Protoatom and its role in the formation of the value of the gravitational constant. Research results.

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Content

1. Annotation

The study is based on the concept of the existence of proto-atoms before the moment of the Big Bang. The physical parameters of the protoatom were determined on the basis of the value of the elementary charge through the application of the Schwarzschild solution. Taking into account the transformation of protoatoms into atoms of chemical elements, **a formula for the gravitational constant was obtained** through the solution of equations.

The new formula 1-11 is based on physical constants: the magnitude of the elementary charge, the speed of light in vacuum and the unit of atomic mass of chemical elements (not to be confused with 1DA, see study). A distinctive feature of formula 1-11 is that it does not contain additional indicators and coefficients for the purpose of adjusting the value of G. The result obtained by the formula was **G= 6,6664 · 10^{-11}** $m^3 \cdot s^{-2} \cdot kg^{-1}$. It differs from the recommended CODATA value 6,67430 (15) · 10^{-11} by **0,12%.** This is comparable to the discrepancies in the experimental measurements of the value of G. (The reasons for the discrepancy by 0,12% are set out in the study).

In a study on the example of 25 calculations of the value of G, it was proved **that the gravitational constant is not a constant** in the strict sense of the word. Calculations showed that the value of G fluctuates within thousandths and hundredths of a percent.

In this study, **the mass of the protoatom was determined**, which was:
$\mathbf{m_{pa} \approx 1,4852 \cdot 10^{-27}}$ kg

Other results of scientific importance have been obtained.

Keywords. Big Bang, cosmological singularity, protoatom, protoatom mass, chemical element atomic mass unit, atomic cell, gravitational constant formula, gravitational field, elementary charge.

2. Introduction

The history of determining the value of the gravitational constant has more than 200 years. The gravitational constant G was first measured in 1798 by the

British physicist Henry Cavendish. For this, the scientist used a torsion balance built by the priest John Michell. The value obtained by Cavendish for the constant was **G = 6,754 · 10^{-11}** m^3·s^{-2}·kg^{-1} (the relative difference with 6,6743 · 10^{-11} is **1,2%**).

Since then, scientists have set up more than 200 experiments to measure the gravitational constant, but have not been able to significantly improve their accuracy**.** Based on the results of the 14 most accurate experiments of the last 40 years, the Committee for Data for Science and Technology (CODATA) recommended a value of **G = 6,67430 (15) · 10^{-11}** m^3·s^{-2}·kg^{-1}.

At the same time, it should be noted that the declared error of some experiments used in calculating the CODATA value did not exceed 14 parts per million, **but the difference between their results reached 550 parts per million (relative difference 0,055%)** https://goo.su/SkRf5J

Scientists suggest that the low accuracy of determining the gravitational constant is due to the weakness of the forces of gravitational attraction that arise in ground-based experiments. This makes it difficult to accurately measure the forces and **leads to large systematic errors** due to the design of the installations.

Of interest in this regard is the experimental measurement of the gravitational interaction of 24 tungsten alloy cylinders, made using atomic interferometers by Italian and Dutch physicists. The authors of the study in an article in the journal Nature (June 2014) point out that since the experiment using atomic interferometers is based on a fundamentally different approach, it will help to identify some systematic errors that are not taken into account in experiments with other equipment. The value of the constant obtained by the researchers was **G = 6,67191(99)·10^{-11}** m^3·s^{-2}·kg^{-1}. The relative difference with G = 6,67430 · 10^{-11} was **0,036%.**

The measurement of the gravitational constant is carried out by various groups of scientists all the time. At the same time, despite the abundance of new technologies, the results of experiments give different values of this constant. From this, some researchers have concluded that perhaps the gravitational constant is actually unstable and is capable of changing its value.

3. Methods.

Before the Big Bang, the Universe was a huge mass of closely packed proto-atoms. These proto-atoms were closely spaced pairs of protons and electrons, each having an elementary charge q. The charge of a protoatom is equal to the **arithmetic sum of two elementary charges.** As a result, each protoatom created a gravitational field numerically equal to:

$$\mathbf{e_{pa} = 4q^2 = 10{,}26787987 \cdot 10^{-38}}\text{m/s}^2 \quad \textbf{(1-1)}$$

where e_{pa} is the value of the gravitational field of the protoatom, m/s^2 (in the process of research, the value of e_{pa} will be confirmed).

q is the value of the elementary charge, $1{,}602176634 \cdot 10^{-19}$ C

In contrast to the electromagnetic field, where the coefficient of proportionality is equal to 9 · 10^9, i**n the gravitational field this coefficient is equal to one**. (In the region of the cosmological singularity, the transition "C^2" to "m/s^2" occurs without the use of conversion factors for units of measurement). Also note that due to the lack of space in the Protouniverse, the gravitational field of the protoatom **had only one value.**

The mass of these proto-atoms was the following value:

$$\mathbf{m_{pa} = \frac{2G}{c^2}} \quad \textbf{(1-2)}$$

where G is the gravitational constant (G value will be determined in the process of research through other physical constants).

c is the speed of light in vacuum, c = 2,99792458 · 10^8m/s.

(In the region of the cosmological singularity, unit conversions occur without the use of unit conversion factors).

At this stage of the study, the expression $\mathbf{m_{pa} = \frac{2G}{c^2}}$ must be accepted as a postulate, which will be confirmed in the course of the study. Note that this postulate plays an important role in obtaining the formula for the gravitational constant.

The expression $\frac{2G}{c^2}$ is taken from the Schwarzschild solution: $\mathbf{R = \frac{2G}{c^2} \cdot M}$

This equation describes the gravitational radius of a black hole. This study assumes that the Schwarzschild solution applies to the Universe before the Big Bang. **All characteristics of the Schwarzschild solution are determined by one indicator - the mass.** Therefore, from the point of view of physics, the expression $\frac{2G}{c^2}$ m/kg should be considered not as an abstract mathematical indicator "m/kg", but as a structural unit of the mass of the Protouniverse, which is the protoatom. (At the same time, let's pay attention to the fact **that before the Big Bang, the gravitational constant did not exist,** because there was no distance between proto-atoms. Therefore, the gravitational constant appears only after the Big Bang).

After the Big Bang, proto-atoms (which, we recall, consist of a proton and an electron) **significantly increased their mass** and turned into hydrogen atoms. Then, as a result of gravitational compression of the masses of hydrogen, which was accompanied by the release of energy and a mass defect, the formation of all other chemical elements (helium, oxygen, carbon, lead, iron, etc.) occurred. The resulting atoms of chemical elements have an equal number of electrons and protons (that is, conditional pairs of a proton and an electron) as well as neutrons, which can also be considered as pairs of a proton and an electron. Thus, **the protoatom, which increased its mass, entered the composition of all chemical elements in the form of a conditional atomic cell.** The number of such atomic cells in an atom of a chemical element is determined by the formula: n= A + B, where A is the number of pairs of electrons and protons in an atom, B is the number of neutrons. To determine the mass of an atomic cell of a chemical element m_c, it is necessary to divide the mass of an atom m_a by the number of atomic cells n: $\mathbf{m_c = m_a / n}$.

As a first example, let's determine the mass of the atomic cell of the carbon isotope $_{12}^{6}C$. An atom $_{12}^{6}C$ consists of 6 electrons, 6 protons and 6 neutrons, that is, these are 12 atomic cells. Therefore m_c =1/12 m_a. At the same time, the atomic mass unit is 1DA = 1/12 $_{12}^{6}C$ = $1{,}660539066 \cdot 10^{-27}$kg. Hence, the mass of the atomic cell $\mathbf{m_c}$ is equal to $\mathbf{1{,}660539066 \cdot 10^{-27}}$kg.

Now let's determine the mass of the atomic cell of lead. Lead has been particularly used in experiments to determine the value of the gravitational constant (the experiment of Cavendish et al.). For this reason, m_c of lead will be used in this study to determine the value of the gravitational constant.

Natural lead consists of 4 stable isotopes: the main isotope $_{208}^{82}Pb$, as well as isotopes $_{204}^{82}Pb$, $_{206}^{82}Pb$, $_{207}^{82}Pb$. The mass of the $_{208}^{82}Pb$ atom is: m_a =207.9766521 Da https://goo.su/fqZ4 (The reference to the source is indicated due to the fact **that the average atomic mass of all isotopes of a chemical element is indicated in the periodic table of Mendeleev. Therefore, this table cannot be used to obtain the exact mass of a particular atom)**. Atom $_{208}^{82}Pb$ consists of 82 electrons, 82 protons, 126 neutrons. Therefore n=208. As a result, the mass of the atomic cell $_{208}^{82}Pb$ will be:

$$\mathbf{m_c} = \frac{207{,}9766521}{208}\,1\text{Da} = \mathbf{1{,}660352671 \cdot 10^{-27}}\ \text{kg} \quad \mathbf{(1\text{-}3)}$$

where 1Da = $1{,}660539066 \cdot 10^{-27}$kg . (Practically the same value of m_c will be when calculating other lead isotopes: $_{204}^{82}Pb$, $_{206}^{82}Pb$, $_{207}^{82}Pb$).

Based on all of the above, m_c can be given a second name: **the unit of atomic mass of a chemical element.**

Now let's move on to one of the important points of the study:

There is a direct analogy between the physical parameters of a protoatom (mass $\mathbf{m_{pa}}$ and gravitational field $\mathbf{e_{pa}}$) **and the geometric parameters of a sphere** (volume **V** and surface area **S**). It lies in the fact that **an increase in the gravitational field of a protoatom with an increase in its mass occurs in the same proportion in which an increase in the surface area of a sphere occurs with an increase in the volume of this sphere.**

As is known from geometry, the proportion between the surface areas (S_1 and S_2) of two spheres and between the volumes (V_1 and V_2) of these spheres is as follows: $\sqrt[2]{\frac{S_1}{S_2}} = \sqrt[3]{\frac{V_1}{V_2}}$ or $\frac{S_1}{S_2} = \sqrt[3]{\frac{V_1^2}{V_2^2}}$ **(1-4)**

Note that exactly the same proportion (1-4) will be in any other volumetric figures (cube, octahedron, dodecahedron, icosahedron, cylinder, parallelepiped, ellipsoid, etc.) **with an increase in their volume.** The main thing is that the proportions of the sides of the figure are not violated.

Now, based on the analogy of the geometric parameters of the sphere (or other figure) and the physical parameters of the protoatom, we obtain:

$$\mathbf{\frac{e_{pa}}{e_c} = \sqrt[3]{\frac{m_{pa}^2}{m_c^2}}} \quad \textbf{(1-5)}$$

where m_{pa} is the mass of the protoatom.

m_c is the mass of the protoatom that has increased its mass or the mass of the atomic cell.

e_{pa} is the gravitational field of the protoatom.

e_c is the gravitational field of the atomic cell.

Based on (1-5) we get: $\mathbf{e_c = e_{pa} \sqrt[3]{\frac{m_c^2}{m_{pa}^2}}}$ **(1-6)**

The atomic cells formed after the Big Bang spread the gravitational field into the resulting space. As a result, the gravitational field began to decrease in proportion to the square of the distance: $\mathbf{E = \frac{e_c}{R^2}}$ **(1-7)**

As a result, the atomic cells formed a common gravitational field of the atom: $\mathbf{E = \frac{e_c}{R^2} n}$, where n is the number of atomic cells in the atom, $n = \frac{m_a}{m_c}$.

Hence $E = \frac{e_c}{R^2} \frac{m_a}{m_c}$ or $E = \frac{\mathbf{e_c}}{\mathbf{m_c}} \frac{m_a}{R^2}$, where $\frac{\mathbf{e_c}}{\mathbf{m_c}} = \mathbf{G}$ **(1-8)**

(The above formulas step by step show **how the gravitational constant appeared in the Universe along with distance).**

Based on f. 1-8 we obtain the classical formula of the gravitational field:

$\mathbf{E = G \frac{m_a}{R^2}}$, where $\mathbf{G = \frac{e_c}{m_c}}$ **(1-9)**

Taking into account that $\mathbf{G} = \frac{\mathbf{e_c}}{\mathbf{m_c}}$ and $\mathbf{e_c} = \mathbf{e_{pa}} \sqrt[3]{\frac{\mathbf{m_c^2}}{\mathbf{m_{pa}^2}}}$ (1-6), we get:

$$\mathbf{G} = \frac{\mathbf{e_{pa}}}{\sqrt[3]{\mathbf{m_c\, m_{pa}^2}}} \quad \textbf{(1-10)}$$

Taking into account the fact that $\mathbf{m_{pa}} = \frac{\mathbf{2G}}{\mathbf{c^2}}$ (1-2) we get the formula:

$$\mathbf{G} = \sqrt[5]{\frac{\mathbf{e_{pa}^3\, c^4}}{\mathbf{4m_c}}} \quad \textbf{(1-11)}$$

The resulting formula contains only known physical quantities and does not have any additional coefficients.

Let us substitute into formula 1-11 the mass of an atomic cell of lead ${}_{208}^{82}\mathrm{Pb}$, where $\mathrm{m_c} = 1{,}660352671 \cdot 10^{-27}$kg (1-3), $\mathrm{e_{pa}} = 10{,}26787987 \cdot 10^{-38}\ \mathrm{m/s^2}$ (1-1), c = 2,99792458 · 10^8m/s. As a result we get:

$\mathbf{G = 6{,}6664 \cdot 10^{-11}}$ $\mathrm{m^3 \cdot s^{-2} \cdot kg^{-1}}$ **(1-12)**

This result is an order of magnitude more accurate than the result of the Cavendish experiment, where the obtained value of G was $\mathbf{6{,}754 \cdot 10^{-11}}$ $\mathrm{m^3 \cdot s^{-2} \cdot kg^{-1}}$ (relative difference **1,2%)** and is comparable with the scatter of the results of modern experiments to determine the value of G (see Section 2).

Given the huge difference in magnitude between the root values of the numbers in the formula 1-11, from a mathematical point of view, an accidental coincidence of the calculated and experimental values of G (with a discrepancy of only 0,12%) **is excluded.** Therefore, returning to the beginning of the study, we can conclude that the value $\mathbf{G = 6{,}6664 \cdot 10^{-11}}$ $\mathrm{m^3 \cdot s^{-2} \cdot kg^{-1}}$ obtained by formula 1-11 **confirmed the postulate 1-2 underlying this formula and the value of $\mathbf{e_{pa}}$ (1-1).**

The reason for the 0,12% discrepancy is the very slight disproportion of 1-5. This disproportion could be caused by both a physical cause and the sum of errors in experimental measurements of atomic mass, elementary charge, gravitational constant and speed of light. Therefore, in order to obtain a more accurate formula for determining the value of G, it is necessary to introduce a correction factor into proportion 1-5: $\mathbf{k\,\frac{e_{pa}}{e_c} = \sqrt[3]{\frac{m_{pa}^2}{m_c^2}}}$ **(1-13)**

Based on 1-13 we get: $\mathbf{e_c = k\,e_{pa}\sqrt[3]{\frac{m_c^2}{m_{pa}^2}}}$ **(1-14)**

Taking into account that $\mathbf{G = \frac{e_c}{m_c}}$ and $\mathbf{e_c = e_{pa}\sqrt[3]{\frac{m_c^2}{m_{pa}^2}}}$ (1-6): $\mathbf{G = \frac{k\,e_{pa}}{\sqrt[3]{m_c\,m_{pa}^2}}}$ **(1-15)**

Substitute $m_{pa} = \frac{2G}{c^2}$ (1-2) into this formula and get:

$\mathbf{G = \sqrt[5]{\frac{k^3 e_{pa}^3\,c^4}{4m_c}}}$ or $\mathbf{k = \sqrt[3]{\frac{G^5\,4m_c}{e_{pa}^3\,c^4}}}$ **(1-16)**

To determine the value of k, we substitute into this formula the recommended CODATA value $G = 6{,}6743 \cdot 10^{-11}$ and the mass of an atomic cell of ${}_{208}^{82}Pb$, where $m_c = 1{,}660352671 \cdot 10^{-27}$kg (1-3), e_{pa}, c. As a result, we obtain a formula with a correction factor:

$\mathbf{G = \sqrt[5]{\frac{k^3 e_{pa}^3\,c^4}{4m_c}}}$, where **k=1,001969731** **(1-17)**

This correction factor, obtained on the basis of the mass of the atomic cell of lead ${}_{208}^{82}Pb$, is accepted as the same for all chemical elements. (Note that in place of lead there could be another chemical element, for example, tungsten (m_c= $1{,}660096236 \cdot 10^{-27}$kg) , which was also often used in experiments to determine the value of G. In this case, the correction factor would be equal to 1,001918138, that is would remain virtually unchanged in size).

Formula 1-17 can also be represented as follows:

$\mathbf{G = k_0\sqrt[5]{\frac{e_{pa}^3\,c^4}{4m_c}}}$ **(1-18)**

where $\mathbf{k_0}$ is the correction factor, 1,001181374 $m^{2\frac{1}{7}} \cdot kg^{-\frac{4}{5}}$.

But in this form, the formula will not be convenient enough for calculations, and in addition, when converting k to $\mathbf{k_0}$, accuracy is lost. Therefore, further calculations of the G value in the study were made using formula 1-17.

Let's apply formula 1-17 for carbon $_{12}^{6}C$, where m_c= 1Da=1,660539066 · 10^{-27} kg (see study above). Recall that $e_{pa} = 10{,}26787987 \cdot 10^{-38}$ m/s^2 (1-1), c = 2,99792458 · $10^8 m/s$, k=1,001969731. As a result, we get: **G = 6,6742·10**$^{-11}$. The relative difference with G = 6,6743 ·10^{-11} is **0,0015%.**

Let us determine the value G for the gravitational field formed by tungsten atoms. Natural tungsten consists of 4 stable isotopes: the main isotope $_{184}^{74}W$ and four isotopes: $_{180}^{74}W$, $_{182}^{74}W$, $_{183}^{74}W$, $_{186}^{74}W$. The atomic mass of $_{184}^{74}W$ is 183,9509312 Da https://goo.su/zqIz The mass of the atomic cell $_{184}^{74}W$ will be: $m_c = \frac{183{,}9509312}{184}$ 1Da =1,660096236 · 10^{-27}kg. We apply the formula 1-17. As a result, we obtain the value **G = 6,6745·10**$^{-11}$. The relative difference with G = 6,6743 ·10^{-11} is **0,003%.**

Let us determine the value of G for platinum. (Platinum is 90% part of the international standard of the kilogram). Natural platinum consists of a mixture of six isotopes, where the largest specific gravity falls on the isotope $_{195}^{78}Pt$. The atomic mass of $_{195}^{78}Pt$ is 194,9647911 Da https://goo.su/cTdgL The mass of the atomic cell $_{195}^{78}Pt$ will be: $m_c = \frac{194{,}9647911}{195}$ 1Da = 1,660239242 · 10^{-27} kg. Apply formula 1-17 and get: **G =6,6744·10**$^{-11}$. The relative difference with G = 6,6743 ·10^{-11} is **0,0015%.**

Let us determine the value of G for iridium. (Iridium is 10% part of the international standard of the kilogram). Natural iridium consists of a mixture of 2 stable isotopes, where the largest specific gravity falls on the isotope $_{193}^{77}Ir$. The atomic mass of $_{193}^{77}Ir$ is 192,9629264 Da https://goo.su/TgOxZQ The mass of the atomic cell $_{193}^{77}Ir$ will be: $m_c = \frac{192{,}9629264}{193}$ 1Da = 1,660220091· 10^{-27} kg. Apply formula 1-17 and get: **G =6,6744·10**$^{-11}$. The relative difference with G = 6,6743 ·10^{-11} is **0,0015%.**

For a full-fledged analysis, we will carry out similar calculations in an abbreviated form with another 20 chemical elements taken from different chemical groups of the periodic table, as their atomic weight increases (links in the text confirm the mass of atoms):

1. Helium ${}^{2}_{4}He$: $\mathbf{m_c} = \frac{4,002603254130}{4}$ 1Da =$1,661619767 \cdot 10^{-27}$kg

G =6,6733· 10^{-11} (Relative difference 0,015 %) https://goo.su/H284

2. Nitrogen ${}^{7}_{14}N$: $\mathbf{m_c} = \frac{14,003074004251}{14}$ 1Da = $1,660903673 \cdot 10^{-27}$ kg

G =6,6739 · 10^{-11} (Relative difference 0,006%) https://goo.su/dJsw7VB

3. Oxygen ${}^{8}_{16}O$: $\mathbf{m_c} = \frac{15,9949146193}{16}$ 1Da =$1,660011286 \cdot 10^{-27}$ kg

G =6,6746 · 10^{-11} (Relative difference 0,0045%) https://goo.su/WISCwAS

4. Neon ${}^{10}_{20}Ne$: $\mathbf{m_c} = \frac{19,9924401753}{20}$ 1Da = $1,659911397 \cdot 10^{-27}$kg

G = 6,6746· 10^{-11} (Relative difference 0,0045%) https://goo.su/FVZrGp

5. Sodium ${}^{11}_{23}Na$: $\mathbf{m_c} = \frac{22,9897692\,820}{23}$ 1Da = $1,659800435 \cdot 10^{-27}$ kg

6,6747 · 10^{-11} (Relative difference 0,006%) https://goo.su/DCsW9

6. Magnesium ${}^{12}_{24}Mg$: $\mathbf{m_c} = \frac{23,98504169}{24}$ 1Da = $1,659504114 \cdot 10^{-27}$ kg

6,6750 · 10^{-11} (Relative difference 0,01%) https://goo.su/KTR3D

7. Aluminum ${}^{13}_{27}Al$: $\mathbf{m_c} = \frac{26,98153841}{27}$ 1Da = $1,659403652 \cdot 10^{-27}$ kg

G =6,6750 · 10^{-11} (Relative difference 0,01%) https://goo.su/B2nox

8. Silicon ${}^{14}_{28}Si$: $\mathbf{m_c} = \frac{27,9769265350}{28}$ 1Da =$1,659170695 \cdot 10^{-27}$ kg

G =6,6752 · 10^{-11} (Relative difference 0,013%) https://goo.su/8bZ3mZ

9. Shlorine ${}^{17}_{35}Cl$: $\mathbf{m_c} = \frac{34,96885269}{35}$ 1Da = $1,659061314 \cdot 10^{-27}$ kg

G = 6,6753 · 10^{-11} (Относительная разница 0,015%) https://goo.su/3Qx8U1

10. Calcium ${}^{20}_{40}Ca$: $\mathbf{m_c} = \frac{39,962590866}{40}$ 1Da = $1,658986083 \cdot 10^{-27}$ kg

G = 6,6754·10^{-11} (Relative difference 0,016%) https://goo.su/hrD5Miv

11. Iron ${}^{26}_{56}Fe$: $\mathbf{m_c} = \frac{55,9349363}{56}$ 1Da = $1,658609766 \cdot 10^{-27}$kg

G =6,6757·10^{-11} (Relative difference 0,02%) https://goo.su/HTk1

12. Copper ${}^{29}_{63}Cu$: $\mathbf{m_c} = \frac{62,9295975}{63}$ 1Da = $1,658683414 \cdot 10^{-27}$ kg

$\mathbf{G = 6{,}6756 \cdot 10^{-11}}$ (Relative difference 0,019%) https://goo.su/pCAIQGU

13. Rubidium ${}^{37}_{85}$Rb: $\mathbf{m_c} = \frac{84{,}911789738}{85}$ 1Da = $1{,}658815812 \cdot 10^{-27}$kg

$\mathbf{G = 6{,}6755 \cdot 10^{-11}}$ (Relative difference 0,018%) https://goo.su/3EReg

14. Silver ${}^{47}_{107}$Ag: $\mathbf{m_c} = \frac{106{,}9050915}{107}$ 1Da =$1{,}659066176 \cdot 10^{-27}$ kg

$\mathbf{G = 6{,}6753 \cdot 10^{-11}}$ (Relative difference 0,015%) https://goo.su/dpSGJN

15. Iodine ${}^{53}_{127}$I: $\mathbf{m_c} = \frac{126{,}904473}{127}$ 1Da = $1{,}65929004 \cdot 10^{-27}$ kg

$\mathbf{G = 6{,}6751 \cdot 10^{-11}}$ (Relative difference 0,012%) https://goo.su/KqoXwc

16. Cerium ${}^{58}_{140}$Ce: $\mathbf{m_c} = \frac{139{,}9054387}{140}$ 1 а. е. м. = $1{,}659417475 \cdot 10^{-27}$ kg

$\mathbf{G = 6{,}6750 \cdot 10^{-11}}$ (Relative difference 0,01%) https://goo.su/UnG0

17. Gold ${}^{79}_{197}$Au: $\mathbf{m_c} = \frac{196{,}9665687}{197}$ 1Da =$1{,}660257269 \cdot 10^{-27}$ kg

$\mathbf{G = 6{,}6744 \cdot 10^{-11}}$ (Relative difference 0,0015%) https://goo.su/x3kUaYR

18. Mercury ${}^{80}_{202}$Hg: $\mathbf{m_c} = \frac{201{,}9706436}{202}$ 1Da = $1{,}660297742 \cdot 10^{-27}$ kg

$\mathbf{G = 6{,}6743 \cdot 10^{-11}}$ (Relative difference 0 %) https://goo.su/wIqGm0

19. Radium ${}^{88}_{226}$Ra: $\mathbf{m_c} = \frac{226{,}0254098}{226}$ 1Da =$1{,}660725765 \cdot 10^{-27}$ kg

$\mathbf{G = 6{,}6740 \cdot 10^{-11}}$ (Relative difference 0,0045%) https://goo.su/wS726Eu

20. Uranium ${}^{92}_{238}$U: $\mathbf{m_c} = \frac{238{,}0507882}{238}$ 1Da =$1{,}660893418 \cdot 10^{-27}$ kg

$\mathbf{G = 6{,}6739 \cdot 10^{-11}}$ (Relative difference 0,006%) https://goo.su/1znly7

As you can see, the relative difference between the obtained values of G with the value G =6,67430 · $\mathbf{10^{-11}}$ and between each other **is thousandths and hundredths of a percent.** Such very small discrepancies are explained by the fact that **the masses of the atomic cells of chemical elements are very close to each other in magnitude.** And due to the fact that in the formula 1-17 there **is a root to the fifth degree,** the values of the gravitational constants **will be two and a half orders of magnitude** closer to each other in magnitude than the values of the masses of atomic cells. It is important to emphasize here that **a small difference in G values is not an error, but a regularity.** Therefore, if different chemical elements are used in the same experiments with the same conditions and the same equipment, **different G values will be obtained.** But the differences in the G value will be so small that it is not yet possible to confirm them with certainty using the available measuring instruments and equipment.

Similar calculations of the G value **can be applied to all chemical elements** of the periodic table, including all isotopes. At the same time, the results obtained will show (verified by the author**) that the fluctuations in the value of G for chemical elements never go beyond the range of thousandths and hundredths of a percent, with the exception of hydrogen.** The reason for the difference in hydrogen lies in a more massive atomic cell than all chemical elements. The atom $^{1}_{1}H$ (protium) has a mass of 1,007825031898 Da https://goo.su/DVKOoB An atom $^{1}_{1}H$ consists of a proton and an electron, so its atomic mass is simultaneously the mass of the atomic cell, where $m_c = \frac{1,007825031898}{1}$ 1Da = 1,673574827· 10^{-27}kg. According to formula 1-17, we get: $\mathbf{G = 6,6637 \cdot 10^{-11}}$ $m^3 \cdot s^{-2} \cdot kg^{-1}$. Thus, the relative difference with G =6,6743·10^{-11} will be **0,16%**.

The fact that the mass of atomic cells of hydrogen is greater than the mass of atomic cells of other chemical elements is explained by the fact that **in the process of the evolution of the Universe, a mass defect occurred in the atoms of all chemical elements, but it was not in hydrogen.** Unfortunately, modern science cannot yet measure the value of the gravitational constant of hydrogen under ground laboratory conditions (even with a very large error). This is because hydrogen is a gas and a very light chemical element.

To determine the mass of the protoatom, we transform formula 1-15 into the formula: $\mathbf{m_{pa} = \sqrt{\frac{k^3\, e_{pa}^3}{m_c\, G^3}}}$ **(1-19)**

Let's substitute into this formula k=1,001969731, $e_{pa} = 10,26787987 \cdot 10^{-38} m/s^2$ (1-1), G =6,6743·10^{-11}, $^{82}_{208}Pb$ m_c = 1,660352671·10^{-27}kg

As a result, we get: $\mathbf{m_{pa} = 1,485232053 \cdot 10^{-27}}$ kg

Please note that when calculating using this formula, the value of m_{pa} will be the same for all chemical elements. This is explained by the fact that in formula

1-19, along with an **increase-decrease** in the mass of the atomic cell of chemical elements $\mathbf{m_c}$, a reverse process of **decrease-increase** in the value of **G** occurs. This can be easily verified by substituting the values of m_c and G from the above 25 chemical elements into this formula. Thus, the mass of the proto-atom m_pa, unlike G, is stable. At the same time, it is impossible to say that $\mathbf{m_{pa}}$ is exactly equal to $1{,}485232053 \cdot 10^{-27}$ kg, because there are errors in the quantities included in formula 1-19. This applies primarily to experimental measurements of the G value (see section 1). Therefore, it would be more correct to write: $\mathbf{m_{pa} \approx 1{,}4852 \cdot 10^{-27}}$ kg.

Now let's briefly touch on the magnitude of the gravitational field E, which is formed by mass M, consisting of different chemical elements, at a distance R from mass M:

$$\mathbf{E = G_1 \frac{m_1}{R^2} + G_2 \frac{m_2}{R^2} + \ldots\ldots G_n \frac{m_n}{R^2}} \quad \textbf{(1-16)}$$

where m_1, m_2….. m_n is the mass of chemical elements in the mass M.

(This formula is valid for any mass, regardless of the chemical composition of the substance).

Thus, **a single field E** will act on a body located at point A at a distance R from the mass M.

Given the almost identical values of G_1, G_2….G_n, we obtain the familiar formula for the gravitational field for applied calculations: $\mathbf{E = G \frac{M}{R^2}}$.

4. Results.

In this study, based on the concept of protoatoms, the following results were obtained:

The formula for the gravitational constant is obtained. Formula 1-11 is based on physical constants: the magnitude of the elementary charge, the speed of light in vacuum and the mass of atomic cells of chemical elements (a unit mass of a chemical element). The difference between formulas 1-11 from all the proposed formulas for the gravitational constant is the absence of additional coefficients and indicators for the purpose of adjusting the value of G. The result obtained by the formula was $\mathbf{G = 6{,}6664 \cdot 10^{-11}}$ $m^3 \cdot s^{-2} \cdot kg^{-1}$ the relative difference with G = 6,6743 $\cdot 10^{-11}$ was **0,12%.** Given the huge difference in magnitude between the root values of the numbers in the formula 1-11, an accidental coincidence of the calculated and experimental values of G (with a discrepancy of only 0,12%) **is excluded.**

Another important result of this research was **that the gravitational constant is not a constant in the strict sense of the word.** To prove this, 25 calculations of the gravitational constant were made using chemical elements taken from all chemical groups of the periodic table. **These calculations showed that the value of G fluctuates within thousandths and hundredths of a percent for all chemical elements.** (The only exception is hydrogen, where the relative difference with a value of 6,6743 $\cdot 10^{-11}$ was 0,16%). The reason for the fluctuations in the value of G is related to the different masses of the atomic cells of chemical elements (see Section 3).

An important result of this study is the determination of the mass of the protoatom. Taking into account the errors in experimental measurements of the value of G (see section 1), the mass of the protoatom was: $\mathbf{m_{pa} \approx 1{,}4852 \cdot 10^{-27}}$ kg.

Also in this study, the issue of the magnitude of the gravitational field, which is formed by a mass that consists of atoms of different chemical elements, was highlighted.

5. Conclusion.

A distinctive feature of this study is that it was conducted on a new theoretical basis, which is described in the previous sections. Research in this direction will be continued.

6. Declarations.

1. **Availability of data and materials.** All data obtained and analyzed in the course of this study is included in this article.
2. **Competing interests.** Not applicable (there are no competing interests).

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