A new atom model

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Abstract: This paper presents a new microscopic extension to the Coulomb's law --- a formula that describes how electron and nucleus interact each other within atom world. Based on this Coulomb's law extension, a new atom model is proposed. Compared with current electron-cloud model and with old Bohr model, this model is most like atom's real physical structure. Using this new model and basic integral calculation, the spectrum of hydrogen gas and the spectrum of ionized helium gas are successfully derived.
Key words: Energy levels, Microscopic, Coulomb's law extension, Balance point, Balance sphere.

Microscopic extension of Coulomb's law

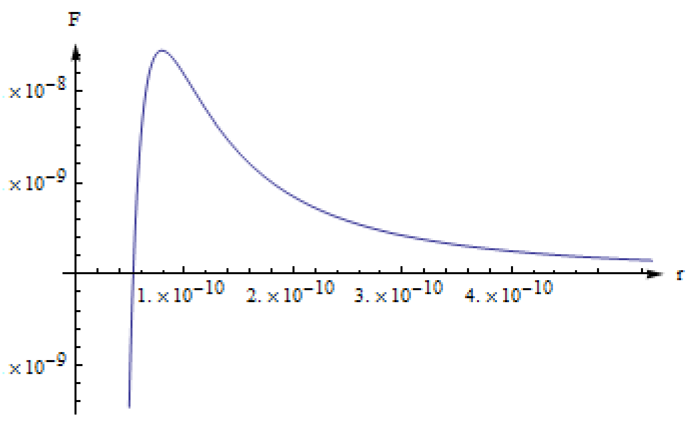
The well-known Coulomb's law $F = k\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$ is true in macroscopic view. However, it's not true in the scope of atom size and needs to be extended. The following is the extension:

The attractive force exerted on an electron by a proton:

$$F = \left(1 - \frac{R}{r}\right) k \frac{q_1 q_2}{r^2} \quad \text{----------} \ (1)$$

where R is Bohr radius (R = 5.2917721067×10^{-11}m), k is the Coulomb constant $\frac{1}{4\pi\varepsilon_0}$,

(k = 8.98755×10^{9} N m^2 C^{-2}) , and q_1=q_2=1.6021892 × 10^{-19}C (elementary charge).



Force exerted on an electron by a proton

It's well known that the attractive force WILL NOT keep growing infinitely when an electron approaches a proton. Actually, there is a balance point B (equal to Bohr radius), the electron is attracted by proton when the distance is greater than B, and repelled when the distance is less than B. At distance B, the electron will not subject to any force. We call B the balance point (balance sphere). The above figure shows the force.

This is the proton-electron interaction rule in atom world. Thanks to this rule, the atoms can be formed so that matter and the world are shaped.

Let us take hydrogen atom as an example:
Balance point B equals Bohr radius R ($R = 52.9pm$). Proton attracts electron when r > R, while proton repulses electron when r < R (nucleus forcefully repulses electrons when r < R).

In macroscopic view, the extension $\left(1-\frac{R}{r}\right)k\frac{q_1 q_2}{r^2}$ degrades into Coulomb law, because r >> R.

Equal opportunity electron configuration
An atom is said to be in the state of equal opportunity configuration if its electrons have equal opportunities to be attracted by the nucleus. For example, the electrons are taking equal and symmetrical geometric positions from the nucleus point of view.

In an atom with equal opportunity electron configuration, the force exerted on a single electron by the remaining of atom (nucleus and other electrons):

$$F = \frac{n_p}{n_e}\left(1-\frac{B}{r}\right)k\frac{q_1 q_2}{r^2} \quad \text{------ (2)}$$

where F is the total force exerted on the electron, n_p represents the number of protons in nucleus, n_e represents the number of electrons attached to the nucleus. B = $\frac{n_e}{n_p}$ R (repulsive force among electrons makes the balance sphere bigger). R is Bohr radius.
Based on formula (2), more electrons than the number of protons can be temporarily attracted and attached to an atom, which is the case $n_e > n_p$。 Formula (1) is the special case of formula (2) when $n_e = n_p = 1$.

How an atom is configured.
When a proton is approached by a nearby electron, the proton attracts electron to the balance point and the electron stays attached, and hence a hydrogen atom forms. The electron is static at a point in the spherical surface with radius R, it exhibits little thermal motion (drifting on the balanced sphere or radial vibration).
Hydrogen atom is the simplest case. For other big atom, such as Na, it is built with electrons placed around nucleus layer by layer. First 2 electrons stays in the balance sphere, the 3nd will not come because the repulsive force between the 2. After the first layer has 2 electrons in place and $\frac{n_p}{n_e}$ is still greater than 1, a new balance point (sphere) will exist outside the first layer (this can be shown by resolving a formula of 2 protons with one electron). So other electrons will fill in the second layer. Maximum 8 electrons will be in the second layer. Then, the 3th layer, until all electrons are placed, e.g. until $\frac{n_p}{n_e}$ =1.

The maximum number of electrons in layers is 2, 8, 18, 32, which is to make sure the electrons are in same sparsity in each layer to avoid repulsing each other too much. $2x2^n$ is proportional to the sphere area of each layer.

Hydrogen atom spectrum

Based on the equation (2) $F = \frac{n_P}{n_e}\left(1 - \frac{B}{r}\right) k \frac{q_1 q_2}{r^2}$, when one electron in place (in the balance point),

$\frac{n_p}{n_e} = 1$, B = R = 52.9177pm, the formula is F(r) =$\left(1 - \frac{R}{r}\right) k \frac{q_1 q_2}{r^2}$, we integrate it from B to infinity, the result should be the energy to move this electron from B to infinity (minus flag ignored):

$E_1 = \int_B^\infty \left(1 - \frac{R}{r}\right) k \frac{q_1 q_2}{r^2}\, dr$ = -13.6058eV

We can simply calculate the integration and get the result E_1 = -13.6058eV. This is the well-known first level energy of H atom.

When 2 electrons are temporarily attached, $n_e = 2, n_p = 1, B = \frac{n_e}{n_p} R = 2R,$

$E_2 = \int_B^\infty \frac{1}{2}\left(1 - \frac{2R}{r}\right) k \frac{q_1 q_2}{r^2}\, dr$ = -3.40145eV

Similarly, when 3 electrons are attached, B = 3R, we get

$E_3 = \int_B^\infty \frac{1}{3}\left(1 - \frac{3R}{r}\right) k \frac{q_1 q_2}{r^2}\, dr$ = -1.51176eV

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Following is a table calculated by the above integration which lists energy levels from E_1 to E_8

energy level	energy(eV)
1	-13.6058
2	-3.40145
3	-1.51176
4	-0.850362
5	-0.544232
6	-0.377939
7	-0.277669
8	-0.212591

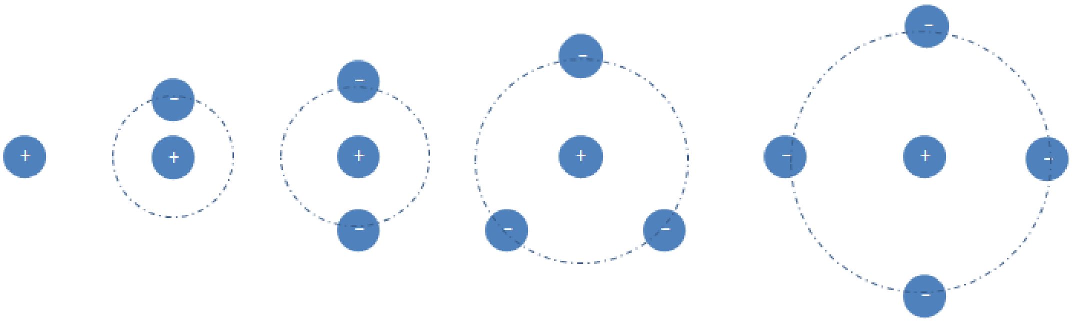
And the well known H spectrum table by subtracting the energy of two levels as well:

Transit from to	energy in eV	photon in nm
2 -> 1	10.2043	121.5003
3 -> 1	12.0940	102.5159
4 -> 1	12.7554	97.2003
5 -> 1	13.0616	94.9221
6 -> 1	13.2279	93.7288
3 -> 2	1.8897	656.1018
4 -> 2	2.5511	486.0013
5 -> 2	2.8572	433.9297
6 -> 2	3.0235	410.0636
4 -> 3	0.6614	1874.5765
5 -> 3	0.9675	1281.4488
6 -> 3	1.1338	1093.5030
5 -> 4	0.3061	4050.0109

6 -> 4	0.4724	2624.4071
6 -> 5	0.1663	7455.7020

What is the energy level, how does it exist? And how the electron energy transition happens?
When hydrogen gas is heated or applied some forms of energy from outside, a lot of atoms will be ionized and lose their electrons. The escaped electrons will drift away, and be attracted by other atoms and attached to them. As a result, the H0, H1, H2, H3…through H8 atoms will temporarily exist in the gas, which is referred to as being atoms in excited state. Each of H1, H2… through H8 atom exhibits a unique energy level (H0 excluded), as illustrated in following Figure.

Excited Hydrogen Gas, H0 – H4 illustrated, H5 and above not shown



H0 H0-ionized **H1** normal **H2** 2 electrons attached **H3** 3 electrons attached **H4** 4 electrons

There is unique energy level for a single H atom (corresponding to each of H1 through H8). H nucleus with one electron (H1) is in energy level 1(13.6eV), H2 with two electrons is in level 2 (3.4Ev), H3 with three electrons is in level 3 (1.51Ev), and so on. When electron jumps from a higher energy level position to a lower energy level position, the transition happens, and the redundant energy emits in the form of photon.

The transition falls into two categories---transition within a single atom and transition between two different atoms.

First category is transition within one single H atom--the electron(s) changes level within one atom. For example, in H2(as illustrated above), when one electron escapes, the other electron transits from level 2 to level 1, an approximate121.5nm wave-length photon will emit. In atom H3, when one electron escapes, the other 2 electrons will transit from level 3 to level 2, two 656.1nm photons will emit. In H4, if 2 electrons escape simultaneously, the other two will transit from level 4 to level 2, which emitting two 486nm photons.

The second category is transition between different atoms. In the first case mentioned above, most of the escaped electrons move to other atoms, and attracted by and attached to them. For example, electron escaped from H3 is attracted by H0 (ionized, no electron), which transits from level 3 to level 1 and emits one 102.5nm photon. In the meantime, other two electrons in H3 will transit from level 3 to level 2, emits two 656.1nm photons.

By the way, 656nm(level 3 to 2) photons must have spectrum line split, due to the fact that the 656nm spectrum is generated by three different electrons: one electron jumps from H3 to H1 (e.g. transits from level 3 to level 2), while two other electrons within H3 also transit from level 3 to level 2. Similarly, 121.5nm (level 2 to 1) photons must present slitting spectral lines, which are generated by 2 electrons: one jumps from H2 to H0 (transits from H2 to H1), and another electron within H2 also transits from H2 to H1. These line splits are hydrogen spectrum's fine structure. Different transition path should have very small energy difference.

With the above explanation, we know that single H atom can not emit multiple wave-length photons. The energy levels exist in the excited hydrogen gas (mass effect of atoms), rather than in each single hydrogen atom. This is also the reason that we must vaporize the matter to observe its full spectrum.

Helium spectrum (HeⅡ)

For atom helium, $n_p = 2(2 \text{ protons})$,

When 1 electron is attached to nucleus, the staying radius $B = \frac{n_e}{n_p} R = \frac{1}{2} R$, The extension

$F = \frac{n_p}{n_e}\left(1 - \frac{B}{r}\right) k \frac{q_1 q_2}{r^2}$ becomes $F = \frac{2}{1}\left(1 - \frac{R\,1/2}{r}\right) k \frac{q_1 q_2}{r^2}$,

When 2 electrons are attached, $F = \frac{2}{2}\left(1 - \frac{R\,2/2}{r}\right) k \frac{q_1 q_2}{r^2}$

When 3 electrons are attached, $F = \frac{2}{3}\left(1 - \frac{R\,3/2}{r}\right) k \frac{q_1 q_2}{r^2}$

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Simply to integrate these functions from B to infinity, we can get the helium energy levels:

level 1	-54.4232eV
level 2	-13.6058eV
level 3	-6.0470eV
level 4	-3.4014eV
level 5	-2.1769eV
level 6	-1.5118eV
level 7	-1.1107eV
level 8	-0.8504eV

And the spectrum lines as well:

Transit	2 -> 1	40.8174eV	30.3751nm
Transit	3 -> 1	48.3762eV	25.6290nm
Transit	4 -> 1	51.0217eV	24.3001nm
Transit	5 -> 1	52.2463eV	23.7305nm
Transit	6 -> 1	52.9114eV	23.4322nm
Transit	7 -> 1	53.3125eV	23.2559nm
Transit	3 -> 2	7.5588eV	164.0254nm

Transit	4 -> 2	10.2043eV	121.5003nm
Transit	5 -> 2	11.4289eV	108.4824nm
Transit	6 -> 2	12.0940eV	102.5159nm
Transit	7 -> 2	12.4951eV	99.2253nm
Transit	4 -> 3	2.6456eV	468.6441nm
Transit	5 -> 3	3.8701eV	320.3622nm
Transit	6 -> 3	4.5353eV	273.3757nm
Transit	7 -> 3	4.9363eV	251.1640nm
Transit	5 -> 4	1.2245eV	1012.5027nm
Transit	6 -> 4	1.8897eV	656.1018nm
Transit	7 -> 4	2.2908eV	541.2287nm
Transit	6 -> 5	0.6652eV	1863.9255nm
Transit	7 -> 5	1.0663eV	1162.7961nm
Transit	7 -> 6	0.4011eV	3091.2487nm

The integration result is exactly the spectrum data of HeⅡ.

Key points of this model

1) Electrons are statically located in positions around nucleus. It can have thermal movement (drifting on the balanced sphere or radial vibration).
2) Standalone electron does not have discrete energy levels--for example, the electrons in cyclotron.
3) Energy level exists in excited hydrogen gas (population effect of atom), not in a single hydrogen atom.

Final discussion and prospect

When the world seems too complicated to us, most probably we are interpreting it the wrong way. The Coulomb law extension and this atom model must be true and can be examined and verified by some well-designed physical experiments. It’s hoped that the experiments can be done in the very near future.

References

Nist database. physics.nist.gov/PhysRefData/Handbook/Tables

Thanks to this database for all the referenced spectrum data used in this paper.