What Causes The Mass To Be Deficit Inside A Nucleus?

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Abstract: *Mass of an object varies with the change in volume of the object. Mass of a gas nebula will increase when it collapses to form a neutron star or black hole. The cause for an object to exhibit the deficit in mass is the increase in the amount of space in which the particles of that object were occupied. Gas nebula will have more deficit in mass compared to the neutron star formed from the same amount of material. Avogadro number, which establishes a relationship between the mass and the number of atoms within an object, is a baseless notion.*

A simple answer for the question is binding energy inside the nucleus. Apart from this explanation, is there any other physical aspect of the nucleus we can attribute as the cause for the deficit?

Mass of two objects causes the gravity between them. So, the mass deficit can also be described as the deficit in gravity between two objects. Because of the association between the mass and gravity, lets ignore the notion of binding energy for a while and explore the deficit in respect to the gravity.

According to the standard theory, the mass of an object is resistance to change in motion. It is a fixed amount for a given object irrespective of the volume of the object. And also, each gram of an element will have a fixed number of atoms. It means, even if we compress an object, the amount of mass it measures and the number of atoms it contains remains same. This relation should hold true as long as the amount of matter in an object remains same. Does an object measure same amount of mass even if we compress that object to a neutron star?

Mass of a Neutron star with "*n*" number of neutrons

What would be the mass of a neutron star with "n" number of neutrons? The only way to measure the mass of a neutron star is by multiplying the mass of a single neutron with the total number of neutrons in the star. In this case, the mass of the neutron star is proportional to the amount of matter, the number of neutrons, inside the star. Is this mass going to be consistent with the mass of the material from which the star was formed?

Let's consider the following two scenarios. A Neon cloud with X moles of atoms collapsed to form a neutron star and another cloud of Calcium dust with $X/2$ moles of atoms collapsed to form another neutron star. Let's also assume that none of the material from the cloud got ejected when those clouds collapsed to form the neutron stars.

A Neon atom contains ten of each basic particles; protons, neutrons and electrons. An atom of calcium contains double the amount of particles, means 20 of each individual particles. A mole of Neon measures 20.1791 grams and a half mole of Calcium measures (40.078/2) = 20.039 grams. Each of these two entities has same number of electrons, protons and neutrons but differ in the amount of mass they measure. Neon cloud will measure X*20.1791 grams and the calcium cloud will measure X * 20.039 grams.

When a cloud collapses to form a neutron star, all the matter inside the object converts to neutrons. Protons and electrons merge to form the neutrons. A neutron star is a compact form of the collapsed neutrons. When X moles of neon and X/2 moles of calcium collapsed, they both generate same number of neutrons. Therefore the neutron stars formed from these two clouds should measure the same amount of mass. But the actual mass of the original clouds differ from each other.

If we calculate the mass of the neutron star as the combined mass of all the neutrons in the star, then the neutron star will have more mass than the mass of the cloud from which it formed because the cloud is a set of atoms. Each atom will exhibit a deficit in mass when compared to the mass of the total particles inside the atom. Therefore the cloud will measure less than the total mass of the particles in the cloud.

Here, we can conclude two things. First one is that the two different clouds of material measuring different amount of mass but same amount of basic particles will result in neutron stars with each having same amount of mass when those clouds collapsed. Secondly, the mass of the collapsed star will be more than that of the cloud from which it formed.

These two statements are in stark contrast to the conclusions of the shell theorem and the definition of mass which states that the size of the material is irrelevant in the amount of mass they measure. But in reality, it appears that the mass of an object does change with the volume or size of the object as seen in the formation of neutron star. Why there is disparity between the mass of two forms of an object with same amount of material?

It is due to the fact that the neon and calcium clouds have the mass deficit. The amount of mass deficit in neutron star will be different from the neon cloud or the calcium cloud. The present theories in physics can’t explain how much of the mass going to be deficit inside the neutron star? There is no rationale in the relation between the mass, matter, deficit of mass and the volume of an object. These all concepts are conveniently defined depending upon the situation.

When an object collapses to a point mass, it is no longer relevant from which atom the particles came from. Many different combinations of different atoms yield same object when they collapse to a point mass if the number of each type of basic particles inside those objects are same. Then the mass of all those point objects will be same even though the original objects have different masses.

Even if we consider the scenario of the binding energy, when all the matter occupies the space of a single particle, that entity will have enormous amount of binding energy compared to the initial cloud. If the amount of binding energy alters the mass of the object, according to the present theories, the point mass object should have different mass than the cloud.

Nuclear fission and release of binding energy

When uranium atom bombarded with a neutron, the atom splits into two different atoms and releases energy. The energy released was termed as the binding energy within the nucleus of the Uranium atom. The amount of binding energy released was equated to the amount of mass that was deficit in the resultant atoms and the process was termed as the nuclear fission [1].

Here, the stored energy is associated with the Uranium atom and the deficit in mass is associated with the resultant products. Mass deficit and the energy will not be associated with the same object. When Uranium atom releases the energy, means when it disintegrates or expands in size, then only we will observe deficit in mass.

When a nucleus occupies less space then it will have more energy and at the same time it measures more in gravity. A point mass object will have tremendous amount of energy and measures zero deficit in mass. As the particles separate and occupy more space in a nucleus, that nucleus will store less energy and measures less in gravity. A gas cloud measures less gravity compared to a neutron star formed from the same amount of material in the cloud.

Measurement of Avogadro Constant

Concept of mole or Avogadro constant (N_A) gives us an impression that the number of atoms of an element inside an object will measure same amount of mass irrespective of the amount of space those atoms occupy.

The prevailing measurement for the N_A is as follows. Volume of a single unit cell will be determined using the x-ray crystallography and then the number of such cells will be calculated in one cubic centimeter volume. By applying the data for the density, molar mass and the number of atoms in a cell, the value for the Avogadro number is calculated.

Volume of a single unit cell of an element = v cm^3
Number of unit cells in one cubic centimeter = $1/v$
Number of atoms in a unit cell = n
Number of atoms in one cubic centimeter = $(1/v) * n = N$ *atoms/* cm^3
Molar volume = Molar mass/Density = V_m cm^3
Avogadro number, $N_A = (V_m * N)$ *atoms/g-mole*

Following are the characteristics of the Titanium used to derive the Avogadro number [2].

Unit cell volume for the Titanium = $(3.306 \times 10^{-8})^3$ cm^3
Number of atoms in a body centric unit cell = 2
Molar mass = 47.88 g
Density = 4.401 g/cm3

Therefore, by applying the above values, we get the value for N_A as 6.02×10^{23} atoms/g-mol. Instead of atoms/g-mol, it is appropriate to name the constant as the atoms/molar volume. We basically calculated the number of atoms in a given volume. Above derivation doesn't establish any relation between the grams and atoms.

The assumption of the mass of an object as the product of density and volume is the main issue in the above derivation. There is no proof for an object to have same mass irrespective of the size of the object. As the object grows bigger in size or in other words if it occupies more space then that object exhibits more deficit in mass compared to smaller objects. As a result, the density (mass/volume) of the bigger objects will be less than the density measured for small objects made from the same material. Product of density (mass measured for one cm^3) and the volume of an object don't yield the mass of that object. With the same number of atoms, an object exerts different amount of gravity depending upon its size. The value derived for the constant will be different when different objects are used made out of different elements. It is no wonder why we don't have a precise value for this constant.

Relationship between the baryons and the deficit of mass

Let's assume four different atoms with different number of protons and neutrons but the total number of baryons (protons + neutrons) as 40. The combination of particles and the mass of the four atoms are given in the Table 1. Combined mass of proton (p) and electron (e) is almost equal to the mass of the neutron (n). So we can treat the combination of one proton and one electron equal to one neutron. The first atom in the following table is the normal calcium atom with 20 of each basic particles. Let's assume the combined mass of all the individual particles is equal to X and the atomic mass of the atom as Y. Due to the deficit of mass inside the nucleus, the atomic mass (Y) will always be less than the mass of all particles combined (X).

Different atoms with Protons(pr), electrons(el) and neutrons(ne)	Number of baryons	Combined mass of particles (grams) (assume $n = p + e$)	Atomic mass (grams)
Atom 1: 20pr,20el,20ne (normal calcium atom)	40	X	Y
Atom 2: 19pr,19el,21ne (Potassium isotope)	40	$X + n - p - e = X$	$Y \pm a$
Atom 3: 18pr,18el,22ne (Argon isotope)	40	$X + 2n - 2p - 2e = X$	$Y \pm b$
Atom 4: 17pr,17el,23ne (Chlorine isotope)	40	$X + 3n - 3p - 3e = X$	$Y \pm c$

Table 1: Atomic mass in different atoms with number of baryons as 40

As seen in the above table, as long as we keep the number of baryons same within the atom, the total mass of all particles remains the same. But the actual measured atomic mass of the atoms will always differ. There is no particular pattern in the change in value of the atomic mass. Any one of the atoms like potassium, argon or chlorine could measure more than the calcium atom. In the same way, any one of those atoms could measure more atomic mass than the calcium atom. It means the amount of mass deficit doesn't depend on the number of basic particles inside the atom.

As seen earlier, a compact form of particles exerts more gravity than when the particles are apart within the atom. It means, the way the particles are grouped together influences the amount of gravity they exert. Therefore, the only possibility here is that the atom in which the baryons are packed together in a smaller volume will have less deficit in mass compared to the atom in which the particles occupy more space in the nucleus. The cause for the deficit of mass has a physical form; that is the structure of the nucleus not just the notion of binding energy.

Mass deficit at the object level

In any object, the total mass of all particles will be equal to the measured mass of the object plus the mass deficit.

Total mass of an object = measured mass + mass deficit

We are simply aligning the mass of an object with gravity and measuring it using the balance scale and ignoring the deficit part of the object. When a set of particles occupy certain amount of volume, like particles in an atom, there will be a mass deficit. Again there will be further deficit of mass, when a set of atoms form as a molecule like the molecule of oxygen with two atoms, in addition to the deficit in each of the individual atoms. This additional mass deficit will exist even if the atoms of same element were grouped together like two atoms of iron. As more and more molecules and atoms occupy more space, the combined deficit will further increase. Eventually, an object of one centimeter cube will have more percentage of deficit of mass compared to a single atom. Deficit of mass will increase as the object grows bigger in size. A cloud of gas or dust will have even more deficit in mass. It is similar to the decrease in resultant force as the angle between the individual forces increases. A ring kept around the earth will stay in place. Gravity of the ring will be zero hence it has zero measured mass or resistance. All of its mass becomes deficit because each pair of particles on the opposite side of the ring are placed at 180^{o} apart and their combined gravity becomes zero. Deficit of mass is not an indication to the amount of energy an object contains. Even though the total mass of a ring becomes deficit, it will have more energy than a cloud of dust made from same amount of material. An object will have a zero deficit of mass; means the combined mass of all particles will be equal to the mass of the object when that object collapses to a point size.

Conclusion

Mass of an object measured using the balance scale will defer depending upon the volume of the object. The same object will measure more gravity if all the matter inside the object was compressed to a smaller volume. Mass measured using the balance scale has no relation to the amount of atoms in that object. Different objects with different sizes and shapes made from same material like iron and measuring same amount of gravity in a balance scale will have different amount of atoms.

Along with the number of particles and the atoms they form within, volume of the object is also an important factor in determining the gravity of an object, which was completely ignored in the definition and the measurement of mass. Kilogram, a gravity based measurement of mass, has no relation to the number of atoms inside the object. The notion of molar mass of an ideal element containing a fixed number of atoms is a baseless proposition.

An object where the matter is occupied in more space will have more deficit in mass and if the same amount of matter occupies less space then that object will have less deficit and measures more gravity in the balance scale. Volume of the matter is the cause for the deficit in gravity [3].

Gravity between two spherical objects with each having one cubic meter in volume and separated at a distance of one meter will increase tremendously if those two objects were compressed to a point size objects. Incoherent relationship between mass, matter, gravity, size, shape and number of atoms of an object made the single fundamental force to get divided into different forms as gravity and strong nuclear force. Theory of everything or the unification of fundamental forces is nothing but discarding the ambiguity in the definition of mass.

If we call the mass as the resistance then that is not fixed for a given object. The only thing that is fixed in an object irrespective of its size is the number of particles within that object. It will be same in gas nebula and in neutron star formed from that nebula. We can't measure the number of particles using the balance scale.

References

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