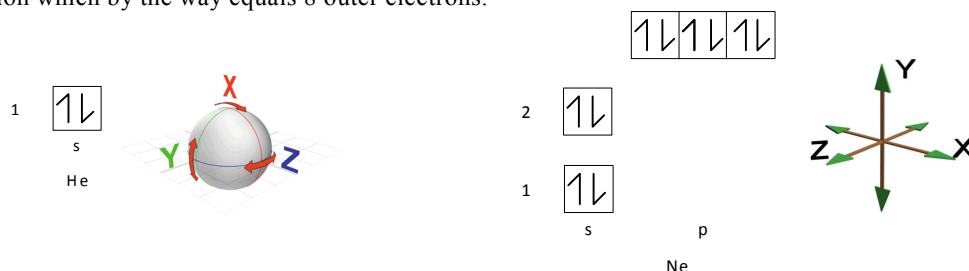


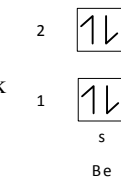
Impacts of Quantum Structure

The focus for both the Bohr-Rutherford model of the atom and the quantum model of the atom was atomic stability and reactivity. However, while the Bohr-Rutherford model only used electron filling and level capacity to account for these trends, the quantum model increased understanding by also addressing the impact of electron position and motion based on the measurable amount or quanta of energy possessed by electrons.

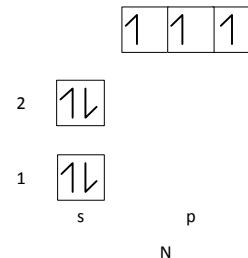
For example, the quantum model can more fully explain atomic stability. Both helium and neon are very stable atoms and from their orbital energy diagrams it becomes apparent (as with all noble gases) that this is due to their full orbitals. It was discovered that when electrons move, they actually generate magnetic forces in the direction of their motion. The quantum model predicts that full orbitals cancel the magnetic forces created by spinning electrons in all directions and this is the reason for stability. No energy is required to maintain the atomic structure. Therefore, with helium, the 1s is full and the two electrons are always spinning in opposing directions constantly cancelling the magnetic forces generated around the sphere of the atom. With neon, the s sub-levels are full and so is the outermost p sub-level which cancels magnetic forces generated by each electron moving in each direction of all 3 planes. None of the noble gases end in d or f so apparently having full s and p is enough for full stabilization which by the way equals 8 outer electrons.



Now, partial stability is possible and can account for some of the anomalies discovered earlier. Again, let's analyze some specific atoms. Consider the orbital energy diagrams for beryllium and nitrogen since these atoms both had unusual ionization energies and electron affinities. Beryllium's 2s is a sphere and you might think this would lead to full stability, but it does not because of the added repulsion of the second level so more force balancing is required to completely manage all the magnetic force generated by more than one level. Clearly, the full 2p in neon is enough to balance the extra magnetic force generated by 2 levels. However, there is some benefit to having a full 2s because beryllium is more stable than anticipated.

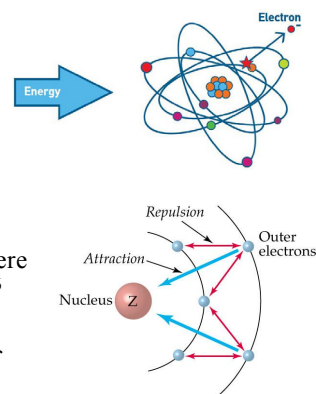


Now consider nitrogen which has an outer p-sub-level with 1 electron in each orientation. Remember electrons are moving near the speed of light and there is one electron in each plane which does generate outward magnetic forces, but the electrons reverse their direction so quickly, the forces are quickly counteracted by an equal force in the opposite direction. This makes nitrogen more stable than anticipated.

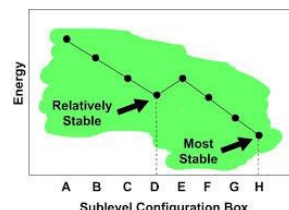


So partial stability is created by incomplete but balanced filling of the outermost orbitals. This means the magnetic forces are balanced in all directions due to rapid motion. This is the case for both beryllium and nitrogen. The same pattern repeats for any atom ending in s^1 or d^5 or f^7 and explains why these atoms are more stable than anticipated (the partial stability effect of s^1 is actually small since there really is little difference between s^1 and s^2 as both are spheres).

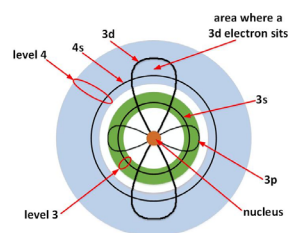
This information can be used to explain what appeared to be energy irregularities of atoms. However, before that can be accomplished, consider identifying the atom with the highest first ionization energy (I.E.) which means hardest or most energy required to remove the outermost electron. First identify the smallest atom; that is the atom with the fewest levels of electrons because this results in the smallest force of repulsion between levels. However, also look for the atom that has the greatest number of outermost electrons in that level as this will ensure that there is no change in the force of repulsion between levels but with more electrons there will be a higher number of protons which ensures the greatest force of attraction. Thus, $1s^2 2s^2 p^6$ has a higher I.E. than $1s^2 2s^2 p^6 3s^2$ since it has fewer electron levels which means it has a substantially lower force of repulsion (and this is even though it also has a slightly lower force of attraction). $1s^2 2s^2 p^4$ has a higher I.E. than $1s^2 2s^2 p^2$ since they both have the same number of electron levels (same force of repulsion) but the first atom has more electrons (really protons) in that level so it has a greater force of attraction. Finally, $1s^2 2s^2 p^6 3s^2 p^6 d^4 4s^2$ has a higher I.E. than $1s^2 2s^2 p^6 3s^2 p^6 4s^2$ since they both have the same force of repulsion (same number of electron levels—d is still part of the third level) but the first atom has more protons so it has a greater force of attraction.



Looking for the atom with the lowest first ionization energy works in the opposite manner. First, look for the largest atom which means it has the most levels of electrons since this results in the greatest force of repulsion between levels. However, also make sure the atom has least number of outermost electrons in that level to ensure that there is no change in the force of repulsion between levels but with fewer electrons there will be a smaller number of protons which ensures the weakest force of attraction. For example, $1s^2 2s^2 p^5$ has a lower I.E. than $1s^2 2s^2 p^6$ since they both have the same amount of force of repulsion (same number of electron levels) but the first atom has fewer electrons within the second level which means fewer protons so the force of attraction will be weaker for the same amount of repulsion. $1s^2 2s^2 p^6 3s^2 p^6 4s^1$ has a lower I.E. than $1s^2 2s^2 p^6 3s^2 p^4$ since it will be easier to remove an electron from the first atom because it has one more level of electrons even though it also has more protons and the extra level of electrons will increase the force of repulsion substantially. $1s^2 2s^2 p^6 3s^2 p^6 d^9 4s^2$ has a lower I.E. than $1s^2 2s^2 p^6 3s^2 p^6 d^{10} 4s^2 p^1$ because though they both have the same number of electron levels and hence the same force of repulsion, the first atom has fewer total electrons and so fewer protons and thus, a weaker force of attraction for the same amount of repulsion.



So far, this is typical and actually can be explained using the Bohr-Rutherford model of the atom. However, now consider partial stability revealed by the quantum model of the atom. This will only be a small factor and so only applies when comparing adjacent atoms as partially stable atoms are slightly more stable than anticipated. For example, $1s^2 2s^2 p^5$ has a higher I.E. than $1s^2 2s^2 p^3$ since they both have the same number of electron levels and; therefore, the same force of repulsion, but the first atom has more protons (indicated by number of electrons in that level) so it has a greater force of attraction. However, $1s^2 2s^2 p^3$ has a higher I.E. than $1s^2 2s^2 p^4$ even though this contradicts the predicted trend since they both have the same number of electron levels and; therefore the same force of repulsion and the second atom has more protons (indicated by number of electrons in that level) so it has a greater force of attraction. However, the first atom ends in p^3 which means this atom is partially stable making its ionization energy higher than expected; that is, balanced magnetic forces reduces the force of repulsion amongst electrons in that second level enough to make it harder to remove an electron than anticipated.



There is one more quantum effect to consider which is called **electron promotion**. Watch for changes in which an electron randomly moves for example from a s sub-level to a d sub-level. This actually requires no energy since it occurs when sub-levels overlap. The change is permanent since it results in a more stable configuration which results in a permanent energy loss. For example, the electronic configuration of chromium would be predicted to be $1s^2 2s^2 p^6 3s^2 p^6 d^4 4s^2$ based on the number of electrons but it is really $1s^2 2s^2 p^6 3s^2 p^6 d^5 4s^1$. The atom automatically promotes an electron from the higher energy level 4 such that the electron moves from 4s to 3d making $3d^4$ become $3d^5$. As a result, the predicted electronic configuration had a partially stable $4s^2$ (needs a full p to become fully stable due to repulsion of underlying levels) and an unstable $3d^4$ (due to unbalanced magnetic forces created by d^4). However, with the change, there is now a partially stable $4s^1$ (because s is half-full and there is no real orientation on a sphere so no real difference between s^2 and s^1) a partially stable half-full $3d^5$. This is the real electronic configuration for this atom and it is more stable than anticipated and affects trends.

element	(c) doc b	3d orbitals	4s
Sc 21 [Ar]	1	1	1
Ti 22 [Ar]	1	1	1
V 23 [Ar]	1	1	1
Cr 24 [Ar]	1	1	1
Mn 25 [Ar]	1	1	1
Fe 26 [Ar]	1	1	1