Open Access Library Journal
2024, Volume 11, e11369
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Simplified Quarks-Based Theoretical Explanation of Fusion

Luis F. Copertari

Computer Engineering Program, Autonomous University of Zacatecas (UAZ), Zacatecas, México
Email: copertari@uaz.edu.mx

How to cite this paper: Copertari, L.F. (2024) Simplified Quarks-Based Theoretical Explanation of Fusion. *Open Access Library Journal*, **11**: e11369.
https://doi.org/10.4236/oalib.1111369

Received: February 28, 2024
Accepted: April 27, 2024
Published: April 30, 2024

Abstract

What is the universe made of? The universe is made of atoms (and vacuum). The basic atom is the Hydrogen atom with one proton in its nucleus and one electron orbiting the electron cloud. This basic Hydrogen atom is called Protium. Protium atoms were created at the Big Bang explosion. Protons, neutrons, and electrons are assumed in this paper to be made of quarks. Three types of quarks are considered: up quark, strange quark, and down quark. Protons are assumed to be made of one up quark and one strange quark. One electron is assumed to be one down quark. Neutrons are assumed to be made of one up quark and one down quark. Considering the electrical charge of the electron to be e, up quarks have a charge of $+1 \times e$ and down quarks have a charge of $-1 \times e$. The corresponding masses are calculated. In stars, fusion processes create all other elements in the Periodic Table: Helium (He), Lithium (Li), and so on. These fusion processes are responsible for the current constitution of the universe and all the different kinds of stable atoms that exist in it. In the fusion process, lighter atoms are merged and the result is the release of strange quarks becoming electromagnetic waves carrying energy. The maximum possible frequency for a strange quark released at the core of a star in a fusion process is calculated as being $\upsilon_s = 3.85 \times 10^{20}$ Hz, slightly lower that the frequency corresponding to gamma rays.

Subject Areas

Mathematics, Modern Physics

Keywords

Atoms, Quarks, Fusion

1. Introduction

What is matter made of? This very basic question ponders upon the limits of science and technology. If one is to take one piece of, say, an apple pie, and were to start cutting it in half, and then each successive half in half, and so on, would there be a limit to the number of cuts to be made? This limit is known as the atom, and the idea of the atom is credited to the Greek philosopher Democritus [1]. Atom means without division.

Except for the very basic hydrogen atom (called protium), which was originated in the Big Bang explosion that created the Universe, all other atoms are made inside the furnace of stars though a process called fusion [2]. Each atom is different and the chemical properties of the elements in the Periodic Table are due to the peculiar properties of each atom. The first atom in the Periodic Table is Hydrogen (H), the second atom is Helium (He), the third atom is Lithium (Li), and so on.

However, as it turns out, atoms are not the end of the story. Atoms have a nucleus and a cloud around with electrons orbiting it. If a hundred million atoms were to be placed one next to the other, they would be as small as a little finger. But if the cloud in which electrons orbit were the size of a tennis court, the nucleus would be the size of a pin head centered within the orbiting electrons cloud.

The basic hydrogen atom (protium) has one electron orbiting in its electronic cloud (with an arbitrary negative charge) and one proton (with an arbitrary positive charge) as its nucleus. There is, however, one variation of hydrogen called deuterium, which also has, in its nucleus, something called a neutron, which is electrically neutral.

2. Electrons and Protons

It is safe enough to assume that the characteristics of the electron are known with good certainty. This is because electricity (due to the passage of electrons though wires) is a technology that has been well developed and studied. Thus, the electrical charge of one electron can be considered as reasonably well measured, and equals $e = 1.60 \times 10^{-19}$ Coulombs [3]. Coulombs are the units of the metric system (meter-kilogram-second, which is m-kg-s or MKS) for electrical charge. Clearly, the electrical charge of one electron is very small when compared with ordinary life, because electrons are very small indeed. Since the proton must have the exact opposite charge so that the electrical attraction between protons and electrons maintains one hydrogen atom intact, the electrical charge of the proton must be equal to that of the electron but opposite. Let us call the electrical charge of the electron as $-1 \times e$ and the electrical charge of the proton as $+1 \times e$.

Also, there is a simple relationship between mass and force given by Newton's second law, as shown in Equation (1), where F is the force, m is the mass and a is the acceleration experimented by some electrical particle of mass m [3]. This equation can be used in electromagnetic experiments (measuring the electromagnetic forces) to calculate the masses of the proton and the electron. Certainly, Equation (1) must be used in combination with a whole system of equations taken from electromagnetic theory [3].

$$F = ma \quad (1)$$

By carrying out such careful electromagnetic experiments, it is possible to determine the mass of the electron (at rest) and the mass of the proton (also at rest), approximately given as $m_e \approx 9.11 \times 10^{-31}$ kg and $m_p \approx 1.67 \times 10^{-27}$ kg, respectively. Since the mass of the proton is higher than the mass of the electron, it must be made of additional "matter". What such matter could be made of?

3. Quarks

The quark model has been proposed as a theoretical construct to explain the properties of particles in Quantum Mechanics. However, the particles in the Physics of Quantum Mechanics can only be observed, typically throughout very small moments, in particle accelerators at ever higher energies and considering ever smaller moments of time [3].

Although the quark model seems to be good enough, I do not believe it is necessary to consider all six "flavors" of quarks, but only the first and most important three: the up quark (u or $\uparrow$), the down quark (d or $\downarrow$) and the strange quark (s or $\leftrightarrow$). Also, I am not going to consider properties such as strangeness, baryon number or the antiparticle (and certainly not spin!). I am not even assuming certainty considering their mass for all of them. And since their name or "flavor" is arbitrary, it only matters how they are defined to be combined in order to produce a proton, an electron, and a neutron.

I assume the down quark to constitute one electron, since the down quark is simply a name to identify a concept such as the electron. Thus, it has the electrical charge of an electron, that is, $-1 \times e$ and its mass, that is, m_e. The proton is assumed to be formed by the combination of two quarks: the up quark and the strange quark. The up quark is assumed to have a charge of $+1 \times e$, whereas the strange quark is assumed to have a charge of zero. However, and since the mass of the proton is higher than the mass of the electron ($m_p > m_e$), the combination of the masses of the up and strange quarks are assumed to constitute the mass of the proton. Nevertheless, the masses of the up and strange quarks are, up to this point in the paper, unknown, as well as the mass of the neutron.

4. Composition of a Protium Atom (H)

Thus, we have the protium atom, as shown in **Figure 1**, composed of a nucleus (a proton that is) made of the combination of up ($\uparrow$) and strange ($\leftrightarrow$) quarks and the electron composed of a down quark ($\downarrow$).

We already know the electric charge and mass of the electron (that is a down quark) because of reasonable certainty involving the electrical experiments performed with the passage of electrons through a wire, a phenomenon known as electricity. However, the properties of the up and strange quarks are not so obvious. Can they be derived?

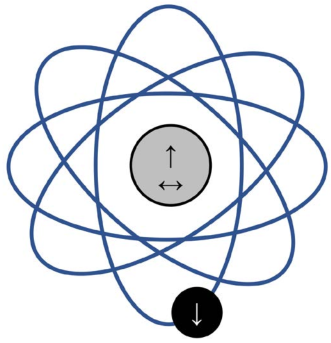

Figure 1. Schematic representation of the protium atom (H).

5. Neutrons and Quarks

What could neutrons be made of? Since an up quark (u or ↑) is assumed to have an electrical charge of +1 × e and a down quark (d or ↓) a charge of −1 × e, it is reasonable to assume that a neutron has no electrical charge because it is made of an up and a down quark. These two quarks cancel each other their electrical charges, so that the neutron has a net electrical charge of +1 × e − 1 × e = 0. What about the mass of the up quark, the strange quark, and the neutron?

The mass of the up quark is unknown and it is denoted as x. We are initially assuming that the mass of the neutron is also unknown and it is denoted as y. The mass of the electron is already known to be $m_e \approx 9.11 \times 10^{-31}$ and it equals the mass of the down quark (m_d). Since the mass of the neutron should be the masses of the up and down quarks, we have Equation (2).

$$x + m_e = y \tag{2}$$

Also, the mass of the proton is known to be $m_p \approx 1.67 \times 10^{-27}$ kg. The proton is assumed to be composed of up and strange quarks. Let us denote the mass of the strange quark as z. Then, Equation (3) must hold.

$$x + z = m_p \tag{3}$$

A deuterium atom includes one proton and one neutron in its nucleus and one electron orbiting in its electronic cloud. It is reasonable to assume that the mass of a deuterium atom is well measured. The mass of the deuterium atom is given as $m_{De} \approx 2.0141 \times u$, where u is the mass given in unified atomic mass units, and it is $u = 1.6605402 \times 10^{-27}$ kg. Consequently, $m_{De} \approx 2.0141 \times u \approx 2.0141 \times 1.6605402 \times 10^{-27}$ kg $\approx 3.344494017 \times 10^{-27}$. Then, we have that Equation (4) must hold, where $(x + z)$ is the mass of one proton and y is the mass of one neutron.

$$(x + z) + y + m_e = m_{De} \tag{4}$$

Solving the system of three variables (x, y and z) and Equations (2)-(4), yields the following results: $x = m_{De} - m_p - 2m_e = 3.344494017 \times 10^{-27}$ kg $- 1.67 \times 10^{-27}$ kg $- 2 \times 9.11 \times 10^{-31}$ kg $= 1.672672017 \times 10^{-27}$ kg; $y = x + m_e = 1.672672017 \times 10^{-27}$ kg $+ 9.11 \times 10^{-31}$ kg $= 1.673583017 \times 10^{-27}$ kg. The mass of deuterium can be approximated to be $m_{De} \approx 3.35 \times 10^{-27}$. Also, $z = m_{De} - x - y - m_e = 3.35 \times 10^{-27} - 1.672672017 \times 10^{-27}$ kg $- 1.673583017 \times 10^{-27}$ kg $- 9.11 \times 10^{-31}$ kg $\approx$

2.833966×10^{-30} kg.

As a result, the mass of an up quark is given as $m_u = x \approx 1.672672017 \times 10^{-27}$ kg. The mass of a strange quark is $m_s = z \approx 2.833966 \times 10^{-30}$ kg. Finally, the mass of a down quark (m_d), already known, is the mass of the electron, given as $m_d = m_e \approx 9.11 \times 10^{-31}$ kg.

Since now we have the masses of the up, strange and down quarks, we can calculate the mass of a protium atom (m_{Pr}) as $m_{Pr} = (m_u + m_s) + m_d \approx (1.672672017 \times 10^{-27}$ kg $+ 2.833966 \times 10^{-30}$ kg$) + 9.11 \times 10^{-31}$ kg $\approx 1.676416983 \times 10^{-27}$ kg. According to tables [3], the mass of a protium atom is given as $m_{Pr} \approx 1.0078 \times 1.6605402 \times 10^{-27}$ kg $\approx 1.673492414 \times 10^{-27}$ kg. Clearly, both measures are almost the same, that is 1.67×10^{-27} kg, so the results check out.

6. Fusion

Now that we have clarified the composition assumed for protons, neutrons, and electrons, what could be happening inside stars as their fusion process proceeds? At the center of the Sun huge fusion reactions produce other elements. The Sun has a surface temperature of about 5770 K and in its core an amazing temperature of 15'000,000 K [4]. Degrees Kelvin (K) are the measure of temperature of the metric system, where 0 K = −273˚C and 0˚C = 273 K[1].

How do I assume fusion to occur in the Sun and how does the Sun releases energy? Let us consider first the formation of a deuterium atom as the fusion of two protium atoms. **Figure 2** schematically illustrates this situation. Notice that in **Figure 2** the neutron is colored white, the proton is colored gray and the electron is colored black.

Figure 2 shows that the combination of two protium atoms (each with an up, strange, and down quarks) results in a deuterium atom that has one proton and one electron (taken from the first protium atom) and one neutron (resulting from the combination of the up quark and the down quark of the second protium atom). The strange quark from the nucleus of the second protium atom gets released as energy, since I assume that strange quarks cannot exist as matter for relatively long periods of time.

For the formation of a Helium atom (composed of two protons, two neutrons

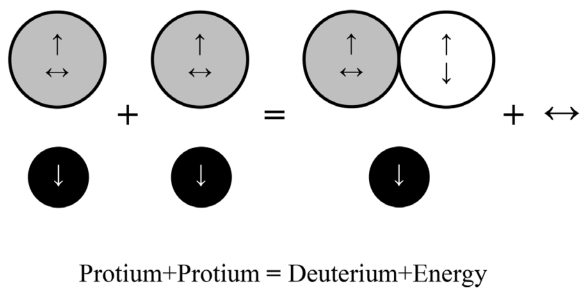

Figure 2. Creation of deuterium and energy from two protium atoms.

[1]A temperature of 0 K would indicate that the atoms are completely stationary, without any quantum activity. Not even in the vacuum of space can we find a temperature of 0 K. There is a temperature of just a few degrees K. A temperature of 0 K would be called absolute zero.

and two electrons), we could consider the combination of a deuterium atom plus two protium atoms, resulting in the corresponding Helium atom plus one strange quark released, as it is schematized in **Figure 3**. Notice that in **Figure 3** the neutron is colored white, the proton is colored gray and the electron is colored black.

Figure 3 illustrates the creation of a Helium atom plus a strange quark released in the form of energy from a deuterium atom and two protium atoms. The Helium atom has two protons, two neutrons and two electrons. The first proton and neutron come directly from the deuterium atom, as well as the first electron. The second proton and the second electron come directly from the first protium atom. However, the formation of the second neutron results from the combination of the up quark from the proton of the second protium atom as well as the electron from the second protium atom. There is one strange quark remaining that is released as energy.

Other combinations are possible, such as the combination of four protium atoms to create one Helium atom and releasing two strange quarks as energy. The formation of heavier atoms occurs in similar fashion. What happens to the strange quarks released through the fusion process? How can we understand what happens to them?

7. Strange Quarks and Energy

What kind of energy can be created when one strange quark is released? Clearly, the answer must be electromagnetic energy (an electromagnetic wave). The mass of the strange quark becomes (presumably in its entirety) energy that is released as electromagnetic waves with a certain frequency given in Hertz (Hz or $1/s = s^{-1}$). Energy in the metric system is given as Joules = Newtons·meters = $(kg\cdot(m/s^2))\cdot m = kg\cdot m^2/s^2$.

If we assume that m is the mass of some particle at rest, then its energy (E) is given according to Einstein's famous equation fundamental for the theory of relativity, shown in Equation (5), where c is the speed of light, given as $c \approx 3.00 \times 10^8$ m/s [5].

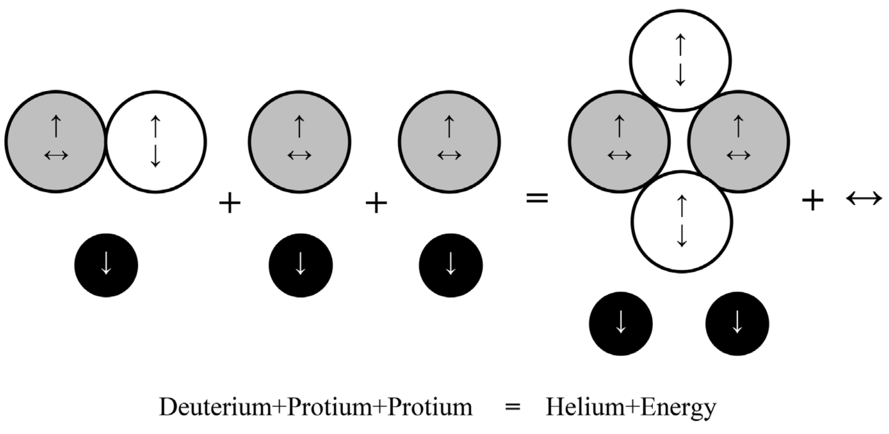

Figure 3. Creation of Helium and energy from one deuterium and two protium atoms.

$$E = mc^2 \quad (5)$$

The mass we are considering is the mass (at rest) of the strange quark, which equals, as we saw in section 4, $m_s = 2.833966 \times 10^{-30}$ kg. The energy associated to such mass would be given as kg·(m/s)^2 = kg·m^2/s^2.

The other equation, fundamental to quantum theory is Max Planck's equation [5], given in Equation (6), where h is Planck's constant given by $h \approx 6.63 \times 10^{-34}$ Joules·s. In the metric system, Joules·s = (Newtons·m)·s = ((kg·m/s^2)·m)·s = kg·m^2/s. The frequency of the electromagnetic wave corresponding to the Energy (E) in Equation (6) is given by the Greek letter *upsilon* or υ.

$$E = h\upsilon \quad (6)$$

Solving for υ from Equation (6) yields Equation (7).

$$\upsilon = E/h \quad (7)$$

Substituting E from Equation (5) into Equation (7) yields Equation (8).

$$\upsilon = mc^2/h \quad (8)$$

The units for υ are (kg·m^2/s^2)/(kg·m^2/s) = 1/s = s^{-1} = Hz. Thus, the frequency (at rest) for a strange quark released at the core of a star (υ_s) after a fusion process is given according to Equation (9), where m_s is the mass of the strange quark.

$$\begin{aligned}\upsilon_s &= m_s c^2/h \\ &\approx 2.833966\times10^{-30}\times\left(3.00\times10^{8}\right)^2/\left(6.63\times10^{-34}\right)\text{ Hz} \\ &\approx 3.85\times10^{20}\text{ Hz}\end{aligned} \quad (9)$$

Figure 4 shows the electromagnetic spectrum [4], where the bottom line is the frequency given in Hz. Clearly, when a strange quark is released near the core of the Sun, its frequency is around 3.85 × 10^{20} Hz, which is close (but lower!) than a gamma ray. However, such electromagnetic wave needs to make its way to the surface of the Sun, thus losing energy (and frequency). The general theory of

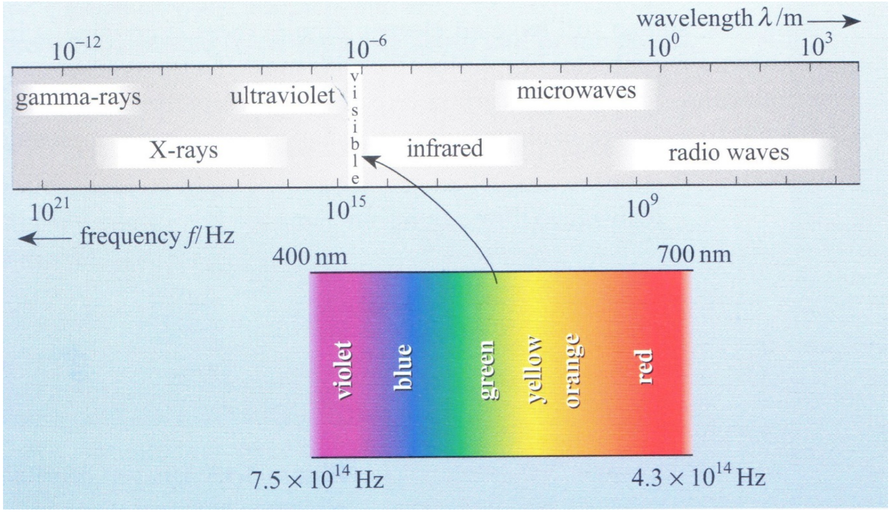

Figure 4. The electromagnetic spectrum.

relativity explains (although perhaps only in part!) this frequency loss due to the shift to the red of electromagnetic waves in the presence of a strong gravitational field as the electromagnetic wave departs from the source of the gravitational field. It takes such electromagnetic wave approximately 10 years to reach the surface of the Sun [2]. During such time, most electromagnetic waves loose frequency to the level of yellow visible light (a photon with a frequency of approximately 5.9×10^{14} Hz), which travels from the surface of the Sun through the vacuum of space reaching Earth. All kinds of electromagnetic waves also reach Earth, since the Sun's radiation constitutes an electromagnetic probabilistic spectrum.

8. Discussion and Conclusions

The correctness of this paper depends on the following assumptions made: 1) Only three kinds of quarks are needed to explain the properties (electrical charge and mass) of protons, neutrons and electrons, 2) An electron is one single quark, 3) Protons must be the result of the combination of two other quarks in order to be stable, 4) The reason why neutrons are electrically neutral is because they are the result of the combination of two quarks of exactly opposite charges, presumable orbiting each other crazily within the confinement of what constitutes a neutron, and 5) A strange quark cannot be stable for relatively long periods of time, thus becoming energy.

These assumptions do not rest on experiments carried out for the purposes of this paper, but rather on "common sense" and an intuition that the crazy zoo of particles in Quantum Mechanics Physics cannot be correct for the purposes of explaining fusion. However, the fact that the sum of the masses of one up, one strange, and one down quark for a protium atom coincides with the value obtained from tables, may be a good indication of soundness.

What is the maximum energy that can be released by one strange quark? The mass of a strange quark is $m_s = 2.833966 \times 10^{-30}$ kg. Then, according to Einstein equation, we have the maximum energy (assuming a 100% efficiency in the conversion from matter to energy) to be $E = m_s c^2 \approx (2.833966 \times 10^{-30}\text{ kg}) \times (3.00 \times 10^8\text{ m/s})^2 \approx 2.5505694 \times 10^{-13}$ Joules. That energy would allow to exercise a force of $2.5505694 \times 10^{-13}$ Newtons along one meter. On the surface of Earth, where the gravitational acceleration is $g \approx 9.8\text{ m/s}^2$, we could lift a mass of $2.5505694 \times 10^{-13}/9.8 \approx 2.602621837 \times 10^{-14}\text{ kg} = 2.602621837 \times 10^{-14}\text{ kg} \times 1000\text{ mg/kg} \approx 0.00000000002602621837$ mg, which is lifting a very small mass. However, going from the core of the Sun to its surface, where the gravitational pull is considerably higher, requires spending much more energy, which is the reason why the electromagnetic waves reaching Earth have a much lower energy (and frequency).

In summary, considering only three kinds of quarks (up, down, and strange) accounts for the properties of protons, electrons, and neutrons, such as electrical charge and mass, as well as the release of energy as a result of the fusion processes inside stars responsible for the creation of all the stable elements in the Periodic Table in existence in the Universe.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Durant, W. (1961) The Story of Philosophy. Simon & Schuster, New York.

[2] Sagan, C. (1980) Cosmos. Editorial Planeta, Madrid. https://doi.org/10.1016/0019-1035(80)90155-4

[3] Halliday, D. and Resnick, R. (1988) Fundamentals of Physics. John Wiley & Sons, Hoboken.

[4] Rothery, D.A., McBride, N. and Gilmour, I. (Eds.) (2011) An Introduction to the Solar System. Cambridge University Press, Cambridge.

[5] Penrose, R. (2012) Cycles of Time. Vintage Books, New York.