correlation of structural interaction degree. In this system the ferment structure active parts (fragments, atoms, ions) have the value of P_E-parameter that is equal to P_E-parameter of the reaction final product. This means the ferment is structurally "tuned" via SEI to obtain the reaction final product, but it will not induced into it due to the imperfect isomorphism of its structure in accordance with (3).

The most important characteristics of atomic-structural interactions (mutual solubility of components, energy of chemical bond, energetics of free radicals, etc) were evaluated in many systems using this technique.[8-15]

TYPES OF FUNDAMENTAL INTERACTIONS

According to modern theories, the main types of interactions of elementary particles, their properties and specifics are mainly explained by the availability of special complex currents e.g., electromagnetic, proton, lepton, etc. Based on the foregoing model of spatial-energy parameter the exchange structural interactions finally come to flowing and equalizing the electron densities of corresponding atomic-molecular components. The similar process is obviously appropriate for elementary particles as well. It can be assumed that in general case interparticle exchange interactions come to the redistribution of their energy masses, *M*.

The elementary electrostatic charge associated with the electron as a carrier is the constant of electromagnetic interaction. Therefore for electromagnetic interaction we will calculate the system proton-electron.

For strong internucleon interaction that comes to the exchange of π-mesons, let us consider the systems nuclides-π-mesons. Since the interactions can take place with all three mesons (π^-, π^0 and π^+), we take the averaged mass in the calculations ($\langle M \rangle$ = 136,497 MeV s^{-1}).

Rated systems for strong interaction are

$$P - (\pi^-, \pi^0, \pi^+), (P\text{-}n) - (\pi^-, \pi^0, \pi^+)$$

and

$$(n\text{-}P\text{-}n) - (\pi^-, \pi^0, \pi).$$

Neutrino (electron, muonic) and its antiparticles were considered as the main representatives of weak interaction.

Dimensional characteristics of elementary particles (*r*) were evaluated in femtometer units (1 fm = 10^{-15} m) by the data presented earlier.[16]

At the same time, the classic radius, $r_e=e^2/m_e s^2$, was used for electron, where e is the elementary charge, m_e is the electron mass and s is the speed of light in vacuum. The fundamental Heisenberg length (6.690×10^{-4} fm) was used as the dimensional characteristic of weak interaction for neutrino.[16]

The gravitational interaction was evaluated via the proton P-parameter at the distance of gravitational radius (1.242×10^{-39} fm).

In the initial eqn. (3) for free atom, P_0-parameter is found by the principle of adding the reverse values q^2 and w_r, where q is the nucleus electric charge, w is the bond energy of the valence electron. Modifying the Eqn. (3), as applied to the interaction of free particles, we receive the addition of reverse values of parameters $P = Mr$ for each particle by Eqn. (21).

$$1/P_0 = 1/(Mr)_1 + 1/(Mr)_2 + \quad (21)$$

where M is the energy mass of the particle (MeV s^{-2}).

By using Eqn. (21) and the earlier data,[16] P_0-parameters of coupled strong and electromagnetic interactions were calculated in nuclides-π-mesons (P_n-parameters and proton-electron , P_e-parameter).

For weak and gravitational interactions only the parameters $P_\upsilon = Mr$ and $P_r = Mr$ were calculated, as in accordance with the Eqn. (21), the similar nuclide parameter with greater value does not influence the calculation results.

The relative intensity of interactions (Table 2) was found by the equations for the following interactions.

$$\text{Strong } \alpha_B = <P_n>/P_n >= P_n/P_n = 1 \quad (22a)$$

$$\text{Electromagnetic } \alpha_B = P_e/<P_n> = 1/136.983 \quad (22b)$$

$$\text{Weak } \alpha_B = P_e/<P_n>,$$

$$\alpha_B = 2.04 \times 10^{-10}, 4.2 \times 10^{-6} \quad (22c)$$

$$\text{Gravitational } \alpha_B = P_e/<P_n> = 5.9 \times 10^{-39} \quad (22d)$$

In the calculations for $\alpha_в$, the value of P_n-parameter was multiplied by the value equaled $2\pi/3$, i.e. $<P>=(2\pi/3)P_n$. Number 3 for nuclides consisting of three different quarks is "a magic" number (see the next section for details). As it is known, number 2π has a special value in quantum mechanics and physics of elementary particles. In particular, only the value of 2π correlates theoretical and experimental data when evaluating the sections of nuclide interaction with each other.[17]

As it has been reported,[18] nuclear interactions are distinguished as very strong, strong and moderately strong. For all particles in the large group with relatively similar mass values of mass, unitary multiplets or supermultiplets, very strong interactions are similar.[18] In the frames of the given model a very strong interaction between the particles corresponds to the maximum value of P-parameter, $P = Mr$ (coupled interaction of nuclides). Taking into consideration the equality of dimensional characteristics of proton and neutron, by eqn. (21), we obtain the values of P_n-parameter as 401.61; 401.88 and 402.16 (MeVfm s^{-2}) for coupled interactions *p-p*, *p-n* and *n-n*, respectively, thus obtaining the average value $\alpha_B = 4.25$. It is a very strong interaction. For eight interacting nuclides $\alpha_B \approx 1.06$ i.e., a strong interaction.

When the number of interacting nuclides increases, α_B decreases – moderately strong interaction. Since the nuclear forces act only between neighbouring nucleons, the value α_B cannot be very small.

The expression of the most intensive coupled interaction of nuclides is indirectly confirmed by the fact that the life period of double nuclear system appears to be much longer than the characteristic nuclear time.[19]

Thus it is established that the intensity of fundamental interactions is evaluated via P_n-parameter calculated by the principle of adding the reverse values in the system nuclides-π-mesons. Therefore, it has the direct connection with Plank's constants.

$$(2\pi/3)P_n \approx Er = 197.3 \text{ MeVfm}s^{-2} \quad (23)$$

$$(2\pi/3)P_т \approx M_n\lambda_k = 197.3 \text{ MeVfm}s^{-2} \quad (23a)$$

where

E and r, Plank's energy and Plank's radius are calculated via the gravitational constant,

M_n, λ_k, energy mass and nuclide Compton wave-length.

In Eqn. (21), the exchange interactions are evaluated via the initial P-parameters of particles equaled to the product of mass by the dimensional characteristic i.e., $P = Mr$.

Since these P-parameters can refer to the particles characterizing fundamental interactions, their direct correlation defines the process intensity degree (α_B):

$$\alpha_B = \frac{P_i}{P_n} = \frac{(Mr)_i}{(Mr)_n} \quad (24)$$

The calculations by the Eqn. (24), using the known Plank's values and techniques are given in table 3. As before, the energy and dimensional characteristics are taken from the literature.[16]

The results obtained are in accordance with theoretical and experimental data.[20,21]

ON QUARK SCREW MODEL

Let us proceed from the following theses and assumptions:

(i) By their structural composition macro- and micro world resemble. One part has some similarity with the other: solar system – atom – atom nucleus – quarks.

(ii) All parts of this "matroshka" are structural formations.

Table 2. Types of fundamental interactions

Interaction type		M, $\langle M \rangle$ MeVs^{-2}	r fm	Elementary particles	M, $\langle M \rangle$ MeVs^{-2}	r fm	P_n, P_e, P_ν, P_g *MeVfms*$^{-2}$	$2\pi/3P_n = \langle P_n \rangle$	α_B, $\langle \alpha_B \rangle$ (Eqn. 22)	α_B (experimental)
Electromagnetic	*P*	938.28	0.856	e^-	0.5110	2.8179	P_e=1.4374	-	1/136.983	1/137.04
Strong	*P*	938.28	0.856	π^-, π^0, π^+	136.497	0.78	P_n=94.0071	196.89	1	1
	P-n	938.92	0.856	π^-, π^0, π^+	136.497	0.78	P_n=94.015	196.90	1	1
	n-P-n	939.14	0.856	π^-, π^0, π^+	136.497	0.78	P_n=94.018	196.91	1	1
Weak				υ_e, $\overline{\upsilon_e}$	$<6 \times 10^{-5}$	6.69×10^{-4}	P_ν=4.014·10^{-8}		$<2.04 \times 10^{-10}$	10^{-10} - 10^{-14}
				υ_μ, $\overline{\upsilon_e}$	<1.2	6.69×10^{-4}	P_ν=8.028 ×10^{-4}		$<4.2 \times 10^{-6}$	10^{-5} - 10^{-6}
Gravitational	*P*	938.28	1.242×10^{-39}				P_c=1.17 × 10^{-36}		5.9×10^{-39}	10^{-38} - 10^{-39}

Table 3. Evaluation of the intensity of fundamental interactions using Plank's constants and parameter $P = Mr$.

Interaction type	Particles, constants	M MeVs^{-2}	r fm	Mr MeVs^{-2}	$\alpha_B = Mr/(Mr)_p$ (calculated)	α_B (experimental)
Strong	Proton	938.28	λ=0.2103	197.3	1	1
	Plank's values	1.221×10^{22}	1.616×10^{-20}	197.3		
Electromagnetic	electron	0.5110	2.8179	1.43995	1/137.02	1/137.036
Weak	$U_e\overline{\upsilon_e}$	$<6 \times 10^{-5}$	6.69×10^{-4}	$<4.014 \times 10^{-8}$	$<2.03 \times 10^{-10}$	10^{-10}- 10^{-14}
	$U_u\overline{\upsilon_e}$	<1.2	$6.69 \cdot 10^{-4}$	$<8.028 \cdot 10^{-4}$	$<4.07 \cdot 10^{-6}$	10^{-5} - 10^{-6}
Gravitational	Proton	938.28	1.242×10^{-39} Gravitational radius	1.165×10^{-36}	5.91×10^{-39}	10^{-38} - 10^{-39}

(iii) Main property of all systems is motion, translatory, rotary and oscillatory.

(iv) Description of these motions can be done in Euclid three-dimensional space with coordinates *x*, *y* and *z*.

(v) Exchange energy interactions of elementary particles are carried out by the redistribution of their energy mass *M* (MeVs^{-2}).

Based on these theses we suggest discussing the following screw model of the quark.

(i) Quark structure is represented in certain case as a spherical one, but in general quark is a flattened (or elongated) ellipsoid of revolution. The revolution takes place around the axis (*x*) coinciding with the direction of angular speed vector, perpendicular to the direction of ellipsoid deformation.

(ii) Quark electric charge (*q*) is not fractional but is an integer, but redistributed in three-dimensional space with its virtual concentration in the directions of three coordinate axes. Each axis having an electric charge = *q*/3.

(iii) Quark spherical or deformed structure has all three types of motion. Two of them, rotary and translator, are in accordance with the screw model, which beside these two motions, also performs an oscillatory motion in one of three mutually perpendicular planes, xoy, xoz, yoz (Figure 2).

(iv) Each of these oscillation planes corresponds to the symbol of quark color, e.g. red for *xoy*, blue for *xoz* and green for *yoz*.

(v) Screw can be "right" or "left". This directedness of screw rotation defines the sign of quark electric charge. Let us assume that the left screw corresponds to positive and right to negative quark electric charge.

(vi) Total number of quarks is determined by the following scheme: for each axis (*x*, *y* and *z*) of translator motion two screws (right and left) with three possible oscillation planes.

(vii) We have 3 × 2 × 3 = 18 quarks. Besides, there are 18 antiquarks with opposite characteristics of screw motions. In all there are thus 36 types of quarks.

These quark numbers can be considered as realized degrees of freedom of all three motions (3 translatory + 2 rotary + 3 oscillatory).

Translatory motion is preferable by its direction, coinciding with the direction of angular speed vector. Such elementary particles constitute our World. The reverse direction is less preferable, this is "Antiworld".

Motion along axis x in the direction of the angular speed vector, perpendicular to the direction of ellipsoid deformation, is apparently less energy consumable and corresponds to the quarks *U* and *d*, forming nuclides.

Such assumption is in accordance with the values of energy masses of quarks in the composition of andirons, 0.33. 0.33, 0.51, 1.8, 5 in $GeVs^{-2}$ for *d, u, s, c, b, t* types of quarks, respectively.

The quark screw model can be proved by other calculations and comparisons also.

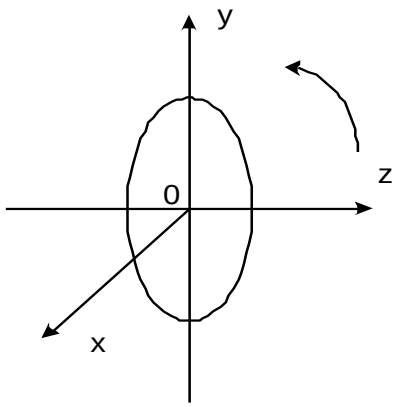

Figure 2. Structural scheme of quark in section *yoz*.

CALCULATION OF ENERGY MASS OF FREE NUCLIDE (TAKING NEUTRON AS AN EXAMPLE)

Neutron has 3 quarks d_1-*u*-d_2 with electric charges -1, +2, -1, distributed in three spatial directions, respectively. Quark *u* cements the system electrostatically. Translatory motions of the screws d_1-*u*-d_2 proceed along axis x, but oscillatory ones proceed in three different mutually perpendicular planes (Pauli principle is realized).

Apparently, in the first half of oscillation period *u*-quark oscillates in the phase with d_1-quark, but in the opposite phase with d_2-quark. In the second half of the period everything is vice versa. In general such interactions define the geometrical equality of directed spatial-energy vectors, thus providing the so-called quark discoloration.

The previously formulated rules of adding *P*-parameters spread to both types of *P*-parameters (P_0 and P_E). In this case, there is an additional energy P_E-parameters, since the subsystems of interactions possess similar dimensional characteristics. As both interactions are realized inside the overall system, P_E-parameters are added algebraically, and more accurately, in this case, geometrically by the following formula

$$\frac{M}{2} = \sqrt{m_1^2 + m_2^2}$$

where, *M* is the energy mass of free neutron, $m_1 = m_2 = 330$ $MeVs^{-2}$ masses of quarks *u* and *d* (in the composition of androns).

The calculation gives $M = 933.38$ $MeVs^{-2}$. This is for strong interactions. Taking into account the role of quarks in electromagnetic interactions,[21] we get the total energy mass of a free neutron as M=933.38+933.38/137=940.19 $MeVs^{-2}$. With the experimental value $M = 939.57$ $MeVs^{-2}$ the relative error in calculations is 0.06 %.

CALCULATION OF BOND ENERGY OF DEUTERON VIA THE MASSES OF FREE QUARKS

The particle deuteron is formed during the interaction of a free proton and neutron. The bond energy is usually calculated as the difference of mass of free nucleons and mass of a free deuteron. Let us demonstrate the dependence of deuteron bond energy on the masses of free quarks. The quark masses are added algebraically in the system already formed, in proton $m_1 = 5 + 5 + 7 = 17$ $MeVs^{-2}$, in neutron $m_2 = 7 + 7 + 5 = 19$ $MeVs^{-2}$. As a dimensional characteristic of deuteron bond we take the distance corresponding to the maximum value of nonrectangular potential pit of nucleon interaction. By the graphs experimentally obtained we know that such distance approximately equals 1.65 fm. Exchange energy interactions of proton and neutron heterogeneous systems are evaluated based on the Eqn. (21). Then we have:

$$1/ (M_C\, 1.65\, K) = 1/(17 \cdot 0.856) + 1/(19 \cdot 0.856),$$

where $K = 2\pi/3$. Based on the calculations we have $M_C = 2.228$ $MeVs^{-2}$, this practically coincides with reference data[20] ($M_C = 2.225$ $MeVs^{-2}$).

After modification, the basic theses of quark screw model can be applied to other elementary particles (proton, electron, neutron, etc) also. For instance, an electrically neutral particle neutron can be considered as a mini-atom, the analog of hydrogen atom.

CONCLUSIONS

(1) The notion of spatial-energy parameter (*P*-parameter) is introduced based on the simultaneous accounting of important atomic characteristics and modified Lagrangian equation.

(2) Wave properties of *P*-parameter are found, its wave equation formally similar to the equation of ψ-function is obtained.

(3) Applying the methodology of *P*-parameter

(a) most important characteristics of exchange energy interactions in different systems have been calculated

(b) intensities of fundamental interactions have been calculated and

(c) initial theses of quark screw model have been given.

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