

Theory of Metallic Bonding

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According to J.N. Spencer (JCE No. 3 p.182 1991) base of quantum-chemical interpretations are 'unteachable'. We have developed an approach that helps explaining major chemical phenomena (covalent bonding, chemical kinetics and catalysis) without introducing quantum chemical entities. Our approach and a General Chemistry text book synopsis utilizing it are presented at www.ITChem.com. Based on that approach we have developed a theory of metallic bonding and explained the differences between bonds in metals and non-metallic compounds. While atoms of non-metals are connected via static two-electron covalent bonds, atoms in solid metals are linked by dynamic one-electron bonds. We have built quantitative models that explain how that bonding difference determines dissimilarity between properties (primarily thermo and electrical conductivity) of metals and non-metals.

General

8:00 AM-11:45 AM, Thursday, 14 September 2006 San Francisco Marriott -- Salon 10, Oral

Division of Chemical

The 232nd ACS National Meeting, San Francisco, CA, September 10-14, 2006

CHED 504Phenomenological explanation of electrical conductivity

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We have developed system of explaining major chemical and physical phenomena without introducing quantum chemical entities (www.ITChem.com). Based on that approach we have developed an explanation of electrical conductivity in metals. Conventionally, a solid metal is described as a 3D lattice with partially ionized atoms in the nodes. Electrons separated from the atoms move freely in all directions ("electron gas", "positive ions in a sea of electrons"). When voltage is applied, free electrons move in the direction of the field propagation. That notion contradicts the modern knowledge that electrons in metals are strongly bonded to atoms and there are neither ionized atoms no electron gas. We have shown that seemingly easy motion of strongly bonded electrons in the direction of the field propagation is determined primarily by consecutive substitution by electrons supplied by the anode.

General

Paper

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Division of Chemical Education

The 232nd ACS National Meeting, San Francisco, CA, September 10-14, 2006

CHED 1773 Phenomenological explanation of metallic bonding and electrical conductivity

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The widely used quantum chemical explanations include paradigms and principles whose physical bases are unclear. We have developed an approach that helps explaining major chemical phenomena (covalent bonding, chemical kinetics and catalysis) without introducing quantum chemical entities. Our approach and a General Chemistry text book synopsis utilizing it are presented at www.ITChem.com. Based on that approach we have developed a phenomenological explanation of nature of metallic bonding and electrical conductivity that explained the differences between bonds in metals and non-metallic compounds. While atoms of non-metals are connected via static two-electron covalent bonds, atoms in solid metals are linked by dynamic one-electron bonds. We have built quantitative models that explain how that bonding difference determines dissimilarity between properties of metals and nonmetals. We have shown that seemingly easy motion of strongly bonded electrons in the direction of the field propagation is determined primarily by consecutive substitution of the electrons.

General

Paper

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Division of Chemical Education

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Theory of Metallic Bonding

The Division of Chemical Education of the American Chemical Society and NSF recognized in 1989 the need to foster the development of alternative General Chemistry Curriculum.

The major differences of the new Curriculum had to be the exclusion from it the quantum- chemical explanations of chemical phenomenons. The widely used quantum chemical explanations include paradigms and principles whose physical bases are unclear. According to J.N. Spencer (JCE No. 3 p.182 1991) base of quantum-chemical interpretations are 'non-teachable'. In 2004 we placed on our web-site ITChem.com the draft of the General Chemistry textbook, in which we tried to explain the basic chemical

phenomenons (the physical nature of the chemical bond in daltonoids and the chemical reaction, including the explanation of the physical nature of the periodic law, Lewis' rules, and the resonance rules) without using the quantum-chemical approach. These data were reported by us and discussed on the previous conferences of ACS (see SciFinderGankin).

Currently, we managed to elucidate the physical nature of the chemical bond in bertolloids or, speaking simpler, the nature of the metallic bond, more correctly, the chemical nature of the bond in the solid metals.

Clearing out the physical nature of the chemical bond in the solid metals allowed answering the next major questions, coming up in the process of the traditional classical development of Chemistry and Physics.

Approximately 80 of 100 known elemental substances (elements) are metals. The metallic double-atom molecular systems present more than a half of all chemical compounds. Accordingly to Pauling (L. Pauling The Nature of the Chemical Bond P.394 1959) the metals must represent a basic part of Chemistry. In reality, only 1% of the pages in the current Chemistry text books is dedicated to the metallic bonds.

The major reason of the existing situation, accordingly to Pauling, is that unlike nonmetals, no structure theory similar to nonmetals was elaborated for metals.

The existing explanations of the metal properties are the explanations ad hoc. For example, in physics the to explain the nature of the electric current, one assumes, that the part of the valent electrons is free and exist in metal as the electron gas. This assumption explains the electric current in metals forms at the extremely low voltage of 10^{-8} volt.

This assumption contradicts the chemical bond theory; accordingly to which the chemical bond forms due to the increase of the absolute value of the valent electron potential energy. I.e., after the chemical bond formation, the valent electrons are connected with the atom nucleus harder, than in the separated atoms.

Accordingly to the experimental data, obtained during the study of the photo-effect, electron emission, and metal atomization, not less than 2 eV of energy should be spent to break off the electron from the atom in the solid metal. Accordingly to I.V.Saveliev (Course of general physics, b.2, p.294, 1998), the electron emission from the metals takes place in the case, when the electric field of the conductance at about 10^8 volt/cm is formed near the metal surface. These data completely exclude the possibility of the free electrons in the form of electron gas existence in the metal.

In the previous works, we showed that the metal atoms in the gaseous phase are connected between themselves with the covalent bond identical both by physical nature and the physical and chemical properties to the covalent bond, formed by the nonmetal atoms.

However, the properties of metals and nonmetals in the solid state are sharply different. The metal valence in the solid phase, determined by the number of the metal atoms joined to one atom, is also sharply different from the nonmetal valence. For example, the first group elements valence in the gaseous

phase is constant and equal 1, but in the solid phase it is either 8 or 12. At the same time, the energies of the chemical bonds between metal atoms in the gaseous and solid phases are equal.

Carbon has the valence of 4 both in diamond and the organic substances. Similarly, iodine is connected with the firm co-valent bond with one iodine atom in the solid as well as gaseous phase.

The physical properties of metals and non-metals in the solid state are sharply different. Metals are electric and thermo-conductive, but nonmetals are isolators.

Accordingly to Peter P. Edwards (The New Chemistry, Editor-in-chief Nina Hall Cambridge university press 2000 p 85), nobody succeeded until 2000 to answering the such basic questions, related to the metal electric conductivity, as: Why does metal conduct the electric current, and nonmetal is the isolator? What is metal? Why are the metal properties are so different from the nonmetal properties? What is the electric current? What is its physical nature? Etc.

We could solve the mentioned contradictions and answer the above listed questions in the frames of the elaborated by us theory of the chemical bond. The question, connected to the thermal stability of the compounds of halogen molecules with halogen anions, arose during the working out this theory. The middle iodine atom in the molecules, described as I-I-I, had the valence 2 (i.e., two times higher, than it is in the molecule I₂) and contained 9 electrons in the outer sphere, what contradicted the covalent bond theory. Accordingly to the chemical bond theory, the connection between iodine molecule and it could be formed only with the thermally unstable Van der Waals' bonds. The investigation of this compound showed, the both bonds in it are equal by the length and the strength. The investigation of compounds, with the identical atoms but the bonds, which are different by the length and the strength, showed, that in all occasions, all the bonds of the central atom are equal by the length and the strength. Phenomenological explanation of this occurrence was achieved as a result of the evaluation and generalization of the experimental works on the election-nuclear isomerization. We proved, that in the case, when, accordingly to the chemical bond theory, the structural formula can be presented with more than one way, the fast and uninterrupted electron transfer in these compounds takes place. As a result, the dynamic equilibrium between the possible structures is established. During elaboration of the chemical bond theory, it was shown that the bond energy equals the energy difference between the energy of valent electrons in the separated atoms and the formed molecule. During the formation of molecule, the valent electron energy of it decreases, i.e., the valent electrons are getting into the energy minimum. This minimum corresponds to their rotation in the plane perpendicular to the axis, connecting the nucleus, bonded by them. During the isomerization process, the ring, in which the electrons are rotating, moves from one energy minimum into another. For example, in the case of the molecule I₂-I-I, the electron couple, rotating in the ring and belonging completely to anion, forces out, during the isomerization process, the electron couple, which bonds iodine molecule in the process of isomerization. As the result of isomerization, the molecule I-I-I is formed. Its electron energy is equal the initial molecule energy. The electrons start moving in the opposite direction. Because the rate of the nucleus transition is one – two orders slower than the speed of the electron movement, , the nucleus in such molecules take the intermediate position. This leads to the length and energy smoothing of the bonds, what is observed experimentally. From the other side, when

one atom connected to the same or identical others atoms with the different types of the chemical bond and the length and the strength of the bond in these atoms are the same, it is possible to say, that these experimental data are the proof, that the bonding electrons in these compounds are moving with the rate (approximately 10^5 m/sec) higher than the nucleus moving speed (approximately 10^3 m/sec) along the bonds from one bond to another. In the frames of the chemical bond theory, developed by us, the bonding electrons are moving along the axis, connecting the nucleus of the bonded atoms. This electrons cross from one bond to another (from on energy minimum to another, closed by the energy level). These bonds, named dynamic, were put apart in the separate group. These bonds, in particular, are formed into multi-atom (more than 2 atoms) molecules, in which the different types of bonds connect the central atoms with the identical atoms. If the system consists of the connected atoms, having only one different by its depth energy minimum, the prevailing in quantity isomer amongst all possible isomers in the equilibrated mixture is the one having the maximum potential energy. I.e., the electrons in this isomer are the closest to the nucleus. In this case, the ring of the bonding electrons moves between the energy barriers, limiting this movement from the both sides.

The short historical review. The compounds in the frame of the Lewis' theory could be presented by not one but the several structural formulas, that, accordingly to Pimentel and Spratly (How the quantum mechanic explains the chemical bond, Mir, Moscow, 1973), caused the serious complications. Pimentel and Spratly in the chapter named "There are too many structures. The situation is saved by the resonance" wrote: "There are quite a few structures, which agree with not only one, but with the several accepted inert gases configurations. **In the each such case, every structure means, that the non-equivalent bonds could be formed, but by the unknown reason they are never formed.** Let's review, for example, the sulfur dioxide (SO_2); One can imagine two such electron configurations, in which every atom will have the respective inert gas configuration. The single and double-electron bond will be in the each structure - one bond will be long and another - short. However, it is known, that the lengths of the two sulfur-oxygen bond in sulfur dioxide are exactly even. To solve this contradiction for chemists was not difficult. The presence of two structures made the matter somewhat mixed up. Nobody could decide, which structure is more preferable. Both structures from the energy point of view have to be equivalent for electrons. The decision is obvious - due to the extreme mobility of electrons, two equivalent structures are realized simultaneously. Chemists introduced the new term "resonance"; it means, that electrons are moving back and forth. Now the both sulfur-oxygen bonds acquire the averaged character thanks to the impetuous electron movement between the two possible configurations. In the light of the quantum mechanic ideas, the individual structures do not take into account the electron movement along the whole molecule, i.e., do not take into account the molecular orbitals. In the reality, during the molecular bond character evaluation in each molecule, using the molecular orbital method, it is necessary to introduce the π -MO, which expand on the whole molecule. The π -orbital influence on the bond stability effects equally all bonds that correspond to the experimental results." **The quantum mechanic proclaims, that the come resonance structures do not exist in reality. The assumption that electrons are moving between two electron configurations is simply the invention.** It is interesting,

that more than 20 reports and 3 monographs have been published since we determined the chemical bond nature, based on the experimental data (1982) Respectively, the articles on the real physical nature of the occurrences, described by the resonance rules and the experimental data supporting the explanation, that **the different structures exist and electrons are moving between two electron configuration** (not paying attention to the quantum mechanic statements) were published in the 70s. Despite all of this, the attitude presented in the bald font is kept unchanged. The discussion touches only the formal sides of this problem. For example, the work, published in 2006 (JCE, v.83, #2, p.223, February 2006) suggests to replace the words “resonance”, “resonance energy”, and “resonance hybrid” with the words “delocalization”, “delocalization energy” and “hybrid structure” respectively. As a whole, we support the scientific expressions – the new is a very well forgotten old, the correct theory is the child of time, but not of authority. We have returned to the well forgotten isomerization. The new experimental data were the reason for the return. Additionally, it should be noted that the earlier explanation by chemists about the chemical bonds leveling off was spreading on the equilibrated isomerization of the compounds, containing the single and double bonds. During the evaluation of the new information, obtained in the recent years, we applied this mechanism to the all cases when the central atom connects with the different bond types, (Van der Waals’, donor-acceptor, etc) with the identical or close to each other by first ionization energy (FIE) of atoms. Our most closed predecessor in this case was L. Pauling. It had been assumed before him, that the resonance is when there were the single and double bonds in the compound. He already assumed the resonance between covalent and ionic bonds in metals. Our explanation is principally different. Instead of the incomprehensible from the physical point of view word “resonance”, the following mnemonic rule was introduced in science: if more than structural formula in the frames of the Lewis’ rules can be suggested, this compound will be more stable, accordingly to quantum chemical calculation. The additional energy gain was named “the resonance energy”. Before Pauling, all structures, described by the resonance rules, were the structures, containing the single and double bonds. Pauling expanded the field of this rule, by the application of the bonds in metals. Our achievement was, that we found out this phenomenon physical sense and widened the number of the bond types, in which this phenomenon is observed (more accurate, the widening of the circle of bonds in which this phenomenon is observed through the inclusion in the evaluation besides the simple and double covalent bonds, also the donor-acceptor, Van der Waals’, single and double electron bonds). Clearing out the physical sense of the resonance rules became possible after the discovery of the isomerization reaction in the analogous to benzene molecules and the study of this reaction kinetics. These experimental data were obtained in the second half of the 20th century and were not generalized before us. It was because at that time in the theoretical chemistry the theory prevailed that the theoretical chemistry is the quantum chemistry and, respectively, all chemical phenomenon’s had to find their explanations in its frames.

The investigation of the electron nucleus isomerization kinetics allowed to determine, that the rate of the electron movement from one minimum to another depends on the bond type, the distance between the minimums, the value of the energy barrier, separating the minimums, and the number of electrons in the moving electron ring.

It was found out in the process of the G-theory development, that electrons, bonding the nucleus, are rotating in the ring perpendicular to the axis, connecting the nucleus. The experimental data generalization, described above, allowed to conclude, that the ring, formed by the bonding electrons, is moving easily (i.e., with the energy expenditures less than 10 kJ/mol) along the chemical bond line with the speed, described by the following equation:

$$V = 10^{17} e^{-2R/L},$$

where R is the distance in Å L (the distance between the minimums of system energy in the described case is 1 Å) and L is a coefficient, depending on the type of the chemical bond, connecting the atoms (L=6.5 for the conjugated systems and L=0.7 for the non-c conjugated systems).

Accordingly to this equation, the electron transfer rate for the conjugated systems is valued at 10^{17} Å/sec and for the non- conjugated systems as 10^{16} Å/sec.

Accordingly to the experimental data, the electron ring transfer rate, which contains one electron, is higher than for the two-electron ring.

As a result of the evaluation of the co-valent bond physical nature, it was found out, that the chemical bond forms thanks to the electric forces and the model, described by three algebraic equations with three unknowns, was suggested. Solving this system of equations allowed determining the bond energy (BE) on the first ionization energy (FIE) of the bonding by it atoms.

The calculation showed (Fig.1),

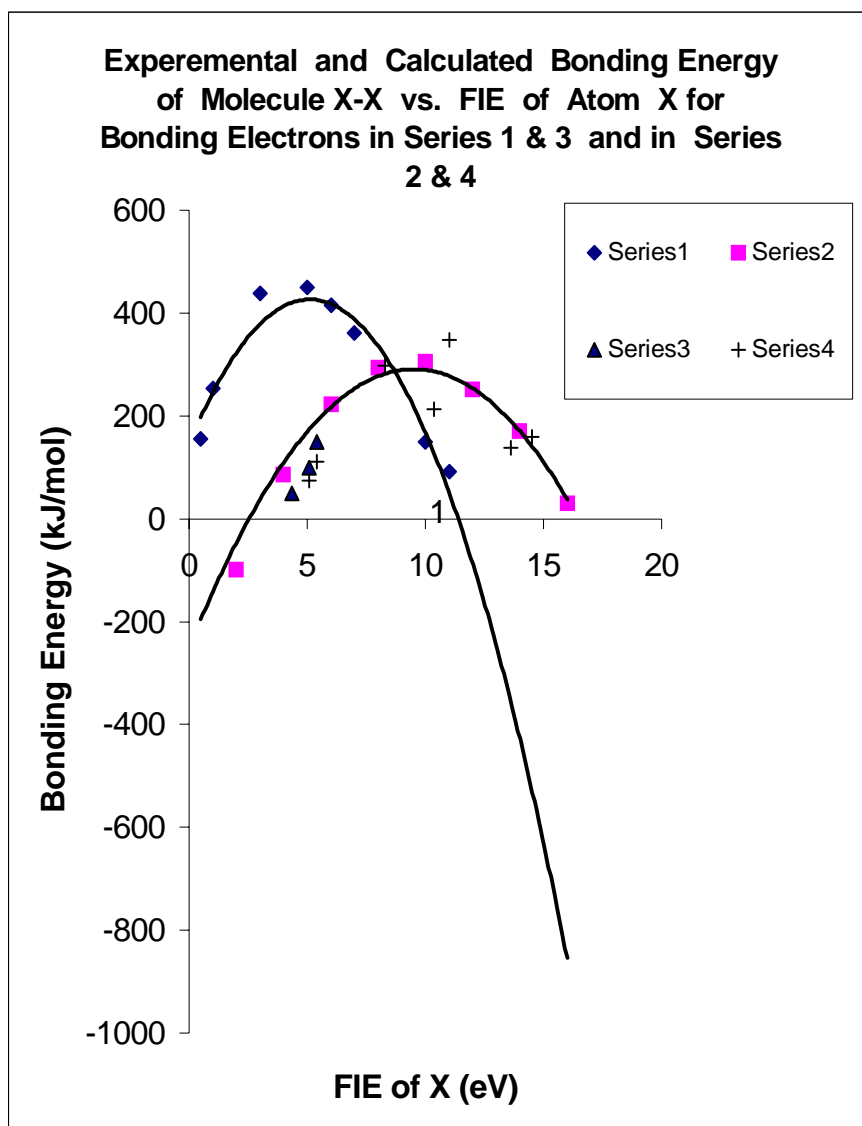


Fig.1

that the dependence BE on FIE both for single and double electron bonds is parabolic. The bond energy maximum is being reached at 5 and 10 eV for the single and double electron bonds, respectively. The double electron bond is not formed if the bonding atoms FIE is less than 3 eV and more than 16 eV. The single electron bond is not formed if the bonding atoms FIE is less than 1 eV and more than 11 eV. The single and double electron energies are equal, if the bonding atoms FIE is 7 eV. Accordingly to the experimental data, the single electron energy in the double atom molecules, formed by the first group metals, is higher than the energy of the two atom bond, which proves, that the calculation, using the model, was correct.

Nonmetallic simple substances (consisting of the identical atoms) accordingly to K.Saito at al (Chemistry and Periodic Table, Moscow, Mir, 1982, p.87) “are built from molecules, in which atoms group into 2, or 4-8 in one molecule and have the same valences as in gaseous phase and even are directed in the space.

In the solid state many of these substances are presented as molecular crystals, in which molecules have the structure of the elongated and other forms, form the structure with the rather loose packing”. “The typical representative of the simple substances, capable of forming the gigantic molecules, is carbon. The length of the bond C-C and the carbon valence angle for diamond is the same as in aliphatic hydrocarbons”.

“The particular peculiarities of metals are the following, specific only for them, properties: electric conductivity, thermal conductivity, specific shine, forging, and plasticity; for their structure, the isotropicity, i.e., the absence of the specific properties along the selected directions, is also typical”. In the same work on page 118: “many metals, depending on the temperature, have the different structure. The amount of the emitted or absorbed energy (the transition heat), does not exceed 1 kJ/mol, if limited by the mutual transitions between the structures A1, A2, A3 (every atom in the structures A1 and A3 is surrounded by 12 atoms and by 8 atoms in the structure A2). This value is extremely small compare to the heat of melting (10 – 40 kJ/mol). Therefore, there is a very small difference between the Energy State of the different crystalline structures”.

How, in the light of the given above, did we succeed to answer the following questions:

Why does metal conduct the electrical current?

Why is nonmetal the isolator?

Why do the metal properties so much differ from the properties of nonmetals?

Let’s compare on the molecular level the properties of the first group metals with the nonmetal – diamond.

In crystalline lithium, every atom is connected with 8 or 12 other lithium atoms (crystalline lithium consists of the 3 structures A1, A2, A3). Every lithium atom has only one valent electron. It is necessary to have 16 electrons for the formation of 8 double electron bonds. Further, after the formation of 8 double electron covalent bonds, the outer sphere of all lithium atoms will contain 16 electrons, because the both connecting during the covalent bond formation electrons are included in the outer layers of the both atoms. At the same time, the maximum possible number of electrons, which can be present in the lithium outer sphere, is 8. I.e., the formation of the 8 double electron covalent bonds is excluded. Accordingly to the experimental data and the calculations (Fig.1) the atoms of the first group can form the single electron covalent bonds. During the formation of the single electron covalent bond, and as well, the double electron bond, the connecting electron is included in the outer spheres of both atoms. I.e., the structures A1 and A3, detected during the solid lithium structural analyses, can not form with only the single electron bonds, because in this case, the atoms of lithium will contain 12 electrons in the outer layer. The only possibility for lithium to form 12 bonds, as in the case of I_3 , is a formation of the Van der Waals’ bonds along with covalent (single and double electron) bonds. In this case, the lithium atom will be connected to the other atoms with the different bonds - covalent (single and double electron) and Van der Waals’. Accordingly to the experimental data and the chemical bond theory, in this case, the bond leveling by the length and energy takes place, because the connecting electrons (the rings, in which the bonding electrons are rotating) transfer from one bond to another, i.e., the bonds become dynamic. The

movement of the electron rings takes place along the bonds with the rate of the order of 10^6 m/sec, which is close to the heat movement rate at the room temperature – 10^5 m/sec. Because every atom in metal is connected, as minimum, to eight atoms, evenly separating the space, surrounding each atom and 8 sectors, the behavior of the bonding electrons is not distinguishable from their behavior in the electron gas, where electrons possess three degree of freedom. The bonding electrons in metal, which remain as bonding the nucleus, behave, at the same time, as the free electrons. This allows to coordinate the listed above experimental data, obtained as a result of the studies of the photo -effect, electron emission, and metal atomization, with the data on the electric current occurring at the voltage less than 10^{-7} eV. Accordingly to Soloviov (p. 272) the average rate of straitened by the field electron movement (even at the very large current density) is 10^{-3} m/sec. The kinetic energy of the electron, bonded with atoms, equals the half of its potential energy and is measured in the eV values. The electron movement rate on the orbit is 10^5 m/sec, which are 10^8 higher. The kinetic energy of the electron is proportional to its movement speed squared. Respectively, The kinetic energy, additionally provided to electron to electron, is $10^{-14}\%$ of the thermal energy, which the electrons have at the room temperature and are measured by the values of the order 10^{-13} eV. I.e., the energy practically is not spent on the increase of the kinetic energy of the electrons. During the voltage creation in metal, electrons are moving along the bonds. At this point, the system energy changes insignificantly, because, while moving away from one atom on the certain distance, the electron is approaching another on the same distance. Because the electron movement speed is two orders higher, than the nucleus movement speed, and because the system energy is completely determined by the distance between the electrons and nucleus, the system energy does not have to change significantly during the bonding electron movement. Also, the energy provided during the imposition of the energy field, does not practically have to be expended on its compensation (its increase) and on the exit of the bonding electrons from the drop of the potential. The independent (in this case semi-quantitative) experimental confirmation of the basic distinguish of the metallic bond from the covalent and Van der Waals' bonds is the comparison of the experimental data on these bonds lengths (Pimentel and Spratley. How the quantum mechanic explains the chemical bond, p.248, Moscow, Mir, 1973).

The ratio of the Van der Waals' and co-valent bond lengths for the first period elements varies in the range of 1.7 – 2.2. Accordingly to Pimentel and Spratley, the ratio is 1:1 between the dynamic bonds in the compounds of the type $(I_3)^-$ and the covalent bonds in the compounds of the type (I_2) .

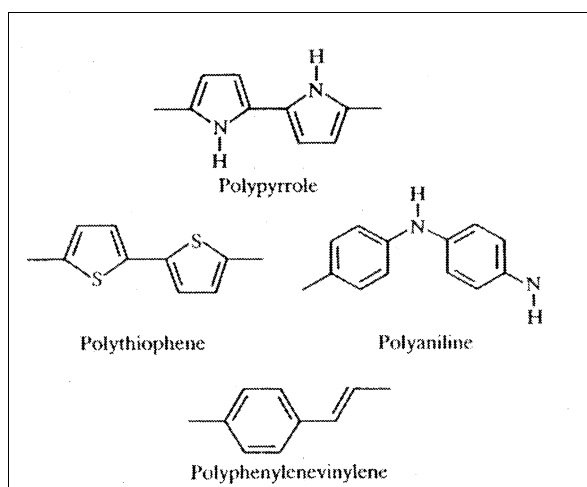
Accordingly to the experimental data by K.Saito (p.110), processed by us, the ratio the bond lengths in the solid metals and double-atom molecules, consisted of the identical atoms, varies in the range of 1.03 – 1.2. For example, this ratio for the row of metals Li, Na, K, Rb, Mg, Ca, Al, Cu, Ag, Au is 1.14, 1.2, 1.16, 1.14, 1.03, 1.13, 1.2, 1.08, 1.07, 1.07 respectively. I.e., the bond length ratio in the solid metals and double-atom molecules, consisted of the identical atoms, practically numerically coincides with the 1:1 ratio between the dynamic bonds in the compounds of the type $(I_3)^-$. It sharply (one even can say qualitatively) differs from the ratio of the Van der Waals' and co-valent bonds for the same period elements and varies in the range of 1.7 - 2.2. For the comparison, for nonmetals, the ratio the bond lengths in the solid non-metals and homogeneous double-atom molecules, consisted from the identical atoms,

varies in the range of 0.7 – 1.0. For example, the ratio in the row of non-metals N, O, C (diamond) is 0.74, 0.8, and 1.0, respectively.

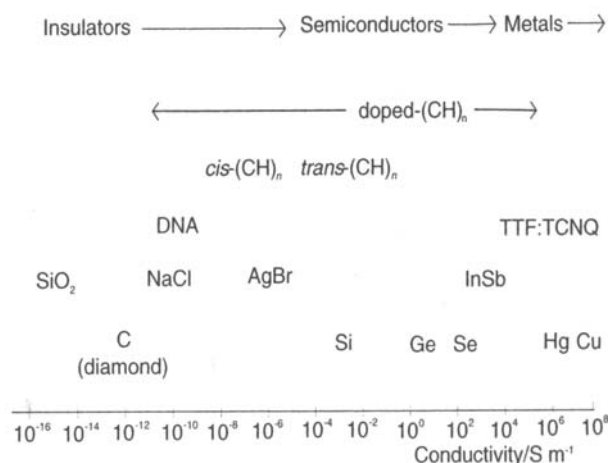
The direct experimental confirmation of the dynamic bond role in the electric conductivity is the comparison of paraffin (it does not contain the dynamic bonds), which has the specific resistance of 10^{16} ohm and polyethin (polyacetylene $-(CH)_x-CH=CH-CH=CH-CH=$), where the dynamic bonds are present – 10^{-5} - 10^{-8} ohm. At the same time in treated with iodine polyethin (see box 1), where the number of the dynamic bond is higher due to $(I_3)^-$, the resistance is 1×10^{-3} ohm.cm.

One can see from the presented photograph (The New Chemistry, Editor-in-chief Nina Hall Cambridge university press 2000 p 85), that the polyethin film, treated with iodine, possesses the metallic shine, at the same time, the not treated film did not have it. The higher metallic shine of the film, in which the number of the dynamic bonds is larger, than in the film, having fewer metallic bonds, allows to assume, that the dynamic bonds (their type and quantity) are the main reason of the metallic shine, typical for metals.

Accordingly to L.E.Smart E.A.Moore (Solid State Chemistry, 2005, p.245), it was shown during the further studies of the organic polymers with the conjugated bonds, treated and not treated by halogens, that the results, obtained during polyethin study, are typical for all investigated polymers with the conjugated bonds, in particular for



The experimental data, carried out by L.E.Smart E.A.Moore were generalized in the form of the table:



It is a solid confirmation, that the explanation of electric conductivity in the solid metals and the lack of it in nonmetals by the different bond types in metals and nonmetals are correct. The bonds in the solid metals are dynamic, and in the solid nonmetals they are static. The differences in the bond types in the solid metals and nonmetals without any additional suggestions explain, along with the electrical conductivity, all other different chemical and physical properties of metals and nonmetals. In particular:

The valence of metal is different in the gaseous into solid phases.

The formation of the electric current in the metal when the voltage is more than two orders lower, than necessary for pulling electrons from the metal.

All general statements of the bond theory in the solid homogeneous metals, besides the analogy, have the direct experimental confirmations. For example, equality of the all twelve bonds in the majority of metals is the direct confirmation of the dynamic bond presence in solid metals. The additional independent confirmation is the measured length of all bonds, which is the intermediate between the covalent and Van der Waals' bond lengths. As a common case, the number of bonds in the homogeneous atom nonmetals in the solid phase is equal to their number in the gaseous phase, does not exceed four bonds, and corresponds to the G-theory of the chemical bond.

Till 2006, we did not find the experiments in the literature, which contradicted or gave the simple explanation (in the frame of offered by us theory), why there were the unusual (paradoxical in the G-theory of the static bond) properties and differences in the behavior of metals and nonmetals. There were also no experiments, in which the answers on the paradoxical questions had not been received until the working out of the chemical bond theory, presented in this report.

By our opinion, all listed above data testify not only about the applicability of the suggested chemical bond theory in the solid metals, but, also, that this theory is correct.