

Possible Evolutionary Models in the Initially Hydride Earth Theory

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Abstract

A modern view of the properties of chemical elements has confirmed the theory of the hot origin of the Earth. The next step in developing this theory was the hypothesis of the initial hydride Earth. In this work, we attempted to find additional evidence for this hypothesis and show additional effects that flow from it. The effect of the physical properties of atoms and ions on their behavior during the formation of the Earth was studied. The maximum contribution to the distribution of elements was made by those elements whose content in the original protoplanets of the disk was the maximum. Correlation dependence is obtained, which allows one to calculate the distribution of elements in the protoplanetary disk. It was shown that hydrogen was the main element in the proto substance located in the zone of the Earth's formation. In this case, various chemical compounds formed, most represented by hydrogen compounds—hydrides. Since the pressure inside the Earth is 375 GPa, this factor forces the chemical compounds to adopt stoichiometry and structure that would not be available in atmospheric conditions. It is shown that many chemical elements at high pressure in a hydrogen medium form simple hydrides and super hydrides—polyhydrides with high hydrogen content. Pressure leads to a higher density of matter inside the planet. Given the possibility of forming polyhydrides, there is the possibility of binding the initially available hydrogen in an amount that can reach 49.3 mole%. Young Earth could contain about 10.7 mass% of hydrogen in hydrides, polyhydrides, and adsorbed form is almost twice higher than previous estimates. This fact additionally confirms the theory of the original hydride Earth. In hydrides, the occurrence of the phenomenon of superconductivity was discovered. Polyhydrides were shown as potential superconductors with a high critical temperature above 200 K. We, based on these data, hypothesized the presence of superconducting properties in the Earth's core, which explains the presence of a magnetic field in the Earth, as well as the unevenness and instability of this field and the possibility of migration of the Earth's poles. The fact that

the Earth has a hydroid core causes its change in time due to the instability of hydrides. Arranged several possible models of the destruction of the Earth's core. The calculations showed that both models give close results. These results give predictions that can be measured. The proposed models also made it possible to estimate the initial size of the Earth. Possible ways of further testing the hypothesis of the initial hydride Earth is shown.

Keywords

Theory of the Hot Origin of the Earth, Magnetic Separation of Elements, Atom Ionization Energy, Hydrides, Polyhydrides, Earth Expansion, Superconductivity of the Earth's Core

1. Introduction

One of the oldest hypotheses about the emergence of the solar system was put forward by the Swedish scientist and theologian E. Swedenborg and developed by the famous German philosopher I. In his essay "General Natural History of the Sky or Theory of the Universe", Kant published in 1755. Following Swedenborg's ideas, Kant suggested that there was a huge diffuse nebula before forming the planets and the Sun. This nebula had to rotate so a central body could emerge from it—the Sun and planets. Forty years after the publication of Kant's essay, the great French mathematician P. Laplace, in addition to the "Presentation of the World System", introduced the fundamental assumption that the primary nebula slowly rotated from the very beginning. The famous book of Laplace was published in 1796. Laplace believed that the nebula was originally hot. As it cooled, it contracted, and its rotation speed increased. With increasing rotation speed, centrifugal forces at the nebula's equator increased, leading to ring stratification. These rings subsequently formed planets and satellites.

In the most general terms, such is the Kant-Laplace conjecture. This model explained well why all the planets move in the same direction and plane. That is why the Kant-Laplace theory was generally accepted for a long time. However, this harmonious theory had weaknesses, clearly manifested by the middle of the XIX century.

In the 20th century, the ideas of the "hot" origin of the Earth, under the Kant-Laplace scheme, throughout all his scientific activity, were developed by the outstanding specialist in the field of petrography, Professor P. N. Chirvinsky. For this purpose, he used the Avogadro law, which states that "in equal volumes of different gases at the same pressure and temperature, the same number of molecules is contained". P. N. Chirvinsky first put forward this idea in 1911 in his master's thesis [1], which he defended at Kazan University in 1912. This idea has been detailed in the article "An attempt to apply the Avogadro law to rocks and meteorites" [2] and further in the doctoral dissertation [3], defended in 1918. He summarized these ideas in his work "On the quantitative chemical

composition of pallasites and the application of the Avogadro law to them” [4] and in the fundamental monograph “Pallasites” [5]. In these publications and dissertations, P. N. Chirvinsky formulated and substantiated the idea that the composition of pallasites and the genesis of their constituent elements are determined by the Avogadro law and are inherited from the gas and even liquid phases. He wrote about the validity of this law to all rocks on the basis that the solid substance of the Earth in its development has passed the gaseous and liquid stages and is a kind of “petrified gas”. According to P. N. Chirvinsky, the liquid and especially gas phases of the state of terrestrial matter are completely consistent with the Kant-Laplace hypothesis and shed light on the structure of the Universe and the origin of chemical elements. The following works were devoted to these issues: “On the Question of the Laws of Formation of Chemical Elements in the Universe” [8] and “On the Question of the Laws of Formation of Chemical Elements in the Universe” [7]. He justified the fallacy of the Earth’s cold formation hypothesis in 1944 by O. Yu. Schmidt [8].

Astrophysics suggests that the formation of galaxies, stars, and planets is based on gravity and rotation. Gravity is the main factor in the condensation of cosmic matter in forming a spherical shape, which is advantageous precisely from the point of view of gravity. With a mass exceeding 0.012 - 0.0767 of the mass of the Sun, or, respectively, from 12.57 to 80.35 of the mass of Jupiter (which is 32 - 40 times the mass of all the planets of the solar system), conditions arise for the initiation of thermonuclear reactions and formation stars. Such cosmic bodies are called brown dwarfs or substellar objects capable of exciting thermonuclear energy sources and passing to the stellar state. Like in stars, they carry out nuclear fusion reactions on the nuclei of light elements (deuterium, lithium, beryllium, boron), but, unlike the main sequence stars, the contribution to the heat release of such stars from the nuclear fusion reaction of hydrogen nuclei (protons) is insignificant. After the exhaustion of the reserves of the nuclei of light elements, thermonuclear reactions in their bowels cease, after which they cool relatively quickly, turn into planet-like objects. This fact is confirmed by astrophysical observations, which establish the luminosity of stars only if they have a mass exceeding a given critical minimum [9] [10] [11] [12]. The ego is true for the Earth, whose small mass could never cause it to warm up to a temperature above a million degrees, which is necessary for initiating nuclear reactions. However, the presence of molten “pyrogenic zones”, according to P. N. Chirvinsky, inside the Earth, considering the data of comparative planetology and direct observations of the state of Venus, whose surface temperature is close to 475°C, indicates that the melting of our planet and all the planets of the earth group in general always happened. In this case, the maximum intensity of the formation of melts corresponded to the very beginning of the evolution of the planets, was caused by their heating, not exceeding 1500°C - 2000°C, and was not accompanied by the synthesis of atomic nuclei.

This study aimed to explain the mechanisms that provide the structure, magnetic properties, and tectonic behavior of the Earth and its structural elements.

2. Initially Hydride Earth Theory

2.1. Formation of Initially Hydride Earth

Currently, cosmogonic hypotheses are being replaced by a new theory based mainly on cosmochemistry data and considering physicochemical processes during the cooling of the primary solar nebula, which led to the appearance of chemical inhomogeneity of different bodies of the solar system. Zonal-shell structure of the Earth and terrestrial planets are associated mainly with the accumulation of particles from a gas-dust cloud, which arose in the cooling and condensation of solar gas and plasma. The formation of the Earth's and its planets' chemical composition was associated with the successive condensation of elements in the reverse order of their volatility. Lowering the temperature of the hot gas system leads to the sequential condensation of the first refractory, then difficult to volatile, and, finally, the most volatile elements and their compounds.

It all started with the Supernova explosion that preceded our sun. The Supernova explosion disrupted the gravitational stability of scattered interstellar matter. As a result, the center of gravity, to which interstellar matter began to contract. As gravitational contraction of the mass increased, central condensation increased. Gradually, it unwound, and centrifugal forces increased until they equated with gravity at the equator. The regime of rotational instability has come.

At this stage, the central condensation was a rapidly rotating nebula, in the form of a biconvex lens, with a radius at the equator of about 50 million kilometers. This value is close to the orbit of Mercury.

A Supernova explosion was a powerful act of nucleosynthesis. Thanks to him, the substance that fell into the zone of gravitational contraction received an additional number of chemical elements from the periodic system of D.I. Mendeleev. At the same time, along with stable isotopes and long-lived radioactive elements that have survived, a mass of short-lived radioactive elements were formed, which has already disappeared. Among these short-lived nuclides, many isotopes with half-lives of 10⁵ - 10⁶ years existed. Radiation from the decay of short-lived isotopes provided ionization of diffuse interstellar matter, which was initially in a partially or fully ionized state, *i.e.*, in the form of plasma—an atomic-ion-electron gas. The nature of the processes occurring in this formation and their implementation mechanisms are described in detail in the monographs of V. N. Larin [13] [14].

During the protoplanetary disk formation, the substance discharged from the protosolar nebula moved across the magnetic lines of force [13] [14]. Ionized particles cannot cross magnetic lines of force if they have nonrelativistic and thermal velocities of motion, so they are captured by a magnetic field and are in the zone of its action. At the same time, neutral atoms freely pass through a magnetic field. This idea was put forward by F. Hoyle [15] and developed in the works of V. N. Larin [13] [14].

Thus, during the formation of a protoplanetary disk, easily ionized elements

should have been captured by a magnetic field and stopped in a near-solar space. In contrast, elements that are difficult to ionize would go to more distant zones. Therefore, the elements were separated due to magnetic separation, depending on their ionization potentials during the protoplanetary disk formation.

Since specialists have extremely limited data on the composition of the Earth and the Moon, only material from its outer geosphere is available on Earth to a depth of about 150 km, and samples are collected on the Moon's surface. Moreover, there is complete information about the composition of the Sun and the asteroid belt separated by three astronomical units.

So, P. N. Chirvinsky calculated the average chemical mineral and atomic composition of the Earth's meteorites, granites, other igneous rocks, and the planet as a whole [1] [5] [6] [7] [16]. The data of his research on the determination of the mineralogical and chemical composition and the origin of such meteorites as pallasites, as well as other types of meteorites, had the most direct impact on many modern problems of the origin, evolution, and structure of Earth-type planets [17]-[26].

Conducted by Larin V. N., a comparison of these compositions was made in pairs: Earth—the Sun, Earth—the asteroid belt, and Earth—the Moon, to their first ionization potentials. The results presented in his works [13] [14] clearly show that the solar system's elements' distribution depends on their ionization potentials. This fact confirmed the hypothesis of F. Hoyle. The results of the calculations are presented in **Figure 1**.

In [27], calculations were carried out under the solar system's formation theory, which refutes the classical ideas about the minimal role of ionization of matter and magnetic field in the original solar nebula. Instead, H. Toulhoat with co-authors [27], proposed the occurrence of a chemical gradient controlled by magnetic fields on the scale of the solar nebula, which fixed the chemical differentiation of planets at subsequent stages of accretion.

For the Earth, the content of elements relative to the Sun was theoretically connected with the first ionization energies and the distance to the Sun. This simple model has been successfully tested based on available data on the chemical composition of CI chondrites and the surfaces of Mars, Earth, the Moon, Venus, and Mercury. In addition, it was shown that deviations from the proposed law for a particular planet of the solar system correspond to later surface segregation of elements due to both gravitational and chemical processes. Thus, a new picture was given for the distribution of elements in the star system and between planets. In particular, the initial hydrogen content in the composition of the primary Earth is determined to be 18 mass%.

To normalize the data on the composition of solar and planetary matter, the authors of [27] calculated the relative abundances of elements relative to the abundance of silicon. The differentiation coefficient of an element for a planetary body was determined as the ratio of its relative content in each body of the solar system to the silicon content. Silicon was taken as a reference. Differentiation coefficients for the Earth were calculated based on data on the Earth's crust [28],

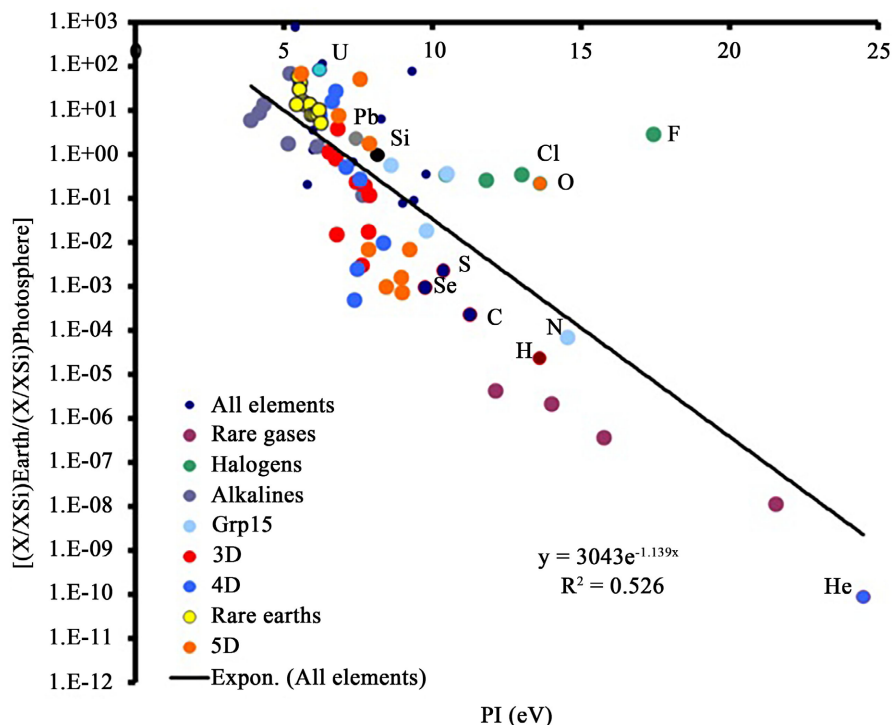


Figure 1. Differentiation coefficients of the Earth's crust depend on the first ionization potential E_1 for elements from hydrogen to uranium. The slope of the regression line in the semi-log section, excluding He, is -1139 eV^{-1} [27].

adjusted for the inclusion of the main elements of the hydrosphere (H, O, Cl, Mg, Na, Ca) and the recommended spectroscopic measurements of the relative content of elements in the solar photosphere [29]. The obtained correlation is presented in **Figure 1**. Data are presented for elements from hydrogen to uranium. The semi-log graph has an average slope of -1.139 eV^{-1} with a squared correlation coefficient of 0.56. The physical meaning of the obtained correlation is associated with electromagnetic forces, and the observed deviations for some elements are associated with radial differentiation.

Since the abscissa axis in this graph is an energy scale, this pattern resembles the Boltzmann distribution [30]. The physical meaning of this phenomenon can be explained as follows. Atoms in a protoplanetary gaseous accretion disk move towards the protosun under the influence of its gravitational attraction due to its rotational instability. This effect determines the net radial flow of matter. However, part of this substance is ionized by various factors. Three main factors cause the ionization of atoms in gases:

- Thermal ionization—ionization in which collisions between atoms provide the necessary energy for separating an electron from an atom due to increased temperature.
- Ionization by an electric field. This type of ionization is due to the excess of the value of the internal electric field strength over the limiting values of energy, the separation of electrons from atoms in a gas.
- Ionization by ionizing radiation.

External factors with similar effects deny Protosun radiation and the radioactive decay of short-lived isotopes.

However, charged particles deviate from the equilibrium orbit under the action of the Lorentz force created by a magnetic field perpendicular to the magnetic field of the nebular disk. Considering the ionization energy $E_n(M)$ of the element M as the value determining the probability of its ionization, we have the molar or mass fraction $X_{SS}^+(M)$ of the element M captured in orbit at an average distance d from the protosun:

$$X_{SS}^+(M) = X_{SS}(M) \exp\left(-\frac{E_n(M)}{k_B T_{elG}(d)}\right) \quad (1)$$

where $X_{SS}(M)$ — the initial average content of element M in the solar system. $T_{elG}(d)$ — the local temperature of plasma electrons depending on the distance from the ionization source.

Suppose we consider the protoplanetary gas as plasma with a low density, which absorbs the radiation of the protosun and emits in the direction of the cosmic background. At a distance d from the protosun, the absorption and emission spectra will have strong lines corresponding to electronic transitions in the energy of 4 - 25 eV, corresponding to the lower bounds of photon energy that can cause the first ionization of chemical elements. From the law of conservation of energy and following the Einstein formula for the photoelectric effect, we have [31]:

$$h\nu = E_n + \frac{mv^2}{2} \quad (2)$$

where E_n — the minimum energy required to remove n electrons from matter,
 $mv^2/2$ — the maximum kinetic energy of the emitted electron,
 ν — incident photon frequency with energy $h\nu$,
 h — Planck's constant.

This formula implies the existence of the lowest frequency:

$$h\nu_{\min} = E_1 \quad (3)$$

Below, the photon energy is no longer enough to “knock out” an electron from an atom. In this case, the photon energy is spent on the atom's ionization, that is, on the work necessary to “tear out” the electron. The remainder goes into the electron's kinetic energy.

The substance of the protoplanetary disk, during its formation, passed through a kind of mass spectrometer, which acted as a magnetic separator. Ionized particles with low ionization potentials were captured by a magnetic field and remained in the near-solar space, in the zone of the Earth's formation. Moreover, elements with high ionization potentials passed without delay and ended up in a zone farther from the Sun. Therefore, the relative carbon content on Earth is thousands of times less than on the Sun. Carbon atoms, mostly neutral, slipped past the Earth's formation zone. The asteroid belt is three times farther from the Sun than the Earth's formation zone.

For this reason, the reason for the enrichment of meteorites with carbon in comparison with the Earth is understandable. This fact also applies to sulfur, gold, platinoids, mercury, and beryllium—these elements have high ionization potentials and are weakly delayed during magnetic separation.

Moreover, a few alkaline earth metals and uranium in meteorites are easily ionized. These remained in the zone of terrestrial planets. Finally, the Earth and the Moon are at the same distance from the Sun, and magnetic separation works similarly.

Based on several reasonable assumptions, the authors of [27] proposed an equation for the distribution of atoms of chemical elements for a diluted atomic cloud irradiated with a spectrum of ionizing radiation:

$$X_{SS}^+(M) = X_{SS}(M) \exp\left(-\left(\frac{E_1(M)}{T_{CB}}\right) 4\pi \left(\frac{R_{PS}}{d}\right)^2 \left(\frac{T_{CB}}{T_G(d)}\right)\right) \quad (4)$$

The ionization power decreases under the solid angle from the radiation source with increasing distance d from the source. Locally, energy is radiated to the cosmic background mainly due to ionized elements with higher E_1 . Consequently, thermal equilibrium with the cosmic background is achieved by maintaining the fraction of elements in the ionized state, which decreases exponentially with E_1 . At a close distance from the protosun (for example, $d \sim 1$ AU), this fraction remains extremely low, even for lower E_1 (~ 4 eV). As the distance from the protosun in the ionized state increases, more elements with higher values should be excited E_1 . For exceptionally large distances, the fraction of ionized atoms approaches 1, even for elements with higher E_p , although the ionizing power of the central star body is greatly reduced. Consequently, the local electron temperature increases with the distance to an ionizing source [27].

Given the normalization of the content of elements relative to silicon and allowing gravitational aggregation of the planetary body at a distance d , the law of magnetic-chemical differentiation of the planets proposed in [27] has the form:

$$\begin{aligned} f_V(d, M) &= \frac{X(d, M)}{X_{Si}(d, M)} \\ &= \left(\frac{X}{X_{Si}}\right)_{SS}(d, M) \exp\left(-\left(\frac{E_1(M) - E_1(Si)}{k_B T_G(d)}\right) 4\pi \left(\frac{R_{PS}}{d}\right)^2 \left(\frac{T_{CB}}{T_G(d)}\right)\right) \end{aligned} \quad (5)$$

where $f_V(d, M)$ —the coefficient of volumetric differentiation of a planetary body gravitating to the average distance d , and the index SS refers to the average composition of the solar system.

From the above equation, it follows that deviations from the regularity described by Equation (5) show information on the ratio of surface and volume concentrations of chemical elements. Based on these data, the authors of [27] conclude that the data points for the Earth's crust located above the regression line indicate elements that are enriched on the surface relative to the volume (for example, F, O, Si, P, B, Cl, ...) or added from outer space to the surface. At the same time, the points located below the regression line indicate elements whose

content is depleted on the surface relative to the Earth's volume (for example, Fe, Co, Ni, Cr, H, ...) or may be lost due to the Jeans effect [32] [33] from due to the dissipation of the planetary atmosphere into space (first of all, this concerns hydrogen H and helium He).

The initial composition of the Earth was calculated in [13] [14] [27] based on the following postulates:

- The composition of the Sun over the entire history of its existence in the form of a Star has changed relatively little: the hydrogen content has decreased, helium has been added, and lithium and beryllium have partially burnt out in thermonuclear fusion. The balance of the remaining elements remained virtually unchanged. Therefore, the composition of the starting material can be judged by the composition of the modern Sun.
- The outer geosphere of the Earth, the composition of which was accepted for consideration, retained a distinctive imprint of the initial composition of the planet. According to this imprint, one can draw a trend of the initial position of the elements, which they had before the Earth's geological processes turned on and the elements began to migrate according to their geochemical features.

Based on the previous, the following results were obtained:

- 1) The composition of the initial substance, which passed through a magnetic separator during the formation of a protoplanetary disk, was established.
- 2) The dependence was revealed by which it is possible to determine the extent to which a magnetic field delayed an element.

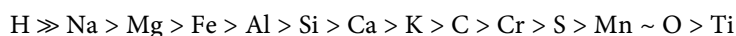
Based on this, the initial content of the main chemical elements in the zone of the protoplanetary disk in which the planet Earth was formed was calculated. The calculated data are presented in **Table 1**.

According to Equation (5), considering traces as elements heavier than Ni and using the available experimental relative abundances for the earth's crust, we can calculate the initial mass fractions of the mass for the Earth (M) (**Table 1**).

This calculation predicts an extremely high initial hydrogen content in the inner Earth, the second most abundant mass of the main element after iron, and surprisingly low oxygen content:



The ranking of molar fractions (**Table 1**) reflects the volume content in atomic percent and allows you to make stoichiometric assumptions:



Particular attention should also be paid to the fact that the main elements in the protest, located in the zone of the Earth's formation, were hydrogen (**Table 1**).

A similar effect is also because our planet's gravity cannot retain hydrogen, and it efficiently dissipates into outer space [32] [33]. Before, the hydrogen content on Earth was greater. The initial hydrogen content can be estimated based on its position in the trend, which is determined by magnetic separation.

Table 1. The initial composition of protoplanetary matter in the zone of Earth's formation is calculated in [13] [14] [27].

Chemical element	Symbol	Mass fraction, mass%	Molar fraction, mol%
Hydrogen	H	18.30	87.43
Helium	He	$1.856 \cdot 10^{-5}$	<0.01
Boron	B	$4.22 \cdot 10^{-5}$	<0.01
Carbon	C	0.755	0.30
Nitrogen	N	$5.562 \cdot 10^{-3}$	<0.01
Oxygen	O	0.139	0.04
Fluorine	F	$1.26 \cdot 10^{-7}$	<0.01
Neon	Ne	$2.675 \cdot 10^{-6}$	<0.01
Sodium	Na	13.41	2.81
Magnesium	Mg	13.89	2.75
Aluminum	Al	8.769	1.57
Silicon	Si	9.028	1.55
Phosphorus	P	$5.715 \cdot 10^{-3}$	<0.01
Sulfur	S	0.379	0.06
Chlorine	Cl	$4.21 \cdot 10^{-4}$	<0.01
Argon	Ar	$1.883 \cdot 10^{-4}$	<0.01
Potassium	K	3.76	0.46
Calcium	Ca	8.79	1.06
Scandium	Sc	$3.601 \cdot 10^{-3}$	<0.01
Titanium	Ti	0.210	0.02
Vanadium	V	$2.329 \cdot 10^{-2}$	<0.01
Chromium	Cr	1.046	0.10
Manganese	Mn	0.452	0.04
Iron	Fe	19.42	1.67
Cobalt	Co	$6.153 \cdot 10^{-2}$	0.01
Nickel	Ni	1.627	0.13
Total balance		100.00	100.00

According to the calculations, the initial concentration of the element in Earth's formation zone was about 87.4 at.% (see **Table 1**).

From this fact, it follows that all elements' atoms and ions were in a hydrogen environment during the Earth's formation. From here, it follows that when the plasma is cooled, the atoms will condense with the formation of various chemical compounds, most of which should be represented by various hydrogen compounds—hydrides.

Conventional stoichiometric compositions for hydrides of primary and secondary elements by the content of elements can only immobilize about 24.4

mol% of the amount of initially available hydrogen. According to the authors of [27], the inner Earth could contain only 5.1 mass% combined hydrogen. Nevertheless, to solve the so-called “nuclear density deficiency problem”, the formation of iron hydride is increasingly regarded as a key ingredient in the Earth’s core [35] [36]. The results [27] show that the Earth’s mantle could be more restored than is usually believed and that hydrogen is distributed more evenly in the solar system.

When considering their model, the authors of [27] did not consider current trends in the chemistry of hydrides of chemical elements at high pressure.

2.2. The Physical Properties of Atoms and Ions Influence on Their Behavior during the Earth Formation

The properties of atoms or ions of chemical elements are determined by three main characteristics: the ionization energy of atoms, their electron affinity, and electronegativity. The physical properties of atoms, such as ionization energies and electron affinity, are measured experimentally. Other properties of atoms are calculated theoretically.

The ionization energy, denoted by, E_1 , is the minimum energy required to remove the weakest bound electron, a valence electron, from an isolated neutral gaseous atom. It should be borne in mind that the atom of this element must be in the ground (unexcited) state, and the electron must be removed at an infinitely large distance. Usually, this process is endothermic. As a rule, the closer the outermost electrons are to the nucleus of an atom, the higher the ionization energy of the atom of the corresponding element.

The ionization energy depends on many different factors. Below are the main factors that determine the ionization energy:

- 1) The charge of the nucleus. The nucleus holds the electrons more densely with the increasing nuclear charge, and the ionization energy increases.
- 2) The number of electronic shells. As the size of the atom increases, the electron shells become less dense, and the ionization energy decreases.
- 3) The effective nuclear charge (Z_{eff}). With an increase in the screening and penetration of electrons into the inner shells of an atom, the electrons begin to be weakened by the nucleus weaker. Accordingly, Z_{eff} decreases; therefore, the ionization energy decreases [37].
- 4) Type of orbital ionization of an atom. An atom of a chemical element having a more stable electronic configuration has a lower tendency to lose electrons and, therefore, has high ionization energy.
- 5) The degree of completion of the corresponding sublevel. If the sublevel is half or full, these electrons are more difficult to remove, and vice versa. When the sublevel is partially filled, the electrons are removed more easily.

The ionization energy (E_i) is the essential quantitative characteristic of the strength of the electronic configurations of individual atoms and the ions formed from them. The ionization energy is a measure of the bond strength of the first or nth electron with an atom and, at the same time, is a measure of the

electron's attraction to this atom.

A detailed analysis of the physical meaning of the ionization energies of atoms of chemical elements, the laws of their change in the D. I. Mendeleev's Periodic system held in my works [38] [39].

To analyze the patterns of changes in the content of chemical elements in the Earth and the composition of the Sun, we used data on atomic ionization energies, refined by us based on the technique presented in [40], as well as from correlation equations presented in [41] [42] [43] and summarized in [38] [39].

To carry out the calculations, we used the averaged data on the composition of the Sun, taken from the works [44] [45] [46]. Differentiation coefficients for the Earth were calculated based on data on the Earth's crust [28]. By analogy with the proposals made by the authors of [27], the normalization of data on the composition of solar and planetary matter is necessary. For these purposes, we calculated the coefficient of differentiation of the element for the Earth. They were defined as the ratio of their relative abundance in Earth composition to the silicon abundance. Silicon was taken as a reference. The resulting correlations are presented in **Figure 2**.

The formula calculated differentiation coefficients:

$$Y = \frac{\left(\frac{X}{X_{Si}} \right)_E}{\left(\frac{X}{X_{Si}} \right)_{ss}} \quad (6)$$

where $\left(\frac{X}{X_{Si}} \right)_{ss}$ —the ratio of the mass content of the element to the silicon content in the composition of the Sun; $\left(\frac{X}{X_{Si}} \right)_E$ —the ratio of the mass content of the element to the silicon content in the composition of the Earth.

When processing data on the correlation of differentiation coefficients of the Earth's crust elements depending on the first ionization potential E_1 , the authors of [13] [14] [27] used the standard least-squares method. To correct the data, they excluded from the analysis those elements that gave the greatest deviations from the obtained regression dependence, explaining this by the presence of a large geological differentiation of the elements in the Earth's crust during the planet's life. In my opinion, this approach is possible, although it introduces uncertainty to the data used.

As you know, one of the urgent problems of mathematical modeling is the determination of the numerical values of the indicators of the constructed model. Often, for example, in our case, the initial experimental data are many disparate observations by different authors made at different points in time, significantly complicating the process of identifying model parameters. It is not always clear what methods should be used to evaluate the parameters and how to measure the degree of closeness of the observed indicators and their calculated values within the framework of the constructed model. One of the widely used

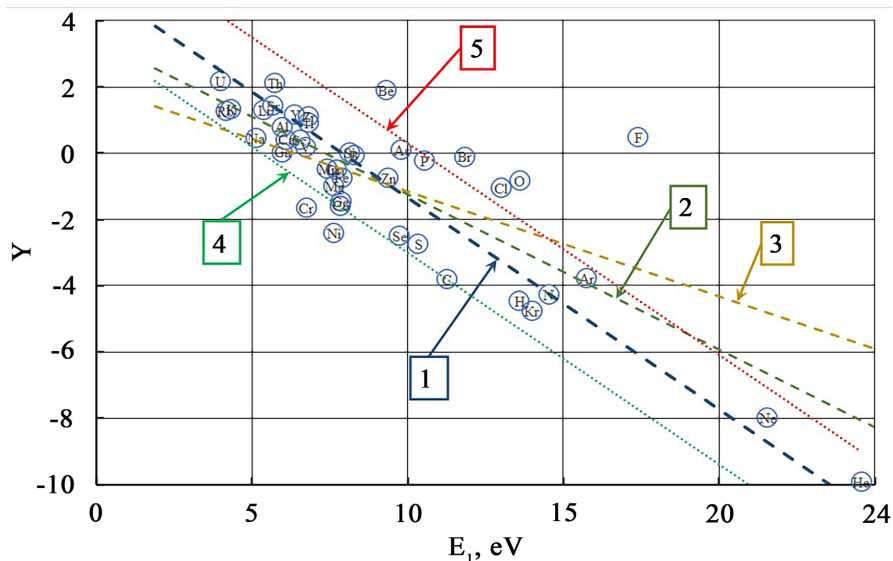


Figure 2. Differentiation coefficients of the Earth's crust elements ($Y = \log f_v$) depending on the first ionization energy E_1 for elements from hydrogen to uranium. 1—Least squares regression line considering weights proportional to the content of elements in the solar photosphere; 2—Regression line calculated using the standard least squares method; 3—Least squares regression line with weight coefficients inversely proportional to the deviation of the data point from the regression line; 4 and 5—lines corresponding to negative (4) and positive (5) standard deviations of the data from the regression line, calculated considering weight coefficients proportional to the content of elements in the solar photosphere.

approaches to solving the problem of estimating numerical characteristics in conditions of incomplete and inconsistent data is an approximation based on functional dependencies that reflect the essence of the simulated system. Various norms can act as a measure of approximation accuracy and weighting coefficients, which make it possible to regulate the contribution of multiple data to the result.

Per model (1), we have an exponential, nonlinear dependence. One can arrive at such a model because of simple logarithmic transformations or the linearization procedure of this nonlinear dependence. The results of evaluating the possible values of the straight-line parameters for different weighting factors are presented in **Table 2**, and the regression lines obtained with their help are shown in **Figure 2**. An analysis was carried out using various weighting options. One option is a regression line calculated using the standard least-squares method. This option is the primary **Figure 2**, *line 2*. The calculated trend parameters are presented in **Table 2**.

Another option is the regression line, calculated by the least-squares method considering weights, inversely proportional to the deviation of the data point from the regression line. The analysis of function (7) allows us to develop a heuristic approach to the choice of weights in the general procedure of the least-squares method. The result of such an approximation is presented in **Figure 2** as a straight *line 3*. The calculated trend parameters are shown in **Table 2**.

Table 2. Trend parameters of the Earth's crust elements' differentiation coefficients depend on the first ionization energy E_1 for various approximation options (**Figure 2**).

Approximation Option	a, eV^{-1}	b	R^2	$\hat{a}^{*1}, \text{eV}^{-1}$	\hat{b}^{*2}	E_{cr}, eV^{*3}
1	-0.639	5.04	0.824	-1.471	108,930	7.88
2	-0.469	3.44	0.824	-1.079	2763	7.34
3	-0.317	2.02	0.824	-0.731	105.69	6.38
[13] [14] [27]			0.526	-1,139	3043	7.04

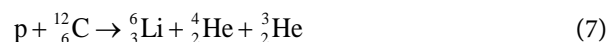
$^{*1} \hat{a} = \frac{a}{\lg e}$ —The actual slope of the regression line is calculated in **Figure 1**. $^{*2} \hat{b}$ — Pre-exponential factor calculated in **Figure 1**. $^{*3} E_{cr}$ —Axis E_1 intersection point.

From these data, both options are unlikely to have any physical meaning. The first option is strongly distorted by a significant scatter of experimental points, and the second mathematically reduces the contribution of data that deviates significantly from the average trend.

In the future, we will try to select the data weights considering their significance in the physical nature of this object. In this case, we chose the relative content of elements in the composition of the solar photosphere as weights. Thus, those elements whose content in the initial protoplanets of the disk was the maximum should contribute to the general trend of this trend. The correlation dependence in *line 1*, shown in **Figure 2**, was obtained using this approach and Equation (8). The calculated trend parameters are presented in **Table 2**. Thus, using Equation (9), the standard deviations of all experimental data from the trend line were calculated. The data obtained are presented in the form of lines corresponding to the negative (*line 4*) and positive (*line 5*) standard deviations of the data from the regression line, calculated taking into account weight coefficients proportional to the content of elements in the solar photosphere. From the presented data, it is seen that most of the points corresponding to the content of elements in the composition of the Earth are in the field between *lines 4* and *5*.

Elements located above *line 5* are enriched on the surface of the Earth. In contrast, the Earth is depleted in elements located below *line 4*. What could be the reason for this behavior of all these elements? Above *line 5* are halogens, oxygen, and beryllium. As the most active elements, Halogens and oxygen could be washed out of the Earth's bowels by rising hydrogen streams during degassing. Larin V.N. and colleagues have repeatedly noted this in their works [13] [14] [27].

Natural beryllium consists of a single isotope ^9Be . All other beryllium isotopes are unstable. There are 11 of them, except stable ^9Be . The most long-lived are ^{10}Be , with a half-life of about 1.4 million years, and ^7Be , with a half-life of 53 days [47]. Today, it is relatively accurately known that beryllium Be, along with lithium Li and boron B, is formed in cosmic rays through cleavage reactions on C, N, and O atoms with high-energy protons of cosmic rays, for example, by the following reaction:



As well as by α - α fusion, the prevalence was less by several orders of magnitude for heavier elements such as ${}^9\text{Be}$, ${}^{10}\text{B}$, and ${}^{11}\text{B}$. Recently, an upper limit for beryllium has been determined for several low-metal stars: ${}^9\text{Be}/\text{H} < 2.5 \cdot 10^{-12}$. This value is a thousand times higher than expected in the standard model of early nucleosynthesis [48].

However, the importance of these factors for nuclear fusion is not unambiguous since the prevalence data suggest the birth of these atoms by cleavage rather than the first nuclear fusion. Nevertheless, these observations are of interest for models of inhomogeneous nuclear fusion. One possibility of explaining the unexpectedly high abundance of ${}^9\text{Be}$ in ancient (low metal content) stars [49] is an inhomogeneous scenario in the theory of the first nuclear fusion. Also, nucleus formation processes are possible with a high concentration of neutrons in regions of low density. Then ${}^9\text{Be}$ formation is permissible if ${}^7\text{Li}$ collisions with helium nuclei occur according to the scheme:



As can be seen, a significant amount of beryllium can be obtained along this path. A detailed discussion of the experimentally determined abundances of light elements is given in [50] [51] [52] [53].

The analysis of the content of various elements in the composition of the Earth, depending on other physical parameters of the atoms, made it possible to understand the cause of the precipitation of nickel and chromium in the zone of low content, compared with the general trend. A comparison of the calculation results using various approximation options is presented in **Table 2**.

Comparing the results obtained, we can conclude that our findings' accuracy is better than those obtained by the authors [13] [14] [27]. The correlation coefficient indicates this R^2 . An important parameter is the intersection point of the E_i axis with a regression line. Its physical meaning can be understood as the energy level of ionizing radiation or the local plasma temperature in a protoplanetary disk by formula (4). Under these conditions, all elements in which the ionization energy is equal to or less than this level was almost completely ionized. This value significantly exceeds the energy of a single chemical bond in most chemical compounds. Therefore, under these conditions, the stable existence of chemical compounds was impossible. All compounds must be completely dissociated and atoms partially ionized. Our calculation gives a higher estimate of this value than the calculations presented by V. N. Larin in their work.

Next, for analysis, we take such a parameter as electron affinity. As is known, isolated energetically stable negative ions can exist along with positively charged ions. It is necessary to expend incredibly significant energy to detach an electron from such ions. So, to detach an electron from F^- 339.13 kJ/mol is required. This energy should be released or absorbed in the process of attachment of an electron to a free atom in its ground state, with its transformation into a negative ion A^- . Thus, negatively charged ions could well exist in the discharged gas of the

protoplanetary disk. Negatively infected ions passing through a kind of magnetic separator, which existed in the protoplanetary gas nebula, should have moved in the opposite direction from the direction of movement of positively charged ions. Thus, these elements should have been concentrated in the zone of elements with low ionization potentials, *i.e.*, closer to the protosun.

All atoms having positive affinities for the electron attach an electron with energy release, *i.e.*, the attractive force of the external electron by the nucleus in them is higher than the repulsive force that the electrons already have in the atom. At the same time, adding another electron to the monovalent negative ions in the gaseous state is impossible due to a sharp increase in the repulsion of other electrons by the outer shell of atoms. Therefore, multiply charged monoatomic anions (O^{2-} , S^{2-} , N^{3-}) cannot exist in the free state.

The affinity for the electron and the first ionization energy characterizes the neutral atom from opposite sides, as it were, determining the energy of electron attachment to it and the energy of separation of the first electron from it. Therefore, the relationship between these quantities is quite complicated.

Due to the low stability in pairs of negatively charged ions, electron affinity has long been determined only for 15 - 20 elements. Later, this value was established for 71 elements. We could calculate or make plausible estimates of this value for all known elements of the Periodic System [38] [39], which allowed us to analyze the effect of electron affinity on the content of elements in the composition of the Earth. The results are presented in **Figure 3**.

As can be seen from **Figure 3**, two main groups of elements can be distinguished. Elements with a positive affinity for the electron represent the first central group of elements. This group is mainly located along with the line corresponding to the same content of elements in the composition of the Earth and Sun. The second group is elements with negative values of electron affinity. They deviate significantly from this trend. The regression line calculated by the standard least-squares method has a slight slope and runs alongside the edge of equality with the concentration of elements. The least-squares regression line considering the weight coefficients proportional to the content of elements in the solar photosphere mainly passes through a group of elements with negative electron affinity. In the first group, halogens can be distinguished separately, far from the general group of all elements. At the same time, it almost precisely lies on the line of equal concentrations. Based on the results obtained, it can be concluded that the formation of negative ions in the protoplanetary disk, if it occurs, is only for halogens. Also, it can be assumed that the creation of such ions does not lead to their significant separation, due to their possible rapid recombination with positively charged ions, with the formation of neutral atoms. Also, let's compare the E_{cr} value in **Table 2** with the electron affinity for halogens. We can understand that the loss of electrons by negatively charged halogen ions is also quite likely, and if they are formed, then only in a tiny fraction by the distribution of Maxwell.

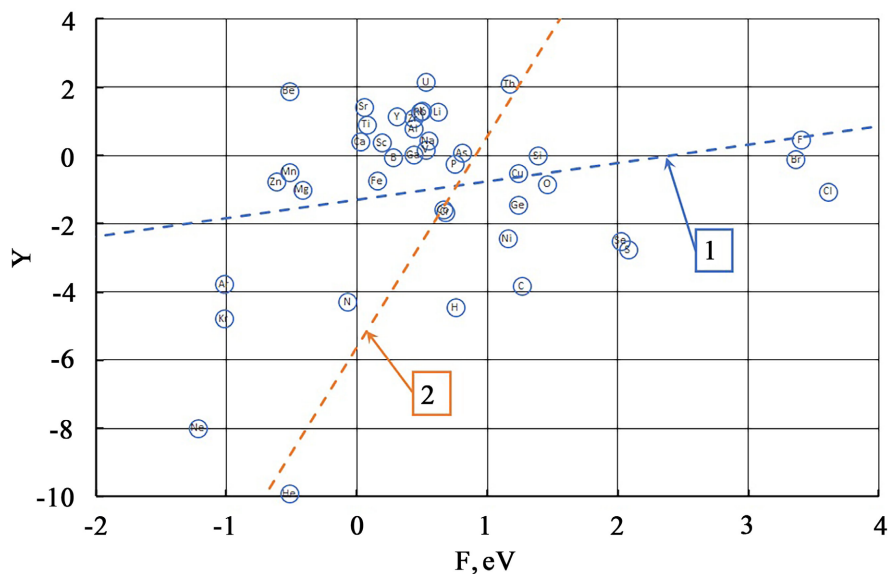


Figure 3. Differentiation coefficients of the Earth's crust elements ($Y = \log f_v$) depending on electron affinity F for elements from hydrogen to uranium. 1—Regression line calculated using the standard least squares method; 2—Least squares regression line considering weights proportional to the content of elements in the solar photosphere.

Another important physical characteristic of atoms is electronegativity, which, like the previous parameters, is energy characteristic. Electronegativity is a chemical property that describes the tendency of an atom to attract a common pair of electrons or the electron density to itself when a chemical bond is formed [38] [39] [54] [55]. Such parameters influence the electronegativity of an atom as its atomic number and the distance from the charged nucleus at which its valence electrons are located. The higher the corresponding number of electronegativity, the more the atom or group of substituent attracts electrons to itself.

Such factors determine electronegativity as the charge of the nucleus and the number and location of other electrons present at various atomic levels. Electronegativity increases with an increasing number of electrons in an atom. Also, the degree of screening of the positive charge of the nucleus increases with increasing distance from the nucleus at which the valence electrons are located. This effect is because other electrons located at lower energy levels protect valence electrons from the action of a positively charged nucleus.

The concept of electronegativity is clear and convenient for teaching chemistry and considering general trends in the changes in the chemical properties of elements and their compounds. The concept of electronegativity was first proposed by L. Pauling [56]. According to L. Pauling, all values of electronegativity are additive. He widely used them to estimate the degree of ionicity of covalency of a chemical bond in compounds formed by different atoms [57].

Around the same time, R. S. Mulliken [58] proposed, as a measure of electronegativity, half the sum of the first ionization potential and electron affinity:

$$\chi = \frac{E_1 + F}{2} \quad (9)$$

Such a definition of electronegativity characterizes a free atom from two opposite and mutually complementary sides: the energy spent on breaking an electron from it (E_i) and the energy released when an electron is attached to an atom (F). Later, the χ value was called the orbital electronegativity [59] [60].

We could calculate or make plausible estimates of electronegativity for all known elements of the Periodic System [38] [39], which allowed us to analyze the effect of electron affinity on the content of elements in the composition of the Earth. The results are presented in **Figure 4**.

Comparing **Figure 4** with **Figure 2**, we can fish that these figures are remarkably similar. From this, we can conclude that the main contribution to the differentiation of elements in the protoplanetary disk is primarily by energies that determine the positive ionization of atoms. In this case, the possibility of the appearance of negative charges practically does not affect the behavior of the entire system of atoms and ions in the protoplanetary disk.

2.3. Properties of Hydrides of Chemical Elements at High Pressure

As noted above, according to the hydrogen ionization potential, the initial concentration of this element in the zone of the Earth's formation was huge (see **Table 1**). This situation indicates that when the planetary body was created, all other elements were in the form of their compounds with hydrogen-hydrides. The geological structure of the Earth's interior results from deep processes that took place in the past and are proceeding now. To understand the essence of these deep-seated processes, we should understand the nature of the interaction of hydrogen with various chemical elements since the initial composition of the planet is a mixture of hydrides of different elements. Almost all elements can react to one degree or another with hydrogen. The interaction of the starting components proceeds by the following steps:

- Hydrogen adsorption on the surface of low-volatility solid particles. Such parts are metals and the resulting chemical compounds.
- Occlusion—the dissolution of hydrogen in the volume of metal or other chemical compounds.
- Chemical interaction with the formation of hydrides and super hydrides.

On the other hand, it is known that the pressure inside the Earth, determined using the hydrostatic equation as a function of density and gravity, is 375 GPa [63]. This automatically raises the question of the individual behavior of hydrides of chemical elements at high pressure. The pressure is critical since it can cause chemical compounds to accept stoichiometry and structure, which would be inaccessible in atmospheric conditions [64] [65] [66] [67].

Under such conditions, the change in free energy associated with such a degree of compression can exceed 10 eV, which exceeds the energy of the most durable chemical bond. Pressure brings dramatic changes to the chemistry of many systems. Due to pressure-induced changes in properties, the reactivity of chemical elements and their compounds is wholly changed. Under these

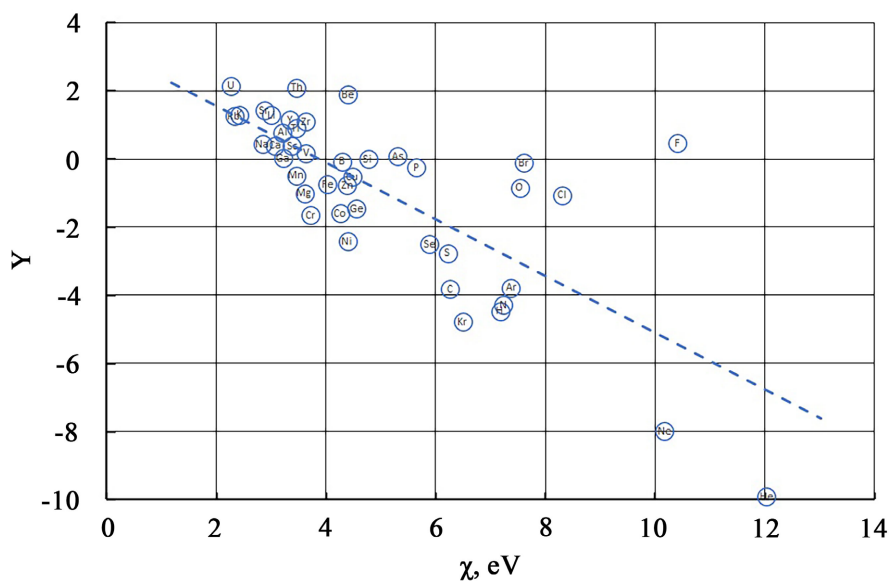


Figure 4. Differentiation coefficients of the elements of the Earth's crust ($Y = \log f_v$) depending on the electronegativity χ for elements from hydrogen to uranium. The regression line was calculated using the standard least-squares method.

conditions, new classes of materials can be formed with unusual physical and chemical properties combinations. Also, applying pressure perfectly adjusts electronic, magnetic, structural, and other features. In this case, cardinal changes to the chemistry of compressible systems. In this case, completely new classes of materials with unusual combinations of physical properties can be formed [64] [65].

Understanding how gases, liquids, and solids react to high pressures at varying temperatures is essential. Much research is devoted to systems representative from an experimental point of view. Such systems are illustrations of critical physical and chemical phenomena. Such phenomena include changes in structure and bonds (including weak interactions), phase transitions and chemical reactions, vibrational dynamics, quantum effects, excited electronic states, and pressure-induced electric and magnetic order states. In this regard, molecular hydrogen is the most fundamental substance. Many observations of new phenomena and assumptions about their origin were verified on this element [68] [69] [70].

Pressure brings materials to lower volume states, so pressure includes the mechanisms necessary to achieve a higher density. In a chemical sense, compression affects the energy of electrons. The total energy of electrons is the sum of the kinetic, Coulomb, exchange, and correlation components. When a substance is compressed, from the point of view of the density functional theory, the kinetic energy of electrons increases sharply. Under these conditions, electrons tend to state with lower kinetic energy. This behavior of electrons means the destabilization of intramolecular bonds. Early it was assumed that at sufficiently high pressures, all materials should go into states with "metal lattices." The molecular system is destroyed, forming a skeleton and/or a tightly packed structure with the formation of a completely metal phase or, ultimately, plasma in which

the concept of chemical bonding is permanently lost.

Recent years have shown impressive achievements in the field of a priori prediction of the crystal structure using the density functional theory [67]. They led to synergies between experiment and theory in high-pressure research. Calculations are performed to predict the structures and properties of synthesis targets and to help characterize the phases obtained in the experiment. This synergy has played an essential role in developing studies of hydrides, their structure, and their properties at high pressure. A hierarchy of the responses of a substance to an increase in density was established [65]:

- Extrusion of van der Waals space for molecular crystals.
- Increased coordination.
- Reduction in covalent bond length and anion size.
- Removal of electrons from atoms and creation of new extreme correlation modes.

It was predicted that hydrogen, the single-atomic solid, the lightest of all elements, would become a superconductor in the metallic form with a high critical temperature (T_c) [71]. However, the current estimate shows that the metallization of pure hydrogen may require pressure above 500 GPa [68]. Hydrogen metallization was reported in several experiments [72].

The phenomenon of superconductivity was found in hydrides with moderate or relatively low hydrogen content. These compounds have been shown as potential superconductors. The possibility of transforming a new form of hydrogen into a metallic state in LiH_2F is shown. This structure is quite stable in environmental conditions. The pressure required to stabilize this compound and turn it into metal is estimated at 4 MPa. This pressure is more than an order of magnitude less than the critical values necessary for forming pure metallic hydrogen. The LiH_2F compound has an extremely high hydrogen density, electrical conductivity, Debye temperatures for the hydrogen sublattice, and superconducting transition temperature [73].

It was shown that LiBeH_3 and Li_2BeH_4 have face-centered cubic lattices of 5.09 and 5.14 Å, respectively. Each cubic cell contains eight formula units and total atomic concentrations of $3.03 \cdot 10^{23}$ and $4.12 \cdot 10^{23} \text{ cm}^{-3}$, 1.7 and 2.3 times higher than diamond. The estimated density is 1.91 and 2.63 g/cm³. Both crystals have a modified perovskite structure. The electron density of Li_2BeH_4 is $4.71 \cdot 10^{23} \text{ cm}^{-3}$, commonly accepted for metallic hydrogen. Therefore, these compounds, if they are metallic, can exhibit high-temperature superconductivity, as in metallic hydrogen [74].

In connection with this, the idea was put forward that metallic and superconducting states are possible for hydrides of covalent elements with high hydrogen content. This idea relates to hydrides of group IV hydrides of the Periodic System, where simple structures have eight electrons per unit cell. In such combinations, the situation lies in the fact that, in the chemical sense, hydrogen has already undergone the form of “preliminary compression” [71] and, under the influence of additional external pressure, more easily enters the metal phase. Elec-

trons come both from hydrogen and from the elements that form the hydride.

This situation is typical for many binary compounds. For example, under normal conditions, the average electron density in magnesium diboride MgB_2 exceeds the density in magnesium metal Mg by 3.2 *times*. Tin and lead are superconductors, while germanium and silicon transform into a metallic state under pressure. Recently, a new class of hydride compounds, the so-called polyhydrides or super hydrides, has been discovered, which contains an abnormally large amount of hydrogen. On the other hand, polyhydrides of the main group with a high hydrogen content were proposed as precursors for the “preliminary compression” of hydrogen [71]. In these hydrides, heavier elements enhance the intermolecular interactions between hydrogen particles, causing the dissociation of hydrogen molecules. Therefore, it can achieve metallization at lower pressures than expected for pure hydrogen. Metal polyhydrides can be used at lower pressures to produce material that may have bound atomic hydrogen. Many theoretical calculations based on the Bardeen-Cooper-Schriffer theory of superconductivity confirm this assumption [75]. As a result, these studies calculated the possibility of formation and properties of hydrides of various elements of the Periodic Table with T_c above 200 K [61] [62]. The data available in the literature are presented in **Table 3**. Recently, $T_c = 203$ K was observed in H_2S , compressed to 200 GPa [76].

Pepin *et al.* [77] synthesized the incredibly hydrogen-rich compound FeH_5 at a pressure of 130 GPa. High pressure promotes the formation of polyhydrides with an unusually high ratio of hydrogen to metal. These polyhydrides have complex hydrogen sublattices. Iron pentahydride (FeH_5) was synthesized by a direct reaction between iron and H_2 above 130 GPa in a laser-heated diamond heater. FeH_5 has a sublattice built only of atomic hydrogen. The material consists of intercalated layers of quasi-cubic elements FeH_3 and four planes of atomic hydrogen. The distribution of valence electron density indicates a bond between hydrogen and iron atoms but not between hydrogen atoms, representing a two-dimensional metallic character. These metal polyhydrides were stable at much more affordable pressures than pure hydrogen. The discovery of FeH_5 offers a low-pressure pathway to create materials that approach bulk-dense atomic hydrogen. This achievement makes it possible to investigate the specific electrical properties expected from atomic hydrogen bonds, such as superconductivity. **Table 3** presents the literature data on the structure and physical parameters of the hydrides of chemical elements having high critical temperatures of the phase transition to the superconducting state, as well as the composition and pressure for which these values were obtained.

From the data in **Table 3**, two critical conclusions follow regarding the possible formation of hydrides in the composition of the Earth’s core and the possible occurrence of superconducting properties in the Earth’s core.

As noted above, the authors of [27] believe that the inner Earth could contain only 5.1 mass% combined hydrogen. Based on the data presented above, it can be assumed that the formation of polyhydrides with the maximum hydrogen

Table 3. Structural and physical parameters of hydrides of chemical elements with high values of T_c (K), as well as the composition, space group, Coulomb pseudopotential (μ), and pressure at which these values were obtained [61] [62].

Group	System	Pressure (GPa)	T_c (K)	μ	Space Group
1	LiH ₆	300	82	0.13	R $\bar{3}m$
	KH ₆	230	59 - 70	0.13 - 0.10	C2/c
2	BeH ₂	365	97	0.10	P4/nmm
	MgH ₆	400	271	0.12	Im $\bar{3}m$
	CaH ₆	150	220 - 235	0.13 - 0.10	Im $\bar{3}m$
	SrH ₆	250	156	0.10	R $\bar{3}m$
	BaH ₆	100	30 - 38	0.13 - 0.10	P4/nmm
3	ScH ₉	300	233	0.10	I4 ₁ md
	YH ₁₀	250	305 - 326	0.13 - 0.10	Fm $\bar{3}m$
	LaH ₁₀	200	288	0.10	Fm $\bar{3}m$
	CeH ₁₀	200	50 - 55	0.13 - 0.10	Fm $\bar{3}m$
4	TiH ₂	1 atm	7	0.10	Fm $\bar{3}m$
	ZrH	120	11	0.10	Cmcm
	HfH ₂	260	11 - 13	0.13 - 0.10	P2 ₁ /m
5	VH ₂	60	4	0.10	Pnma
	NbH ₄	300	50	0.10	I4/mmm
	TaH ₆	300	124 - 136	0.13 - 0.10	Fdd2
6	CrH ₃	81	37	0.10	P6 ₃ /mmc
7	TcH ₂	200	7 - 11	0.13 - 0.10	I4/mmm
8	FeH ₅	130	51	0.10	I4/mmm
	RuH ₃	100	4	0.10	Pm $\bar{3}m$
	OsH	100	2	0.10	Fm $\bar{3}m$
9	RhH	4	~2.5	0.13	Fm $\bar{3}m$
	IrH	80	7	0.13	Fm $\bar{3}m$
10	PdH/PdD/PdT	1 atm	47/34/30	0.085	Fm $\bar{3}m$
	PtH	77	25	0.13	Fm $\bar{3}m$
11	AuH	220	21	0.13	Fm $\bar{3}m$
13	B ₂ H ₆	360	90 - 125	0.20 - 0.13	Pbcn
	AlH ₃ (H ₂)	250	132 - 146	0.13 - 0.10	P2 ₁ /m
	GaH ₃	120	90 - 123	0.20 - 0.10	Pm $\bar{3}n$
	InH ₃	200	34 - 41	0.13 - 0.10	R $\bar{3}$
14	Si ₂ H ₆	275	139 - 153	0.13 - 0.10	Pm $\bar{3}m$
	GeH ₃	180	140	0.13	Pm $\bar{3}n$
	SnH ₁₄	300	86 - 97	0.13 - 0.10	C2/m
	PbH ₄ (H ₂) ₂	230	107	0.10	C2/m

Continued

	PH ₂	270	87	–	I4/mmm
15	AsH ₈	450	151	0.10	C2/c
	SbH ₄	150	95 - 106	0.13 - 0.10	P6 ₃ /mmc
	BiH ₅	300	105 - 119	0.13 - 0.10	C2/m
	H ₃ S	200	191 - 204	0.13 - 0.10	Im $\bar{3}$ m
16	H ₃ Se	200	131	–	Im $\bar{3}$ m
	H ₄ Te	170	95 - 104	0.13 - 0.10	P6/mmm
	PoH ₄	250	46 - 54	0.13 - 0.10	C2/c
	H ₂ Cl	400	44 - 45	0.13 - 0.10	R $\bar{3}$ m
17	HBr	200	44 - 51	0.13 - 0.10	P2 ₁ /m
	H ₂ I	240	24 - 33	0.13 - 0.10	R $\bar{3}$ m
18	XeH	100	~29	0.12	Immm

content occurred in the proto-earth at the initial stage. Suppose we take the new possible stoichiometric compositions for polyhydrides of primary and secondary elements by the content of the elements. In that case, they can immobilize only about 49.3 mol% of the initially available hydrogen. From here, the inner Earth could contain about 10.7 mass% combined hydrogen.

Thus, our estimate of the initial hydrogen content in the composition of the Earth is almost two times higher than the forecast made by V. Larin in his works. In this case, of course, the remaining hydrogen remained in a gaseous state and left the atmosphere of the formed Earth due to Jean's effect [32] [33] due to its dissipation into space.

The second conclusion from the above data indicates the possible superconducting properties of the Earth's inner core. This conclusion directly explains the occurrence of a magnetic field near the Earth and its historical behavior. The most critical effect describing the behavior of a superconductor in a magnetic field is the Meissner-Ochsenfeld effect—the complete displacement of the magnetic field from the volume of a conductor upon its transition to the superconducting state [79].

2.4. Possible Consequences of the Superconducting Properties Presence of Earth's Core Consisting of Hydrides

Superconductors are divided into first and second kinds according to their magnetic properties. The first kind of superconductor includes all materials based on individual chemical elements. In turn, niobium, superconducting alloys, and chemical compounds belong to the second kind of superconductor. The main difference between superconductors of the first kind and superconductors of the second kind is their response to an external magnetic field. In superconductors of the first kind, the Meissner-Ochsenfeld effect is observed. This effect consists of the magnetic field displacement from the conductor volume

upon its transition to the superconducting state. Pure substances have a full Meissner-Ochsenfeld effect. Alloys and chemical compounds do not completely eject the magnetic field from the volume; the so-called partial Meissner-Ochsenfeld effect is observed in them. However, it is worth noting that in low magnetic fields, all superconductors have the full Meissner-Ochsenfeld effect [80]. Superconducting polyhydrides at high pressure should be attributed to superconductors of the second kind.

For superconductors of the second kind, circular currents appear in the volume, creating a magnetic field that does not fill the entire volume of the material but is distributed in it in the form of separate filaments—Abrikosov's vortices [81]. Abrikosov's vortex is a superconducting current that circulates a nonsuperconducting core—a vortex filament, inducing a magnetic field with a magnetic flux equivalent to a magnetic flux quantum. As in superconductors of the first kind, the resistance is zero. This effect is observed regardless of the movement of the vortices under the action of passing current. The current creates an effective resistance inside the superconductor due to dissipative losses of the magnetic flux movement. This phenomenon is observed due to the presence of defects in the structure of the superconductor. Defects are pinning centers for which vortices “cling”. However, vortices can spontaneously attach to nanoscale inhomogeneities in the material. This process is called pinning, and these heterogeneities are called pinning centers. The vortex pinning disrupts the order in the vortex lattice and contributes to the conservation of the superconducting phase even when extremely high currents flow [82].

The magnetization is created by circular currents circulating in the superconductor. However, these currents completely cancel each other out in the bulk of the superconductor. Thus, only a surface current remains in the superconductor. Surface currents persist even after the external magnetic field is turned off. Thus, they will create their magnetic field in a superconductor of the second kind, which is impossible in a superconductor of the first kind. In this case, a superconductor of the second kind is multiply connected. Therefore, superconducting currents can circulate in it without attenuation over the surface of this superconductor. In such superconductors, the so-called intermediate state can occur. For example, if a superconducting ball is placed in a magnetic field exceeding the critical value for this superconductor, it will go into the so-called intermediate state. At the same time, it will break into a network of alternating regions of the superconducting and normal phases. In this case, the boundary surfaces of these regions will always be parallel to the magnetic field. However, they can form bizarre figures in a cross-section perpendicular to the magnetic field [83].

As you know, the magnetic field in outer space of the solar system is approximately estimated at $5 \cdot 10^{-5}$ G. For comparison: in intergalactic space, the magnetic field is of the order of 10^{-9} G, and near the plane of the Galaxy, it is 10^{-6} G [84]. Thus, the motion of the Earth in this magnetic field will lead to the appearance of currents in its superconducting core due to the phenomena of magnetic induction. As noted above, these currents will circulate in the supercon-

ducting core without attenuation.

Another possible mechanism for the appearance of the Earth's magnetic field, in the presence of a superconducting core inside it, is the so-called London effect or the London Moment [85]. The moment of London is a quantum mechanical phenomenon. The essence of this phenomenon is the generation of a magnetic field during the rotation of a superconductor. The axis of this field is aligned precisely with the axis of rotation. It is caused by the lag of electrons from the object's rotation, although the field strength does not depend on the density of charge carriers in the superconductor [85].

The London moment is a magnetic moment acquired by a rotating superconductor. This phenomenon reveals the following fundamental properties of the superconducting state [86]:

- 1) Superconductors (unlike ordinary metals) know the sign of charge carriers.
- 2) Free electrons are superconducting charge carriers.
- 3) The electrons are pushed onto the conductor's surface when it enters the superconducting state.
- 4) Electrons acquire the property of superfluidity and occupy the orbits of the radius twice the penetration depth of London.
- 5) There is a spin current in the ground state of superconductors.

These properties are also consistent with the Meissner-Ochsenfeld effect. However, the Meissner-Ochsenfeld effect is not causally related to the sign of the charge carriers and the mass of this carrier, which is the mass of free electrons. It is also not related to the existence of spin current in superconductors, which also possibly contributes to the appearance of the Earth's magnetic field. The listed above critical properties of superconductors, none follow from the Bardeen-Cooper-Schrieffer theory of superconductivity. At the same time, all these properties are predicted by the theory of hole superconductivity [86].

3. Earth Core Destruction Models

3.1. Earth Structure and Initial Parameters of its Expansion Model

Figure 6 shows the density distribution in the crust and mantle in the framework of traditional concepts of silicate mantle [1]. Here, jumps in density in the upper mantle, tied to seismic data, are reflected. The density jumps are well manifested in the diagram of the gradients of the increase in the Earth's density, shown in **Figure 7**. Gradients of density increase in the lower mantle (deeper than 1050 km) were adopted according to the results of shock compression of oxides (of which silicates consist). With this variant of the density distribution in the mantle, it is necessary to attribute to the core a density in the range from 10 to 12.5 g/cm³. Otherwise, it is impossible to maintain the planet's total mass and moment of inertia.

In the framework of the model proposed by V. N. Larin, the nature of the density distribution in the upper mantle (to a depth of 1050 km) corresponds to classical concepts. However, according to these ideas, the metal sphere should

have significantly lower compaction gradients in the lower mantle since metals differ from silicates and oxides. However, this fact makes a small contribution to the total density of the Earth's crust and mantle; therefore, we did not consider it in our calculations. Larin proposed a significant increase in the density of the Earth's inner core to preserve the Earth's total mass to 25 g/cm^3 . His calculations also showed that this is necessary to achieve the total moment of inertia of the planet. Also, for these purposes, it was required to slightly change the nature of the density distribution in the outer core while maintaining its mass, as shown in **Figure 5** and **Figure 6**.

Thus, in the framework proposed by the V. N. Larin model [13] [14], the structure of the Earth is as follows. Under the lithosphere lies the metal sphere with small compaction gradients deeper than 1050 km. This approach requires a sharp increase in the planet's inner core density. Estimates show that it is necessary to double the density of the inner core to 25 g/cm^3 .

With such a density of hydrides at the pressure of several megabars, the development of the initial hydride Earth should have led to a significant increase in it. The calculated values of the size of the Earth during its expansion by the proposed models are presented in **Table 5**.

Of great importance is the originality of the planet's expansion process. Several factors could cause this decomposition of hydrides. One of the factors is the chemical interaction of solid hydrides with gaseous hydrides and other gases in the protoatmosphere surrounding the Earth [89] [90]. The second factor is additional thermal heating due to radiogenic heat. Initially, the content of uranium and potassium on Earth was an order of magnitude higher than in meteorites, and thorium was about two times greater.

3.2. Maintaining the Integrity of the Specifications

By the theory of the initial hydride Earth, the planet's development must undoubtedly be accompanied by its significant expansion.

Consider the simplest model of the planet's structure: a core and a mantle with a crust. For all proposed models, we believe that the shape of the Earth and its core is spherical. Since their real deviations from the shape of the sphere are small, we neglect them. At the first modeling stage, we ignore the planet's crust's thickness and depth differences between the mantle's structure and the planet's core. The initial data on the Earth's parameters adopted in further calculations are presented in **Table 4**. A simplified diagram of the Earth's structure is shown in **Figure 7**.

By this model, the average values of the parameters of the density of the core and the total density of the Earth's crust and mantle were adopted. The calculations of these parameters were carried out as follows. Since the functions of the density distribution of matter in the Earth's crust, mantle, and core are known from various seismic data, the average density can be estimated as the integral of the density distribution function shown in **Figure 5** and related to the width of the corresponding zone:

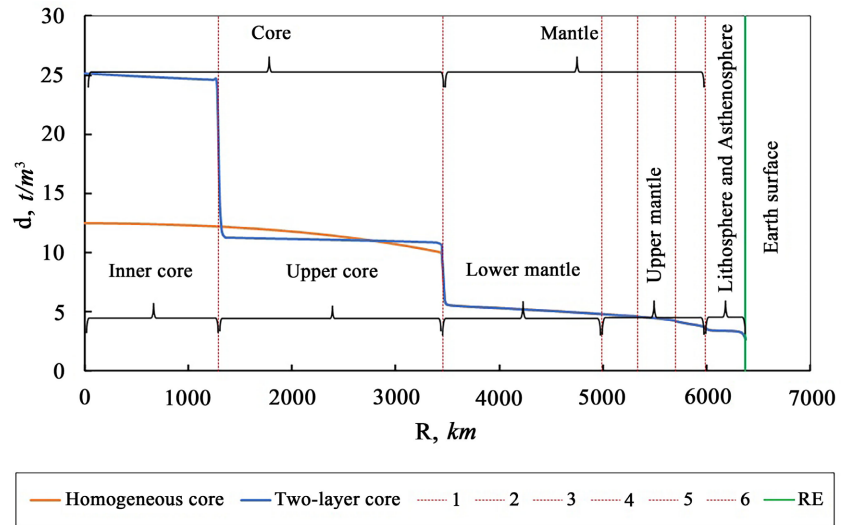


Figure 5. Density distribution in the crust, mantle, and core of the Earth. The section of the curve for the mantle and crust is presented by the traditional concepts of silicate mantle [87]. The plot of the curve for the planet’s core: *Brown curve*—conventional ideas about the density of the core [1]; the *Blue curve* is according to the two-layer core model [13] [14] [88]. 1 - 6—density jumps in the Earth’s crust, mantle, and core. RE—Earth’s surface. R is the distance from the center of the Earth.

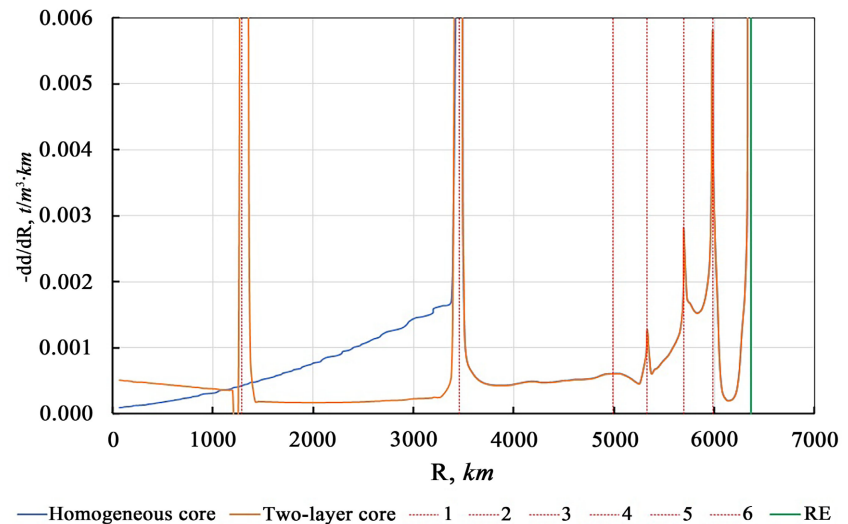


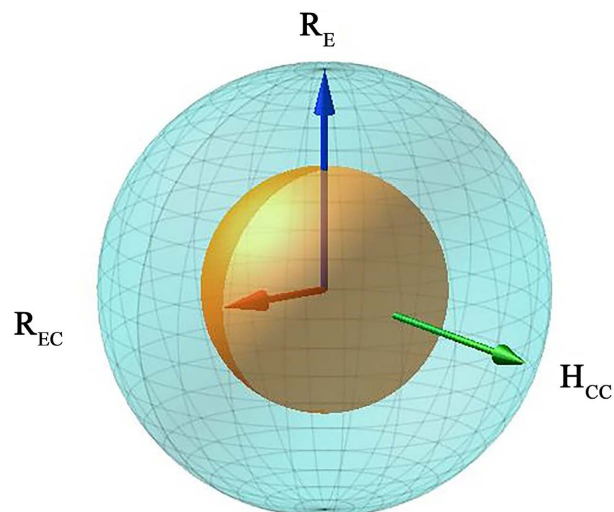
Figure 6. Density gradients in the crust, mantle, and core of the Earth. *Blue curve*—Gradients of the density of the crust, mantle, and core by traditional concepts of silicate mantle [87]; *Brown curve*—the density gradients of the planet’s core, calculated according to the model of a two-layer core [13] [14] [88]. 1 - 6—density jumps in the Earth’s crust, mantle, and core. RE—Earth’s surface. R is the distance from the center of the Earth. Gradient values are taken with the opposite sign.

$$\tilde{d}_{\alpha\beta} = \frac{1}{R_\beta - R_\alpha} \int_{R_\alpha}^{R_\beta} d_{\alpha\beta}(R) dR \tag{16}$$

The symbols α and β , respectively, refer to the beginning and end of the corresponding zone inside the Earth. The boundaries of these zones are determined

Table 4. The initial data on the Earth's parameters were adopted in the calculations.

Option	Symbol	Units	Value	
Earth age	t_P	billion years	4.567	
Earth radius	R_E	Km	6371	
Earth's core radius	R_{EC}	Km	3471	
The relative size of Earth's core	$\frac{R_{EC}}{R_E}$	-	0.5448	
Average core density in a homogeneous model	d_{EC}	tons/m ³	11.71	
The average density of the Earth's core under a double-layered model	Inner core		24.83	
	Core-shell	d_{EC}	tons/m ³	11.08
	Average core density		16.35	
The average density of the mantle and earth's crust	d_{CC}	tons/m ³	4.66	

**Figure 7.** A simplified diagram of the structure of the Earth is adopted as a model for calculating the change in its size over time. R_E —Radius of the Earth; R_{EC} —Radius of the Earth's core; H_{CC} —the total thickness of the Earth's crust and mantle.

based on the behavior of density gradients in the crust, mantle, and core of the Earth, shown in **Figure 6**. To calculate the average density of the mantle and the Earth's crust, the first jump in the density α was density 2 in the Earth's crust, mantle, and core. The outer radius of the Earth R_E was adopted as the boundary β . The center of the Earth was taken as the lower boundary for calculating the average density of the Earth's core in the case of both variants of its structure. Leap No. 2 was adopted as the upper boundary of β . The results are presented in **Table 4**. These data were subsequently used to calculate the corresponding Earth expansion models.

The initial data on the Earth's parameters adopted in further calculations are presented in **Table 4**.

This process can be written in the form of Equation (17):

$$\frac{dV_{EC}}{dt} = -k_s \cdot S_{EC} \quad (17)$$

where V_{EC} —Earth core volume; S_{EC} —Earth core surface area; k_s —the rate constant of the transformation of the substance of the Earth's core into the material of the mantle and crust in the model of the surface process of destruction of the Earth's core; t —the time from the moment the stable planet Earth.

In this case, the volume of the Earth's core will be equal to the following:

$$V_{EC} = \frac{4\pi}{3} R_{EC}^3 \quad (18)$$

The surface area of the Earth's core:

$$S_{EC} = 4\pi R_{EC}^2 \quad (19)$$

We substitute expressions (18) and (19) into Equation (17), and after simple transformations, we obtain the following differential equation:

$$\frac{dR_{EC}}{dt} = -k_s \quad (20)$$

Integrating Equation (20) over time, in the range from the moment of the occurrence of the Earth ($t = 0$) to the current moment of time t , we obtain:

$$R_{EC}(t) = \begin{cases} R_0 - k_s t, & t < t_{end} \\ 0, & t \geq t_{end} \end{cases} \quad (21)$$

where R_0 —the radius of the Earth and its core at the time of its formation.

The presented model indicates that the core of the earth should have a finite lifetime, which, at $R_{EC} = 0$ will be:

$$t_{end} = \frac{R_0}{k_s} \quad (22)$$

The constants calculated for this model are presented in **Table 5**.

Consider the following model of the destruction of the planet's core. In this model, the rate of decay of the planetary core is proportional to the mass of the planetary core and corresponds to the acting masses law. For convenience, upon further consideration, we will call this model the V model, or the model of the bulk destruction of the Earth's core. This model can be written in the form of Equation (23):

$$\frac{dm_{EC}}{dt} = -k_v \cdot m_{EC} \quad (23)$$

where m_{EC} —Earth core mass; k_v —the rate constant of the transformation of the substance of the Earth's core into the material of the mantle and the crust in the process of Earth's core destruction model by the law of mass action.

To simplify the calculations, we introduce the assumption that the Earth's core is homogeneous in composition and density, and all processes of its transformation into mantle matter and the Earth's crust material occur only at the

Table 5. Earth expansion parameters obtained based on the proposed models.

Option	Symbol	Measurement units	Model S	Model V
The radius of the Earth now of its formation	R_0	km	4315	4459
Constant rate of destruction of earth's core substance	k_V, k_s	billion years ⁻¹	0.04282	0.1645
The possible lifespan of the Earth's core	t_{end}	billion years	23.4	∞
Earth's core half-life	$t_{0.5}$	billion years	11.68	4.21
The rate at which the Earth's core is reduced in the initial period	v_0	km·billion years ⁻¹	185	733
The relative total thickness of the Earth's crust and mantle is now	$\hat{H}_{CC}(t_p)$	-	0.804	0.778
The earth's relative radius now	$\hat{R}_E(t_p)$	-	1.577	1.511
The relative speed of the Earth's expansion is now	$\frac{d\hat{R}_E(t_p)}{dt}$	billion years ⁻¹	0.0593	0.0424
The rate at which the Earth's crust expands near the equator		mm·year ⁻¹	1.51	1.12
The specific rate of expansion of the Earth's crust near the equator		nm·year ⁻¹ ·km ⁻¹	37.6	28.1

interface between the core and the mantle. Also, we assume that the composition and density of the Earth's core do not change over time; that is, the density of the Earth at the time of its formation is equal to the density of the core $d_0 = d_{EC}$. In this case, the mass of the planet's core depends only on its density and volume:

$$m_{EC} = V_{EC} \cdot d_{EC} \quad (24)$$

where d_{EC} —planet core density. Substituting expression (24) into Equation (23), we see that this model of changing the size of the planet's core does not depend on its density:

$$\frac{dV_{EC}}{dt} = -k_V \cdot V_{EC} \quad (25)$$

By analogy with the previous model, we substitute expression (18) into Equation (25), and after simple transformations, we obtain the following differential Equation:

$$\frac{dR_{EC}}{dt} = -\frac{k_V}{3} \cdot R_{EC} \quad (26)$$

Integrating Equation (26) over time, ranging from the moment of the Earth's origin ($t = 0$) to the current time t , and making the appropriate transformations, we obtain:

$$R_{EC} = R_0 \cdot e^{-\frac{k_V t}{3}} \quad (27)$$

The constants calculated for this model are presented in **Table 4**. A compari-

son of dependences (21) and (27), calculated in relative units concerning the radius of the Earth at the time of its formation, is presented in **Figure 8**.

The dependences presented in the figure are calculated when the rates of the planetary core's destruction processes are constant in time $k = \text{const}$. It is also assumed in these models that at the time of the formation of the Earth, it lacked a crust and mantle, and the radius of the Earth R_0 was equal to the radius of its core. The value of the rate constant of transforming the Earth's core's substance into the mantle and crust material in each model was calculated from the following parameters, which are relatively accurately known to date. These parameters are the Earth's current age, radius, and size of the planet's core. These initial data and the calculated parameters of these models are presented in **Table 4**.

3.3. Resizing the Earth in the Model of Surface Destruction of the Earth's Core

We try to calculate the Earth's size change based on the proposed models. For such a calculation, it is necessary to make certain approximations. The first approximation is that we believe that the mass of the Earth has not changed from its inception to the present. The Earth was losing hydrogen, which almost freely left the Earth's atmosphere in outer space. In this case, we accept that this loss was negligible compared to the Earth's total mass. Another approximation is that these models do not consider the flow of matter from meteorites, comets, and asteroids to the Earth, which fell on its surface during its lifetime. Thus, this approximation can be expressed by the following Equation (28):

$$m_0 = m_{EC} + m_{MC} \quad (28)$$

where m_0 — Earth mass; m_{EC} — Earth core mass; m_{MC} — the mass of the mantle and Earth's crust.

Substituting expression (24) into Equation (28), we can obtain the expression for the mass of the mantle and the Earth's crust:

$$m_{MC} = V_0 \cdot d_0 - V_{EC} \cdot d_{EC} \quad (29)$$

where V_0 — Earth's volume at the time of its formation; d_0 — Earth's density at the time of its formation. Since we assumed that the core of the Earth during its life does not change in composition and density, then the density of the Earth's substance at the time of its formation should be equal to the density of the core of the planet $d_0 = d_{EC}$. From here, we get the following:

$$m_{MC} = V_0 \cdot d_{EC} - V_{EC} \cdot d_{EC} \quad (30)$$

Given that the volume of the Earth at the time of its formation is equal to:

$$V_0 = \frac{4\pi}{3} R_0^3 \quad (31)$$

Then the volume of the Earth's core is determined by expression (18), then substituting these expressions in (30) and making simplifications, we obtain the expression for the mass of the mantle and the Earth's crust:

$$m_{MC} = \frac{4\pi}{3} d_{EC} (R_0^3 - R_{EC}^3) \quad (32)$$

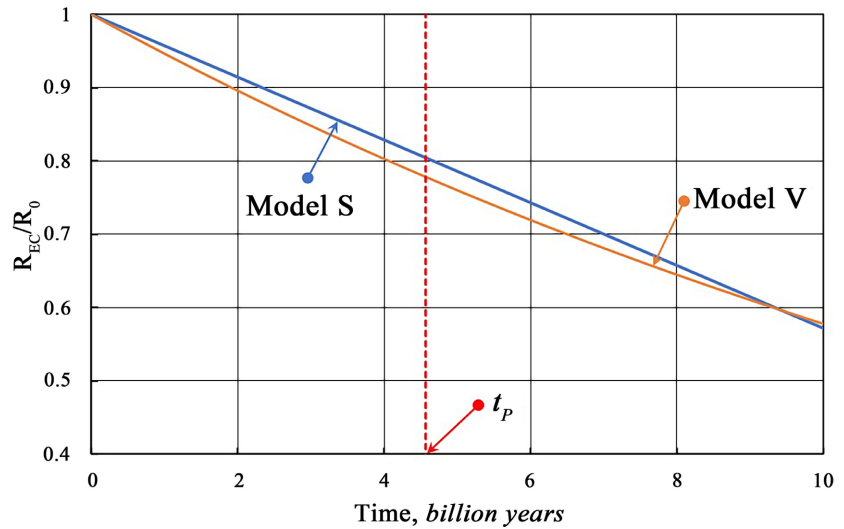


Figure 8. Change in the relative size of the Earth’s core for the model represented by Equation (17) (Model S curve) and the model described by Equation (26) (Model V curve). The dashed straight line (t_p) corresponds to the current time $t_p = 4.567$ billion years from the moment the Earth was formed.

On the other hand, the mass of the mantle and the Earth’s crust can be written through the difference between the volumes of the Earth (V_E) and the Earth’s core:

$$m_{MC} = (V_E - V_{EC}) \cdot d_{CC} \tag{33}$$

where d_{CC} —the average density of the mantle and the Earth’s crust.

Substituting expressions (18) and (33) into Equation (32), we obtain the equation for the volume of the Earth:

$$V_E = \frac{4\pi}{3} R_{EC}^3 + \frac{4\pi}{3} \frac{d_{EC}}{d_{CC}} (R_0^3 - R_{EC}^3) \tag{34}$$

Given that the volume of the Earth now is:

$$V_E = \frac{4\pi}{3} R_E^3 \tag{35}$$

where R_E —the radius of the Earth at the current moment, then after appropriate substitution in Equation (32) and conversion, we get

$$R_E = \sqrt[3]{R_{EC}^3 + \frac{d_{EC}}{d_{CC}} (R_0^3 - R_{EC}^3)} \tag{36}$$

As part of the analysis of the first model of surface destruction of the Earth’s core, substituting into Equation (36) the expression for the radius of the Earth’s core described by Equation (21), we obtain:

$$R_E(t) = \begin{cases} \sqrt[3]{(R_0 - k_s t)^3 + \frac{d_{EC}}{d_{CC}} (R_0^3 - (R_0 - k_s t)^3)}, & t < t_{end} \\ R_0 \cdot \sqrt[3]{\frac{d_{EC}}{d_{CC}}}, & t \geq t_{end} \end{cases} \tag{37}$$

From here, it is easy enough to calculate how the total thickness (H_{CC}) of the Earth's crust and mantle changes, as the difference between the radius of the Earth and the radius of the Earth's core:

$$H_{CC} = R_E - R_{EC} \quad (38)$$

All the obtained dependencies are dimensional and depend on the radius of the Earth at the time of its formation. Strictly speaking, this quantity is indefinite. In connection with these and for the convenience of comparing various models, all the obtained dependencies must be normalized. Normalization refers to the value of the radius of the Earth at the time of its occurrence— R_0 :

$$\hat{R}_E(t) = \frac{R_E(t)}{R_0} \quad (39)$$

$$\hat{R}_{EC}(t) = \frac{R_{EC}(t)}{R_0} \quad (40)$$

$$\hat{H}_{CC}(t) = \frac{H_{CC}(t)}{R_0} \quad (41)$$

$$\hat{k}_s = \frac{k_s}{R_0} \quad (42)$$

Since all models are tied to the same time scale, bringing these equations to a full dimensionless form or a dimensionless time scale makes no sense. Substituting these expressions into Equations (21), (37), and (38), we obtain a normalized form of equations describing the change in the relative sizes of the Earth by the model of surface destruction of the planet's core:

$$\hat{R}_E(t) = \begin{cases} \sqrt[3]{(1-\hat{k}_s t)^3 + \frac{d_{EC}}{d_{CC}}(1-(1-\hat{k}_s t)^3)}, & t < t_{end} \\ \sqrt[3]{\frac{d_{EC}}{d_{CC}}}, & t \geq t_{end} \end{cases} \quad (43)$$

$$\hat{R}_{EC}(t) = \begin{cases} 1-\hat{k}_s t, & t < t_{end} \\ 0, & t \geq t_{end} \end{cases} \quad (44)$$

$$\hat{H}_{CC}(t) = \hat{R}_E(t) - \hat{R}_{EC}(t) \quad (45)$$

The value of the rate constant for the destruction of the Earth's core must be estimated for numerical calculations of the change in time: the size of the Earth, its core, and the total thickness of the mantle and the Earth's crust. Its value can be estimated from Equations (43) and (44), substituting data on the Earth's age and its core's relative size. For you need to calculate the ratio $\frac{\hat{R}_{EC}(t)}{\hat{R}_E(t)}$ and for the current time moment, t_p solve the obtained equation concerning \hat{k}_s . An illustration of the solution to this problem is **Figure 10**. For the calculated value of the core destruction rate constant, the relationship curve $\frac{\hat{R}_{EC}(t)}{\hat{R}_E(t)}$ should pass through the intersection point of the straight line corresponding to the ratio

of the sizes of the core and the Earth and the line corresponding to the current moment.

The initial data required for the calculation are presented in **Table 4**. The value of the rate constant calculated in **Figure 9** and other parameters calculated for this model are shown in **Table 5**. The behavior of dependences (43), (44), and (45) in relative units calculated for the obtained parameters are presented in **Figure 10**.

An analysis of the dependence of the Earth's radius on time is best done using its time derivative:

$$\frac{d\hat{R}_E(t)}{dt} = \begin{cases} \frac{\hat{k}_s (\hat{k}_s t - 1)^2 \left(\frac{d_{EC}}{d_{CC}} - 1 \right)}{\left(1 + (\hat{k}_s t)^3 \left(\frac{d_{EC}}{d_{CC}} - 1 \right) - 3(\hat{k}_s t)^2 + 3\hat{k}_s t \left(\frac{d_{EC}}{d_{CC}} - 1 \right) \right)^{2/3}}, & t \leq t_{end} \\ 0, & t > t_{end} \end{cases} \quad (46)$$

The change in the size of the Earth and its components over time demonstrates the dependencies shown in **Figure 10**. For greater clarity, **Figure 10** shows the derivative (46), which characterizes the rate of change in the Earth's radius over time. The presented data shows that the rate of change of the radius of the Earth to date has significantly decreased compared to the initial stage.

3.4. Resizing the Earth in the Model of the Destruction of the Earth's Core by the Law of Mass Action

We substitute expression (28) into Equation (23), and, after simplification, we obtain a differential equation for changing the total mass of the Earth's crust and mantle:

$$\frac{dm_{CC}}{dt} = k_V (m_0 - m_{CC}) \quad (47)$$

Integrating Equation (47) over time, in the range from the moment of the Earth's origin ($t = 0$) to the current time t , and making the appropriate transformations, we obtain:

$$m_{CC} = m_0 (1 - e^{-k_V t}) \quad (48)$$

We express the initial mass of the Earth and the total mass of the Earth's crust and mantle through their volumes and densities:

$$m_0 = V_0 \cdot d_0 \quad (49)$$

$$m_{CC} = V_{CC} \cdot d_{CC} \quad (50)$$

Substituting expressions (49) and (50) in Equation (48), we obtain:

$$V_{CC} = V_0 \frac{d_0}{d_{CC}} (1 - e^{-k_V t}) \quad (51)$$

The total volume of the Earth's crust and mantle is equal to the difference between the volumes of the Earth and the Earth's core:

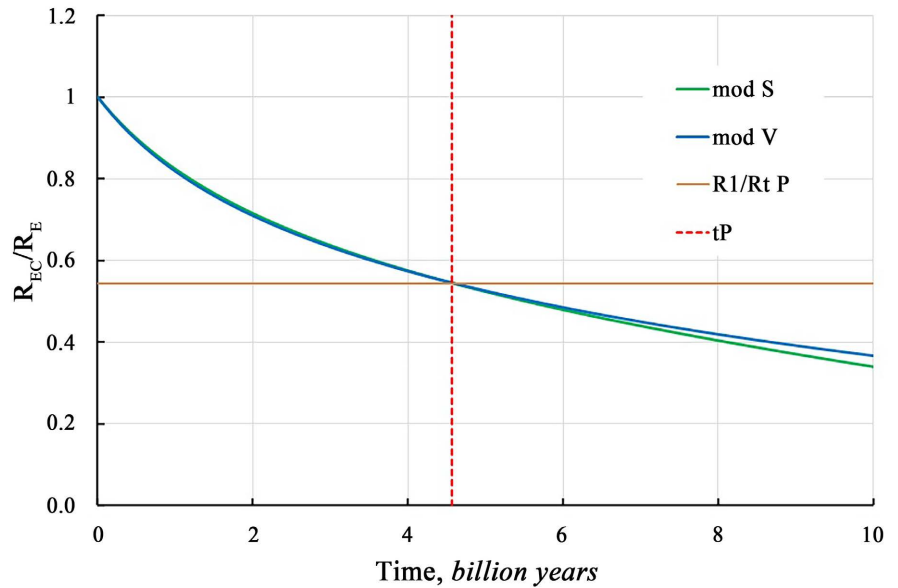


Figure 9. Illustration for calculating the value of the rate constant \hat{k}_s of the destruction of the planet's core. The curves mod S and mod V are the dependencies of the relation $\frac{\hat{R}_{EC}(t)}{\hat{R}_E(t)}$ on time for the corresponding models. R2/RtP—The relative size of the Earth's core $\frac{R_{EC}}{R_E}$. t_p —Earth age t_p .

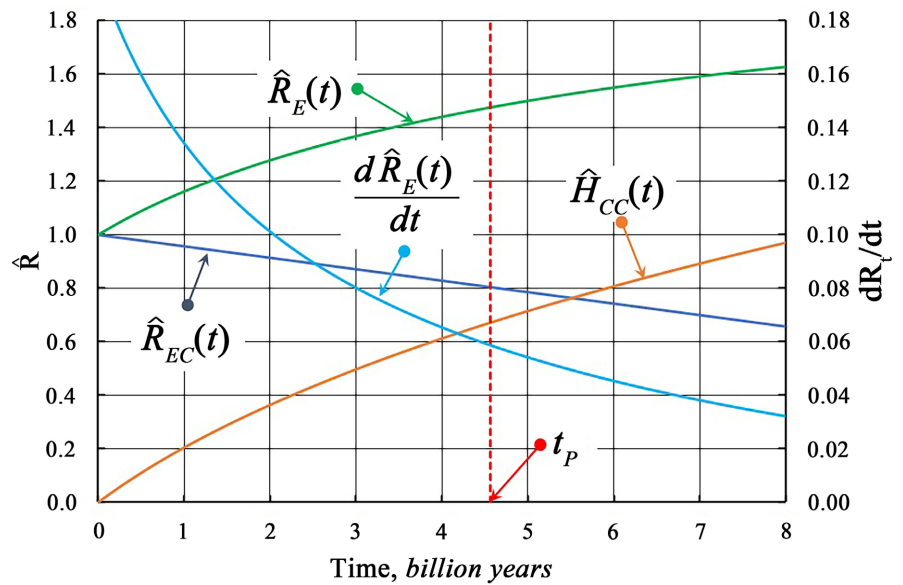


Figure 10. Change in the relative size of the Earth's core (Curve $\hat{R}_{EC}(t)$), the radius of the Earth (Curve $\hat{R}_E(t)$), the total thickness of the Earth's crust and mantle (Curve $\hat{H}_{CC}(t)$) for the model represented by the normalized Equations (43), (44), and (45). The dashed line (t_p) corresponds to the current time $t_p = 4.567$ billion years from the moment the Earth was formed. The curve $\frac{d\hat{R}_E(t)}{dt}$ is the time derivative of the Earth's radius.

$$V_{CC} = V_E - V_{EC} \quad (52)$$

We substitute Equation (52) into Equation (51), considering expressions (18) and (33) for the corresponding volumes and using Equation (27). After the relevant transformations, we obtain the following:

$$R_E = R_0 \sqrt[3]{e^{-k_v t} + \frac{d_0}{d_{CC}} (1 - e^{-k_v t})} \quad (53)$$

From here, it is quite easy to calculate how the radius of the Earth's core changes, which in this model is determined by Equation (27), as well as the total thickness (H_{CC}) of the Earth's crust and mantle according to Equation (38). For the convenience of the corresponding numerical calculations and comparison of the results obtained, we bring all the calculated parameters to the normalized form by Equations (39)-(42). By analogy with the previous model, the normalization of the model parameters is the assignment of the radius of the Earth to its radius at the time of occurrence— R_0 . Substituting the indicated expressions in Equations (27), (38), and (53), we obtain the normalized form of the equations describing the change in the relative sizes of the Earth by the model of surface destruction of the planet's core:

$$\hat{R}_E(t) = \sqrt[3]{e^{-k_v t} + \frac{d_0}{d_{CC}} (1 - e^{-k_v t})} \quad (54)$$

$$\hat{R}_{EC}(t) = e^{-\frac{k_v}{3} t} \quad (55)$$

$$\hat{H}_{CC}(t) = \hat{R}_E(t) - \hat{R}_{EC}(t) \quad (56)$$

By analogy with the previous model, to carry out numerical calculations of the time changes in the size of the Earth, its core, and the total thickness of the mantle and the Earth's crust, it is necessary to estimate the value of the rate constant for the destruction of the Earth's core. Its value can be expected from equation (53), substituting data on the age of the Earth and the relative size of the Earth's core now. These initial data are presented in **Table 4**. The calculated parameters for this model are presented in **Table 5**. The behavior of dependencies (54), (55), and (56) in relative units is shown in **Figure 11**.

An analysis of the dependence of the Earth's radius on time for this model is also better done using its time derivative:

$$\frac{d\hat{R}_E(t)}{dt} = \frac{k_v e^{-k_v t} \left(\frac{d_0}{d_{CC}} - 1 \right)}{3 \left(-\frac{d_0}{d_{CC}} e^{-k_v t} + e^{-k_v t} + \frac{d_0}{d_{CC}} \right)^{2/3}} \quad (57)$$

The dependencies of changes in the size of the Earth and its components over time are presented in **Figure 11**. For greater clarity, **Figure 11** shows the derivative of the time dependence of the Earth's radius $\hat{R}_{EC}(t)$ (Equation (57)), which characterizes the rate of change of the Earth's radius over time. From the data presented for this model, it is seen that the rate of change of the radius of the

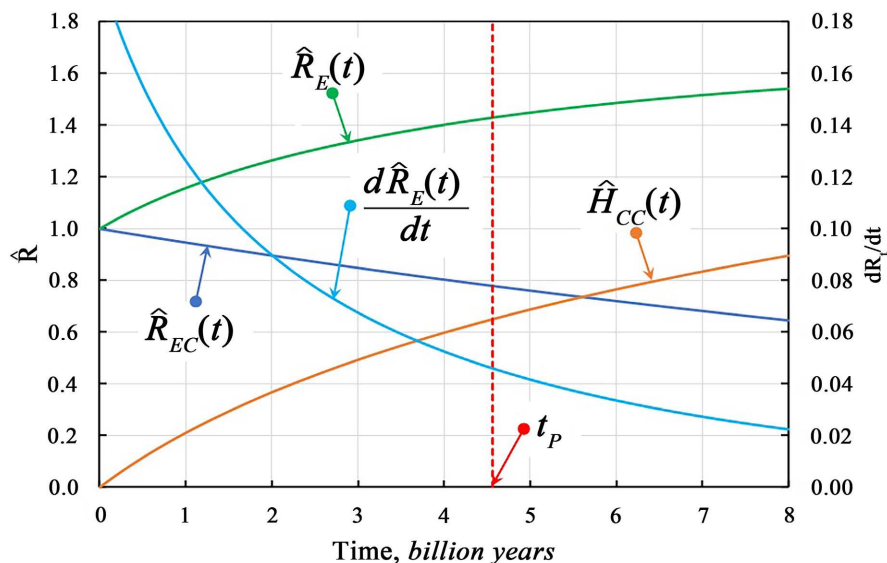


Figure 11. Change in the relative size of the Earth's core (Curve $\hat{R}_{EC}(t)$), the radius of the Earth (Curve $\hat{R}_E(t)$), the total thickness of the Earth's crust and mantle (Curve $\hat{H}_{CC}(t)$) for the model represented by normalized Equations (54), (55), and (56). The dashed line (t_p) corresponds to the current point in time $t_p = 4.567$ billion years from the moment the Earth was formed. The curve $\frac{d\hat{R}_E(t)}{dt}$ is the time derivative of the Earth's radius.

Earth to date has also significantly decreased compared to the initial stage. However, as seen in **Figure 9**, the obtained dependencies for both models are remarkably similar and close to each other over time.

4. Discussion of the Results

The analysis showed that the main contribution to the differentiation of elements in the protoplanetary disk is primarily the energies that determine the positive ionization of atoms. In this case, the possibility of the appearance of negative charges practically does not affect the behavior of the entire system of atoms and ions in the protoplanetary disk.

In the case of the Earth, from the data given in **Table 1**, characteristic periodic trends in depletion or enrichment in chemical elements on the Earth's surface relative to the Earth's volume were revealed [27]:

- Noble gases are increasingly depleted from the surface, with an increase in atomic mass in an approximately linear trend. Since noble gases can be chemically inert, this trend is interpreted as radial differentiation based solely on gravity.
- Rare earth elements are systematically more numerous on the surface with similar distribution coefficients. This observation is consistent with the known diagrams for the rocks of the Earth's crust and basalts.
- Most electronegative elements, such as oxygen, halogens, and chalcogens, are

much more common on the surface than in the Earth's volume.

- Transition elements in the 3rd, 4th, and 5th series exhibit complex periodic structures.

The data obtained show that the early Earth was richer in hydrogen and poorer in oxygen than previously thought [34]. In quantitative terms, Equation (5) gives the early Earth's initial hydrogen content of 18.3 masses.%. The diffusion of molecular hydrogen to the Earth's surface contributes to its release into outer space without oxidizing agents in the atmosphere, as was assumed for the early Earth. However, chemically and physically bound hydrogen cannot escape.

Opponents of the initial hydride Earth hypothesis have almost one critical argument, which leads to a logical question: why is hydrogen practically not found in meteorites? The following two factors must be considered to get an answer to this question. The first factor is that polyhydrides can only be obtained at extremely high pressures. The second factor is that those simple hydrides are not stable compounds and actively interact with many substances, such as water, or are easily oxidized by molecular oxygen, halogens, sulfur, selenium, and other electronegative elements. Currently, hydrides are widely developing in the field of hydrogen energy to create systems for practical hydrogen storage. This use of hydrides is based precisely on the reversibility of the synthesis and decomposition of hydrides when external factors, such as pressure and temperature, change [78]. This fact again indicates that in a vacuum, hydrides readily decompose into hydrogen and the hydride-forming element.

An analysis of the behavior of hydrogen-containing systems showed that changes in these substances associated with a high degree of compression could exceed the energy of chemical bonds. High compression leads to dramatic changes in the chemistry of hydride systems. Under these conditions, new classes of materials are formed with an unusual combination of physical and chemical properties. Also, high pressure substantially changes their structure and electrical and magnetic properties. In this case, new materials with unusual features can be formed.

The discovery of a new class of hydride compounds, such as polyhydrides, justified the possibility of obtaining compounds containing an abnormally large amount of hydrogen. High hydrogen polyhydrides act as catalysts for the "chemical compression" of hydrogen. In these hydrides, heavier elements enhance the intermolecular interactions between the hydrogen molecules, catalyzing their dissociation and the possibility of reaching the state of metallic hydrogen at lower pressures than expected for pure hydrogen.

An analysis of the presented data leads to two conclusions regarding the possible formation of hydrides and polyhydrides in the composition of the Earth's core and, because of the presence of superconducting properties of these compounds—the possible occurrence of superconducting properties in the Earth's core itself.

From the first conclusion, it follows that the stoichiometric compositions of the polyhydrides of primary and secondary elements, by the content of the ele-

ments, can immobilize ~49.3 mol% of the amount of initially available hydrogen. According to my calculations, during the formation of the Earth, it could contain ~10.7 mass% hydrogen in the form of hydrides, polyhydrides, and adsorbed form. Our estimate of the hydrogen content in the composition of the original Earth is almost two times higher than the estimate made by V. Larin in his works. This fact further confirms his conclusions on the structure and behavior of the Earth system.

The second conclusion about the possible superconducting properties of the Earth's inner core directly explains the occurrence of the Earth's magnetic field and its historical behavior, namely the migration of the Earth's poles.

Our calculations of various models of the initial hydride Earth allowed us to obtain the following summary data on the development and properties of such a complex system as the core-mantle-core. The obtained calculation results for the simplest models are presented in **Table 5**.

From the presented data, both models give relatively close results. Some of these results give predictions that can be measured in the future if measuring instruments allow us to achieve the required accuracy of measuring distances at the level of a few nanometers per kilometer.

The construction of more complex models made it possible to detect the possibility of the manifestation of such critical phenomena as the formation of temporary and spatial structures in the zones of the Earth's internal structure.

Currently, several dozen homogeneous and heterogeneous vibrational reactions have been discovered and studied in which periodic changes in the concentrations of reacting substances are observed both in time and in space. Accordingly, the dependence on speed on time is regular.

Such reactions are called oscillatory or periodic. Studies of kinetic models of such complex reactions made it possible to formulate several general conditions necessary for the emergence of stable oscillations of the reaction rate and concentrations of intermediate substances:

- Stable oscillations occur in most cases in open systems where it is possible to maintain constant reagent concentrations.
- A complex reaction should include autocatalytic steps as well as steps that are inhibited by reaction products.
- The reaction mechanism should include steps higher than the first.

These conditions are necessary but insufficient for occurrence in the system of self-oscillations. Also, the relationship between the rate constants of the individual stages and the values of the initial concentrations of the reactants plays a significant role.

The systems of differential equations analyzed in Section 4 show the presence of various types of singular points. Such "node" and "center" points were shown. There are other types of phase trajectories of the saddle and focus type. Suppose we have a singular point of the "saddle" type, then an analysis of the corresponding phase portrait with a field of directions. In that case, we can see that all phase trajectories approach the singular point, then move away from it. If the

phase trajectory has the form of a spiral and is “wound” at a singular point, then such a path is called a “focus”. In detail, various phase portraits and singular points were analyzed in [95].

The study of the nature of the singular points of the system is closely related to system stability issues. Here, chemical kinetics borrows concepts from the dynamical systems theory and Lyapunov’s stability criteria. The matrix eigenvalues of the differential equations system obtained are used to judge the nature of the singular point and the stability of the stationary state of the system. Six cases are possible here, each analyzed in detail and schematically presented in [95]. From the analysis of these data, a wide range of behavioral possibilities of complex nonequilibrium systems arises.

Proceeding from all the above, one can emphasize the thought of the Nobel laureate I. Prigogine wrote: “The main point to remember is that in all these cases, there appears to exist a thermodynamic threshold for self-organization that corresponds to a clear distinction between the class of equilibrium structures and those structures that have been called dissipative structures because they only appear as a spontaneous response to a large deviation from thermodynamic equilibrium” [91].

Indeed, the Earth must be considered a complex system with significant deviations from equilibrium. The formation of temporal and spatial structures in irreversible and nonequilibrium processes is associated with certain conditions. In these processes, just as in the case of equilibrium, a qualitative jump in the type of phase transition is observed upon reaching individual threshold values of thermodynamic parameters, called critical parameters.

Under thermodynamic equilibrium, the system is at rest; no heat and diffusion fluxes are leaving the system. If the system is closed, then the entropy of the system is maximum: $S = \max$. The equilibrium condition determines the choice between the various possible aggregate states. The system implements a structure corresponding to specific circumstances with maximum entropy. Thus, there are various equilibrium structures—aggregate states with different symmetries and degrees of order, which have short-range or long-range order. Similar structural classes arise when the conditions change in the direction of deviation from equilibrium, and the transition to such structures occurs stepwise.

According to the theorem of I. Prigogine [92], entropy production in a linear stationary state is minimal concerning adjacent states. Entropy production is the primary physical quantity investigated by this theory. It plays the same important role in irreversible processes as entropy in equilibrium systems. This quantity includes general physical principles, which are also called evolutionary criteria. The term “evolution” is used in the narrow sense of “physical evolution”; that is, it refers to the directed development of physical systems. The existence of a specific correlation between the production of entropy and the exchange of entropy with the environment is a prerequisite for the formation of ordered structures in open systems. For the structure formation to begin in the system, the return of entropy must exceed a specific critical value. Self-organization is a

“supercritical” phenomenon. This concept means it is only possible if the system’s parameters exceed specific critical values.

When a system deviates strongly from equilibrium, its variables satisfy not linear but more precise non-linear equations. Nonlinearity is an essential and common feature of processes far from equilibrium. On the other hand, the supercritical return of entropy is possible only if the system has an unusual, unique internal structure. This factor means that self-organization is not a universal property of matter but exists only under special internal and external conditions; however, this property is not associated with any special class of substances.

Based on the provisions of [95], it is determined that, in nature, there are two main classes of irreversible processes:

1) The destruction of the structure near the equilibrium position is a universal property of systems under arbitrary conditions.

2) The appearance of structures far from the equilibrium position under special external and internal conditions, namely that the system is open. It has non-linear internal dynamics, and its external parameters have supercritical values.

I. Prigogine proposed to call dissipative structures all spatial, temporal, or spatiotemporal structural formations that can occur far from equilibrium in the nonlinear region when the parameters of the systems exceed critical values.

A typical example of dissipative structures is the so-called Benard cells. Benard or Rayleigh-Benard cells—the appearance of ordering in the form of convective cells in cylindrical shafts or regular hexagonal structures in a layer of a viscous fluid with a vertical temperature gradient is evenly heated from the bottom [93] [94]. The manifestations of Benard’s cells can explain the origin of volcanic formations in the form of a bundle of vertical columns—such are the natural monuments Devils Tower (USA) and Giants Bridge (Northern Ireland). The emergence of such structures on a macroscopic scale is also possible in the Earth’s crust, mantle, and, probably, the planet’s core.

5. Conclusions

A modern look at the properties of chemical elements has practically confirmed the hypothesis of outstanding scientists of past centuries, such as Immanuel Kant, Pierre-Simon Laplace, and P. N. Chirvinsky, about the hot origin of the Earth. P. N. Chirvinsky even defined the Earth as “petrified gas”. V. N. Larin’s hypothesis proposed the next step in developing this theory, initially hydride Earth. This hypothesis explained the whole spectrum of phenomena observed on Earth and made it possible to predict new ones. In this work, we attempted to find additional evidence for this theory and show other effects directly following it.

An analysis of the possible formation process of the initial hydride Earth showed that during the creation of the protoplanetary disk, its substance passed through a kind of magnetic separator—such as a mass spectrometer. Ionized particles with low ionization potentials were captured by a magnetic field and remained in the near-solar space, in the zone of the Earth’s formation. Moreo-

ver, elements with high ionization potentials passed without delay and ended up in an area farther from the Sun. At the same time, dependence was revealed by which it is possible to determine the extent to which a magnetic field delayed one or another element. Based on these postulates, the initial content of the principal chemical elements around the protoplanetary disk in which planet Earth was formed was calculated. The calculations showed that the main elements contained in the protost, located in the zone of the Earth's formation, were hydrogen. From these data, it follows that the atoms and ions of the elements were present in a hydrogen atmosphere during the Earth's formation. When the resulting plasma-gas mixture was cooled, atoms were molded to form various chemical compounds, most represented by multiple hydrogen compounds—hydrides.

The effect of the physical properties of atoms and ions on their behavior during the formation of the Earth was studied. The features of atoms or ions of chemical elements are determined by three main characteristics: the ionization energy of atoms, their electron affinity, and electronegativity. The effect of these physical properties of atoms on the distribution of elements in the protoplanetary disk was determined.

Their ionization energies exert the most potent effect on the distribution of the element. Various variants of correlation dependences were obtained, considering the weight contribution of each element was checked. The best result was achieved using weighting factors for these data, considering the significance of the corresponding element in the physical nature of this object. In this case, we chose the relative content of elements in the composition of the solar photosphere as weights. Thus, the contribution to the general trend of this trend should be made by those elements whose content in the initial protoplanets of the disk was the maximum. The corresponding correlation dependence, which allows more accurate calculations of the distribution of elements in the protoplanetary disk, was obtained using this approach.

The effect of electron affinity on the distribution of atoms in a protoplanetary disk turned out to be more complicated than the fact of ionization energy. Based on the results obtained, it can be concluded that the formation of negative ions in the protoplanetary disk, if it occurs, is only for halogens. Also, creating such ions does not lead to a substantial separation, due to their possible rapid recombination with positively charged ions, with the formation of neutral atoms. Comparing the E_{cr} value with the electron affinity of halogens, it can be understood that the loss of electrons by negatively charged halogen ions is also quite likely. The Maxwell distribution shows that they are formed only in a tiny fraction.

It was shown that their effect is remarkably similar when comparing such complex indicators as electronegativity and ionization energy. From this, we can conclude that the main contribution to the differentiation of elements in the protoplanetary disk is primarily by energies that determine the positive ionization of atoms. This fact again confirmed that the possibility of negative charges

practically does not affect the behavior of the entire system of atoms and ions in the protoplanetary disk.

A refined analysis of the influence of physical factors on the behavior of elements in the protoplanetary disk is carried out. The correctness of calculations of the composition of the Earth at the time of its formation was additionally confirmed. As a result, additional confirmation was obtained that during the creation of the planetary body; all other elements were in the form of their compounds with hydrogen-hydrides.

It is shown that the interaction of the initial components proceeds through the following stages:

- Hydrogen adsorption on the surface of solid particles of low volatile components—metals and the resulting chemical compounds.
- Occlusion—the dissolution of hydrogen in the volume of metal or other chemical compounds.
- Chemical interaction with the formation of hydrides and super hydrides.

On the other hand, it is known that the pressure inside the Earth is 375 GPa. This fact automatically raises the question of the properties of hydrides of chemical elements at high pressure. The pressure is a significant factor, as it can cause chemical compounds to accept stoichiometry and structure that would not be available under atmospheric conditions. Based on an analysis of current literature data, it was shown that many chemical elements at high pressure in a hydrogen medium form not only simple hydrides but also form super hydrides—polyhydrides with high hydrogen content.

The analysis showed that pressure leads materials to states of smaller volume, so pressure includes mechanisms necessary to achieve a higher density. In a chemical sense, compression affects the energy of electrons. Under these conditions, electrons tend to state with lower kinetic energy. This effect means the destabilization of intramolecular bonds. The molecular system is destroyed, forming a skeleton and/or a tightly packed structure with the formation of a completely metal phase or plasma, in which the concept of a chemical bond is lost. A new class of hydride compounds, such as polyhydrides, has been proposed as precursors for the “precompression” of hydrogen.

Calculations were carried out, considering the possibility of forming polyhydrides of primary and secondary elements. These calculations showed that immobilization of about 49.3 mol is possible by the content of elements% hydrogens of its initially available amount. From here, the inner Earth could contain about 10.7 mass% hydrogens in the form of hydrides, polyhydrides, and adsorbed form. Thus, our estimate of the initial hydrogen content in the composition of the Earth is almost two times higher than the forecast made by V. Larin in his works. This result is an additional fact confirming the theory of initially hydride Earth.

Also, superconductivity was discovered in hydrides with moderate or relatively low hydrogen content. Such hydrides have been shown as potential superconductors. In polyhydrides, heavier elements enhance intermolecular inte-

reactions between hydrogen molecules. Such an effect causes the dissociation of hydrogen molecules. The decay of hydrogen molecules allows metallization to be achieved at a lower pressure than expected for pure hydrogen. Metal polyhydrides provide a material that contains bound atomic hydrogen. Many theoretical calculations based on the Bardeen-Cooper-Schrieffer theory of superconductivity confirm this assumption. In the literature, the formation and properties of polyhydrides of various elements of the Periodic system were calculated. Many of these compounds have a high critical transition temperature to the superconducting state, which exceeds 200 K.

Based on these data, we hypothesized the presence of superconducting properties in the Earth's core. The alleged existence of superconducting properties in the Earth's core, consisting of hydrides, has various possible consequences. Such features of superconducting materials determine these consequences as the Meissner-Ochsenfeld effect, the Abrikosovvortex effect, and the London or Moment of London effect. As a result, all these effects explain the presence of a magnetic field near the Earth. Besides, the above effects allow us to describe the unevenness and instability of the Earth's magnetic field and explain the possibility of migration of the poles of the Earth.

The fact that the Earth has a hydroid core causes its change in time due to the instability of such chemical compounds as hydrides. The destruction of the Earth's core occurs due to several mechanisms. On the one hand, a simple decomposition of hydrides into constituent elements can occur. On the other hand, hydrides can be destroyed because of their oxidation during interaction with electronegative elements in the Earth's composition. Hydrolytic decomposition of hydrides is also possible. Due to the significant difference in the density of hydride compounds and the density of oxide compounds that make up the crust, asthenosphere, and part of the Earth's mantle, an increase in the volume of the Earth will occur during the destruction of hydrides. Thus, the theory of initially hydride Earth unambiguously assumes the Earth's expansion. In this regard, we attempted to quantitatively describe the expansion of the Earth because of these processes. Several possible models are proposed, based primarily on destroying the Earth's core. Calculations of the averaged structure of the Earth were carried out. These structural parameters were used to build the proposed models for its expansion.

The following types of models for the destruction of the Earth's core have been proposed. Following all models, hydrides in the core are supposed to be destroyed with the formation of the mantle and Earth's crust minerals. Under the first model, hydride destruction occurs on the surface of the planet's core. The core surface area and the rate of the core material conversion into the mantle and crust material determine the model's kinetic parameters. This model was called the S-model, the model of surface destruction of the Earth's core. The second model assumes that the rate of destruction of the planet's core is proportional to the mass of the Earth's core and corresponds to the law of the acting masses. This model was called the V-model, or the model of volumetric destruc-

tion of the Earth's core. The V-model corresponds to the law of the masses in effect. A study and a quantitative comparison of both models were conducted.

The calculations showed that both models give relatively close results. Some of these results give predictions that can be measured in the future if the measuring instruments allow us to achieve the necessary measurement accuracy. The proposed models made it possible to estimate the initial size of the Earth after its formation. It amounted to 4315 km for the S-model and 4459 km for the V-model.

For a more detailed understanding of the interaction processes in the core-mantle of the Earth crust system of the general approach analysis, several simplified versions of describing changes in the Earth system using systems of differential equations have been proposed. The construction of these models made it possible to detect the possibility of manifestation of such critical phenomena as the formation of temporary and spatial structures in the zones of the Earth's internal structure.

Based on the studies, possible ways of further testing the hypothesis of the initial hydride Earth are shown.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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