CORPUSCULAR-WAVE PROCESSES IN QUANTUM TRANSITIONS

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Two principles of adding energy characteristics of structural interactions are fulfilled if the process flows either along the potential gradient or against it. Transforming these rules onto the corpuscular-wave dualism, we can assume that corpuscular interactions flow along the potential gradient (principle of adding reciprocals of energies), and wave processes – against the potential gradient (principle of algebraic addition of energies). Such approach is confirmed by the empiric equation, in which the act of quantum action is narrowed to the energy redistribution in the system "particle-wave". It is demonstrated that the angular vector of rotational-translation motion of electrons at quantum transitions changes in compliance with the quantum number of the square tangent of this angle.

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Introduction

The problem of quantum-wave dualism was mainly solved in the period of quantum mechanics development. Thus, the application of de Broglie equation allows defining the borders of such phenomena. But the predominating property depends on the process conditions. And it is quite complicated to find out which of them will operate in each particular case, although it is known that the wave pattern more often takes place at low energies, and corpuscular at high ones.

According to Max Born each process can be interpreted either from the corpuscular or wave point. However, it is very difficult to prove that whether one is dealing with particles or waves since all the characteristic properties of the process cannot be defined. Therefore, wave and corpuscular descriptions should be considered as two ways of considering one and the same objective process complementing each other.[1]

Thus, these problematic issues of quantum-wave dualism need to be further investigated and discussed. In this paper the attempt is made to clarify them from the point of the notions of space-energy interactions.

Results and Discussion

Principles of adding energy characteristics of interactions

The analysis of kinetics of various physical and chemical processes shows that in many cases the reciprocals of velocities, kinetic or energy characteristics of the corresponding interactions are added.

In particular, such supposition is confirmed by the formula of electron transport possibility (W_∞) due to the overlapping of wave functions 1 and 2 (in steady state) during electron-conformation interactions (eqn.1).

$$W_\infty = \frac{1}{2}\frac{W_1 W_2}{W_1 + W_2} \tag{1}$$

Eqn. (1) is used for evaluating the characteristics of diffusion processes followed by non-radiating transport of electrons in proteins.[2]

From classical mechanics it is known that the relative motion of two particles with the interaction energy $U(r)$ takes place as the motion of material point with the reduced mass μ in the field of central force $U(r)$, and general translational motion as a free motion of material point with the mass (eqn. 2 and 3)

$$\frac{1}{\mu} = \frac{1}{m_1} + \frac{1}{m_2} \tag{2}$$

$$m = m_1 + m_2 \tag{3}$$

Such things take place in quantum mechanics as well.[3]

For dynamic thermodynamic systems, the first commencement of thermodynamics is as follows.

$$\delta E = d\left(U + \frac{mv^2}{2}\right) \pm \delta A \tag{4}$$

where δE is the amount of energy transferred to the system, element $d(U + mv^2/2)$ characterizes the changes in internal and kinetic energies of the system, $+\delta A$ is the work performed by the system and $-\delta A$ is the work performed with the system.

Table 1. Directedness of the interaction processes.

No.	Systems	Type of potential field	Process	U	r_2/r_1 x_2/x_1	U_2/U_1	Sign ΔU	Sign δA	Gradient
1	opposite electrical charges	electrostatic	attraction	$-k\,(q_1q_2/r)$	$r_2 < r_1$	$U_2 > U_1$	-	+	along the gradient
			repulsion	$-k\,(q_1q_2/r)$	$r_2 > r_1$	$U_2 < U_1$	+	-	against the gradient
2	similar electrical charges	electrostatic	attraction	$k\,(q_1q_2/r)$	$r_2 < r_1$	$U_2 > U_1$	+	-	against the gradient
			repulsion	$k\,(q_1q_2/r)$	$r_2 > r_1$	$U_2 < U_1$	-	+	along the gradient
3	elementary masses m_1 and m_2	gravitational	attraction	$-\gamma(m_1m_2/r)$	$r_2 < r_1$	$U_2 > U_1$	-	+	along the gradient
			repulsion	$-\gamma(m_1m_2/r)$	$r_2 > r_1$	$U_2 < U_1$	+	-	against the gradient
4	spring deformation	field of elastic forces	compression	$k(\Delta x^2/2)$	$x_2 < x_1$	$U_2 > U_1$	+	-	against the gradient
			extension	$k(\Delta x^2/2)$	$x_2 > x_1$	$U_2 > U_1$	+	-	against the gradient
5	photoeffect	electrostatic	repulsion	$k\,(q_1q_2/r)$	$r_2 > r_1$	$U_2 < U_1$	-	+	along the gradient

As the work value numerically equals the change in the potential energy, therefore,

$$+\delta A = -\Delta U \qquad (5)$$

$$-\delta A = +\Delta U \qquad (6)$$

It is probable that not only in thermodynamic but in many other processes in the dynamics of interaction of moving particles, not only the value of potential energy is critical, but its change as well. Therefore the following criteria should be fulfilled for two-particle interactions (eqn. 7),

$$\delta E = \left(\frac{m_1 v_1^2}{2} + \frac{m_2 v_2^2}{2}\right) \pm \Delta U \qquad (7)$$

Here

$$\Delta U = U_2 - U_1 \qquad (8)$$

where U_2 and U_1 are the potential energies of the system in final and initial states.

The character of the change in the potential energy value ΔU was analyzed by its sign for various potential fields and the results are given in table 1.

From the table it is seen that the values $-\Delta U$ and accordingly $+\delta A$ (positive work) correspond to the interactions taking place along the potential gradient, and ΔU and $-\delta A$ (negative work) occur during the interactions against the potential gradient.

The solution of two-particle task of the interaction of two material points with masses m_1 and m_2, obtained under the condition of the absence of external forces, corresponds to the interactions flowing along the gradient, the positive work is performed by the system (similar to the attraction process in the gravitation field).

The solution of this equation via the reduced mass, μ, is the Lagrange equation for the relative motion of the isolated system of two interacting material points with masses m_1 and m_2, which in coordinate x is as follows:

$$\mu \cdot x'' = -\frac{\partial U}{\partial x} \qquad\qquad \frac{1}{\mu} = \frac{1}{m_1} + \frac{1}{m_2}$$

Here U is the mutual potential energy of material points and μ is reduced mass. At the same time, $x'' = a$ (feature of the system acceleration). For elementary portions of the interactions Δx can be represented as follows:

$$\frac{\partial U}{\partial x} \approx \frac{\Delta U}{\Delta x}$$

That is

$$\mu a \Delta x = -\Delta U.$$

Then

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

$$\frac{1}{(1/(m_1 a\Delta x) + 1/(m_2 a\Delta x))} \approx -\Delta U \qquad (9)$$

$$\frac{1}{\Delta U} \approx \frac{1}{\Delta U_1} + \frac{1}{\Delta U_2} \qquad (10)$$

where ΔU_1 and ΔU_2 are the potential energies of material points on the elementary portion of interactions and ΔU is the resulting potential energy of this mutual interactions.

Therefore, one can conclude that

1. In the systems in which the interactions proceed along the potential gradient (positive performance), the resulting potential energy is found to be based on the principle of addition of reciprocals of the corresponding energies of subsystems.[4] Similarly, the reduced mass for the relative motion of two-particle system is calculated.

2. In the systems in which the interactions proceed against the potential gradient (negative performance), the algebraic addition of their masses as well as the corresponding energies of subsystems is performed (by the analogy with Hamiltonian).

From the equation (10) it is seen that the resulting energy characteristic of the system of two material points interaction is found based on the principle of addition of reciprocals of initial energies of interacting subsystems.

Electron with the mass m moving near the proton with the mass M is equivalent to the particle with the mass[5] μ i.e.

$$\mu = \frac{mM}{m+M}$$

Therefore when modifying the eqn. (10), we can assume that the energy of atom valence orbitals (responsible for interatomic interactions) can be calculated[6] by the principle of adding reciprocals of some initial energy components based on the following equations:

$$\frac{1}{q^2/r_i} + \frac{1}{W_i n_i} = \frac{1}{P_E} \qquad (11)$$

$$\frac{1}{P_0} = \frac{1}{q^2} + \frac{1}{(Wrn)_i} \qquad (12)$$

or

$$P_E = P_0/r_i \qquad (13)$$

Here W_i is the electron orbital energy,[7] r_i is the orbital radius of i–orbital,[8] $q = Z^*/n^*$,[9] n_i is the number of electrons of the given orbital, Z^* and n^* are the effective nucleus charge and effective main quantum number, and r is the bond dimensional characteristics.

For a free electron $P = P_E = Wr$, where $W = 0.510034$ MeV or 0.81872 J.

As the dimensional characteristic, we used the value of electron classic radius $r = 2,81794 \times 10^{-15}$ m and, therefore, $P_E = 2,30712 \times 10^{-28}$ J m.

Act of quantum action

The formulation of eqns. 10, 11 and 12 is not principally new. Already in 1924 the following equation was obtained based on Compton's effect

$$\frac{1}{h\nu'} = \frac{1}{h\nu} + \frac{1-cos\theta}{mc^2} \qquad (14)$$

Here $h\nu'$ is the energy of scattered photon, $h\nu$ is the energy of incident photon, mc^2 is the own energy of electron, θ is the scattering angle. At the same time, the energy of photons decreases by the value additionally obtained by the electron. In this way the act of quantum action takes place, resulting in the energy redistribution between the corpuscular and wave properties of the interacting systems.

It is even easier, if the action proceeds during the interaction of the pair of similar particles. During the interaction along the potential gradient (corpuscular mechanism) the resultant energy $W_k = W/2$. If this process goes against the gradient (wave movement), the total energy $W_w = 2W$. The ratio between them $W_w/W_k = 4$.

Electric current is the motion of electrons along the potential gradient. If we assume that the magnetic field generated by them is the wave process, the ratio between the electric and magnetic constants needs to contain this digit 4, which is confirmed in the following empirical equation:

$$h = \left(\frac{4+2\alpha}{2\pi}\right)^2 P_e \frac{\varepsilon}{\mu} \qquad (15)$$

Here ε is the electric constant, μ is the magnetic constant, h is Plank's constant and α is fine structure constant, a parameter characterizing the interactions of quantum electron-positron and electromagnetic fields. Number π is determined by the ratio between the rotational motion (circle perimeter) and translational motion (length of diameter).

Size α can pay off on the equation:

$$\alpha = \frac{P_e}{E_P \lambda}, \qquad (15a)$$

where E_P - energy of a proton and λ – compton wavelength. The percentage error of calculations in this equation is about 0.06 %.

The proportionality coefficient in the eqn. (15) has the dimension of velocity (m s^{-1}) for the ratio (F/Hn), i.e. in such way the rate of energy redistribution in the system "particle-wave" is characterized.

Table 2. Energies of quantum transitions.

Atom	Transition	W_1 (eV)	W_2 (eV)	ΔW (J)	W_k (J)	λ (A⁰) *	$h\nu$ (J)
C(IV)	2s-2p	19.201	11.792	11.871	11.705	1549	12.824
N(V)	2s-2p	25.724	15.445	16.469	15.462	1238	16.046
O(VI)	2s-2p	33.859	17.195	26.699	18.267	1031	19.267
Al(III)	3s-3p	10.706	5.7130	7.9997	5.9886	1854	10.7145
Si(IV)	3s-3p	14.690	8.0848	10.583	8.3554	1393	14.260
C(III)	2s²-2s2p	19.201·2	19.201+11.792	11.871	27.480	977	20.332
N(IV)	2s²-2s2p	25.724·2	25.724+15.445	16.469	36.638	765	25.967
Si(III)	3s²-3s3p	14.690·2	14.690+8.0848	10.583	20.557	1206	16.4715
Al(II)	3s²-3s3p	10.706·2	10.706+5.7130	7.9997	14.889	1670	11.895

* Reference 11

Table 3. Quantization of the geometry of structural transitions

Atom	Transition	$\varphi = h\nu/W_k$	$\langle\varphi\rangle$	K	$\theta°$	$\langle\theta\rangle$	$\langle 4/3\,\theta°\rangle$	Functions of square tangent (k)
C(IV)	2s-2p	1.0956	60.9°	2	54.45°	60.02°	-	$tg^2\varphi_r = 2$
N(V)	2s-2p	1.0377		2	59.67°			
O(VI)	2s-2p	1.0547		2	65.93°			
Al(III)	3s-3p	1.7951	$\varphi_g° + 45.47° = 100.2°$	3 = 2+1	45.45°	46.2°	61.6°	$tg^260° = 3$
Si(IV)	3s-3p	1.7067		3 = 2+1	47.02°			
C(III)	2s²-2s2p	0.7399	43.1°	1	31.97°	31.7°	42.27°	$tg^245° = 1$
N(IV)	2s²-2s2p	0.7087		1	35.38°			
Si(III)	3s²-3s3p	0.8013		1	29.27°			
Al(II)	3s²-3s3p	0.7589		1	30.17°			

Therefore, the act of quantum action expressed via Plank's constant is narrowed to the energy equilibrium-exchange redistribution between the corpuscular and wave processes.

Generalizing the formalism of eqns. (10 and 15) onto all other interactions flowing along the potential gradient, we can make the conclusion that corpuscular processes take place in these cases, and wave dualism corresponds to the interactions against the potential gradient.

Angle of electron winding

It is known that a particle can have three main motions: translational, rotational and oscillatory. But quantum mechanics does not consider the issue of electron trajectory as we can speak only of the possibility of its location in the given point in space.

But an electron also moves if this translational motion goes along the potential gradient, then it correspond to corpuscular process, and rotational motion to wave one. The correlation of these energy redistribution acts depends on the values of initial energy criteria of the subsystems. During quantum transitions these can be orbital bond energies of the corresponding levels.

Thus, the main parameters of quantum transitions are as follows:

1. Energy of electromagnetic wave of quantum transition follows Plank's equation, $E=h\nu$, where ν is the electromagnetic wave frequency, in such a way that the oscillatory motion demonstrates itself in quantum transitions, since the electromagnetic wave itself is the process of distribution of the corresponding oscillations.

2. Difference of bond energies of electrons on different energy level of transition, $\Delta W = W_2 - W_1$.

3. Resultant energy of their corpuscular interaction:

$$\frac{1}{W_k} = \frac{1}{W_1} + \frac{1}{W_2} \qquad (16)$$

Let us consider some important macroprocesses in this case. The silkworm winds the natural (organic) silk thread only at a definite rotation angle. In cosmonautics the cellulose-viscose thread is wound around the metal cylinder of the spaceship following the special technology, and, what is important, at the same winding angle as the silkworm. The spaceship becomes most durable, more technologically high-quality and lighter.[10] We can also speak of other examples of such phenomenon.

This angle (mainly as applicable to organic systems) was called the geodesic angle: $\varphi_g = 54.73°$ or $54°44'$.

In a general case, the winding angle (θ) is the angle between the geodesic line and vector of rotational motion.

The geodesic line is the shortest distance between two points in a geometric figure of rotation. Besides, planets are also rotating around the sun along the geodesic line. For five primary planets the angle between the axis of rotation and orbit equals from 62° up to 66.5°. The earth θ apparently taking into account also the influence of moon is 66°33'. The sun has the same value Θ. In astronomic terms: obliquity of the sum ecliptic and obliquity of the earth equator to the orbit are numerically the same and equal 22°27'. Isn't it the reason of special efficiency of solar action on the earth biophysical processes?

Nitrogen, oxygen, hydrogen and, most important, carbon are the main elements of organic materials. Carbon is a specific element, capable of easier hybridization of atomic orbitals with the quantum transition 2s-2p. Therefore, when temperature and pressure rise, the conditions for such hybridization of carbon atoms are formed in organic materials, and this, apparently, takes place in the winding technique in spaceships. And in the silkworm, the same way as in many other natural processes, the corresponding fermentative reactions take place, on which we are still learning how to work.

To calculate θ and φ_g we use the formulation of Compton equation (14), modifying it as applicable to quantum transitions:

$$\frac{1}{h\nu} - \frac{1}{W_k K} = \frac{1 - \cos\theta}{\Delta W} \qquad (17)$$

By this equation the difference of energies of wave and corpuscular processes numerically equals the difference of bond energies of electrons on the corresponding orbitals, but when implementing the addition principles (in this case – deduction) of reciprocals of these parameters and taking into account the quantum geometry of transitions. In accordance with the law of energy conservation, this is the process of its redistribution during the quantum action. Angle θ is the angular vector of electron movement, which is quantized by integer number (K) via the square tangent of this angle i.e. $tg^2\varphi_g = 2$, $tg^2 60° = 3$ and $tg^2 45° = 1$. The notion of gyromagnetic (magnetic-mechanical) ratio (γ) numerically equaled to the ratio of magnetic moment of the particle (electron or atom) to its mechanical moment is used in quantum mechanics. For atoms $\gamma = -g\mu_B$, where μ_B – Bohr magneton; g – Lande factor (g - factor). For orbital magnetic moment of the electron $g_L = 1$, for spin magnetic moment of the electron $g_S = 2.00233$. Their ratio $g_S/g_L \approx 2$ that in accord with the ratios of rotational and translational components of electronic winding in the equation $tg^2\varphi_e = 2$.

The calculations by the equation (17) are given in tables 2 and 3. At the same time, the values of the angle θ are mainly correlated with the value $\varphi = h\nu/W_k$ in compliance with Table 3.

The notions of breaking stress in the process of plastics stretching by its winding pitch are used in papers,[10,12,113] σ_α is the axial σ_β is the circumferential stress, which are replaced by the value N_α, the axial effort and N_β, the circumferential

effort, which are proportional to the stresses. At the same time, the following equation is fulfilled.

$$\frac{\sigma_\beta}{\sigma_\alpha} = \frac{N_\beta}{N_\alpha} = tg^2\varphi_g = 2 \qquad (18)$$

This condition allows obtaining the equally tensioned system of threads with the minimal item weight.[12]

The quantum functions of square tangent $k = 1, 2, 3$ numerically determine the ratios of two triangle legs, whose values characterize energy dependencies via axial and circumferential stresses in the system with quantum and wave processes.

From Table 3 it is seen that quantum transitions of 2s-2p type for carbon atom, as distinguished from all other elements, are not accompanied with the changes in geodesic angle and coefficient k. Obviously, this property predetermines the unique features of the winding geodesic angle influence on the biosystems stability. Besides, in all transitions (except for 2s-2p) the correlation $\varphi \approx 4/3$ is fulfilled, which proves that such coefficient mainly compensates structural features of more complex transitions.
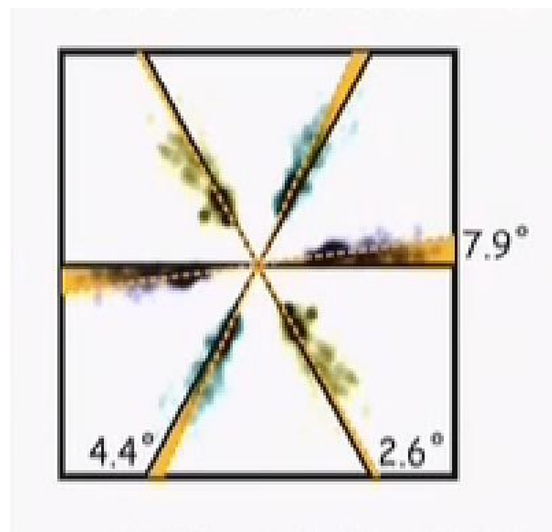

Figure 1. Statistic distribution of the cell number along the coordinate axes.

Some difference between the values of the angles φ and Θ or φ and $4/3\,\Theta$ is obviously determined by the effect of particle scattering around the main coordinate axes. Similarly, at the conformation of cellular structures the particles are statistically concentrated along the coordinate axes of hexagons (Figure 1) with the deviations by 2.6°; 4.4° and 7.9°.[14]

The average number of such deviations equaled to 4.97 approximately corresponds to the difference 60° – φ_g° = 5.27°.

The dynamics of hexagonal formation of cellular systems is in compliance with the established[15] condition of approximate equilibrium of spatial-energy characteristics of

the subsystems by all bond lines. This is also facilitated by the fact that biosystems with elements of the second period in their structure produce the winding angular vector (Θ) of 60°.

Conclusions

1. Two principles of adding energy characteristics of structural interactions can be transformed onto the processes of corpuscular-wave dualism.

2. It is assumed that in the process of rotational-translation motion of the electron the energies redistribute in the system "particle-wave", which is demonstrated via the angular vector of such motion (winding angle).

References

[1]Marison J. B., *General Physics with Biological Examples*, Vysshaya shkola, Moscow, **1986**, 623.

[2]Rubin A. B., *Biophysics*, Vol.1. *Theoretical Biophysics*, Vysshaya shkola, Moscow, **1987**, 319.

[3]Blokhintsev D. I., *Basics of Quantum Mechanics*, Vysshaya shkola, Moscow, **1961**, 512.

[4]Korablev G. A., Zaikov G. E., *Quantum and Wave Characteristics of Spatial Energy Interactions, Bioscience Methodologies in Physical Cemistry*, Apple Academic Press, Waretown, **2013**, 130-143.

[5]Eyring G., Walter J., Kimball G., *Quantum chemistry*, M., F. L., **1948**, 528.

[6]Korablev G. A., *Spatial-Energy Principles of Complex Structures Formation*, Brill Academic Publishers and VSP, Netherlands, **2005**, 426.

[7]Fischer C. F., *Atomic Data,* **1972**, 301-399.

[8]Waber J. T., Cromer D. T., *J. Chem. Phys.*, *1965*, *42 (12)*, 4116-4123.

[9]Clementi E., Raimondi D. L. *J. Chem. Phys.*, **1963**, *38(11)*, 2686-2689; *J. Chem. Phys.*, **1967**,*47*, 1300-1307.

[10] Kodolov V. I., *Polymeric composites and technology of producing aircraft engines from them*, Izhevsk Mechanical Institute, **1992**, 200.

[11]Allen K.U., *Astrophysical magnitudes*, Mir, Moscow, **1977**, 446.

[12]Ayushev T. Yu., *Geometric aspects of adaptive technology of producing structures by winding from fibrous composite materials*, BNC SO RAS Publishers, Ulan-Ude, **2005**, 212.

[13]Pidgainy Yu. M., Morozova V. M., Dudko V. A., *Mechanics of Polymers*, **1967**, 1096-1104.

[14]Moser, E., *Nobel lecture in Physiology*, 11.03.2015, TV channel Science".

[15]Koablev G. A., Vasiliev Yu. G., Zaikov G. E., *Chem. Phys. Mesoscopy*, **2015**. *17*, 424-429