Chemistry - 101

Let’s continue the journey – day 4

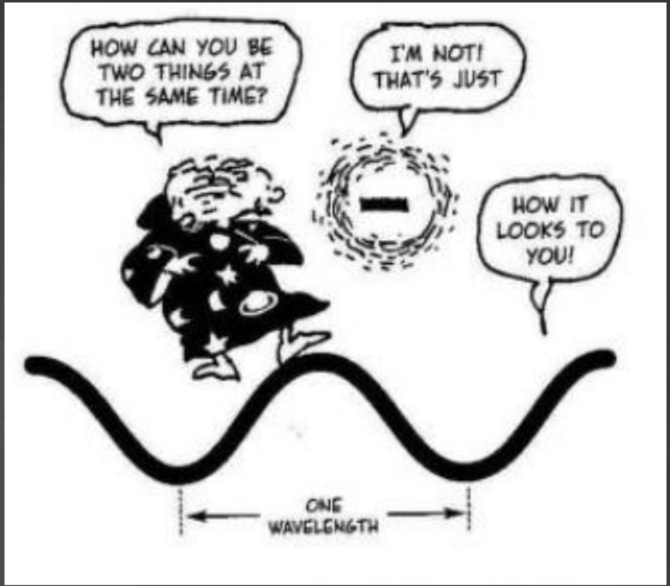
October 24th 2021

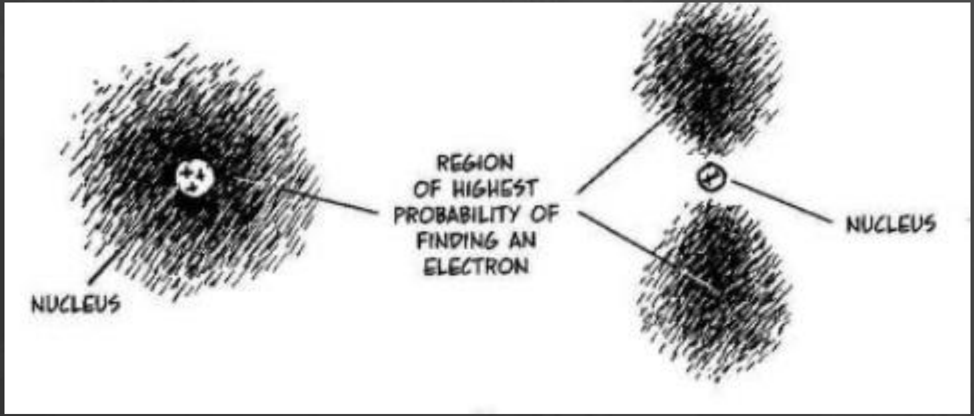
Electrons

What are electrons?
Where are electrons in the atom?
What role do they play in elemental properties and can they be predicted based on the electron configuration of the atoms?

Electrons obey the bizarre rules of **quantum mechanics**

An electron is both a particle like a marble (it has mass, charge, spin) and a wave (it has a wavelength) as a beam of light

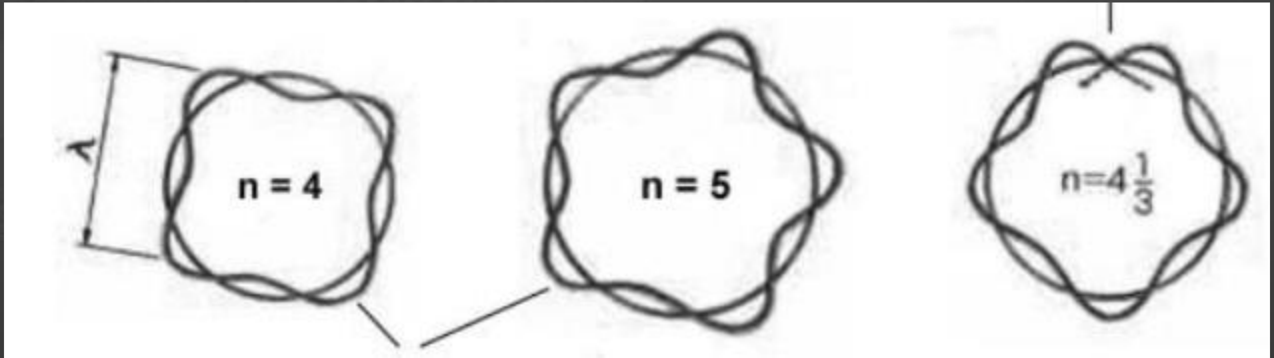




An electron inhabits a "probability cloud" with the densest parts of the cloud being where the electron is likeliest to "be" - if it can be said to be anywhere, which it can't exactly

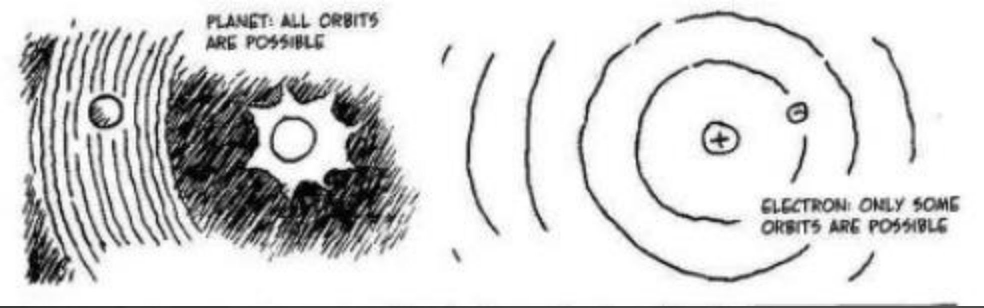
We can also visualize electron as a wave, beaming around the nucleus. Quantum mechanics tells us that the electron is always a "standing wave" that is it "goes around" the nucleus a whole number of wavelength, but never a fractional value.

Never

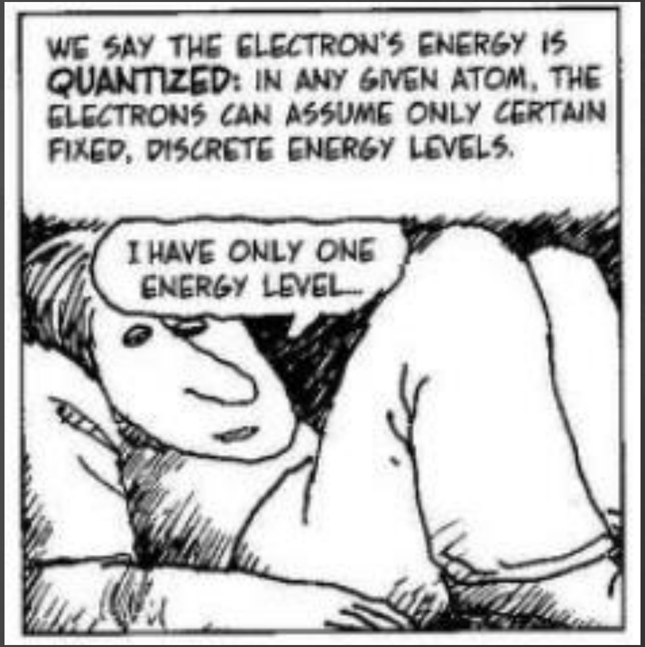


OK

The Bohr Model is a **planetary model** in which the negatively charged electrons orbit a small, positively charged nucleus similar to the planets orbiting the sun.

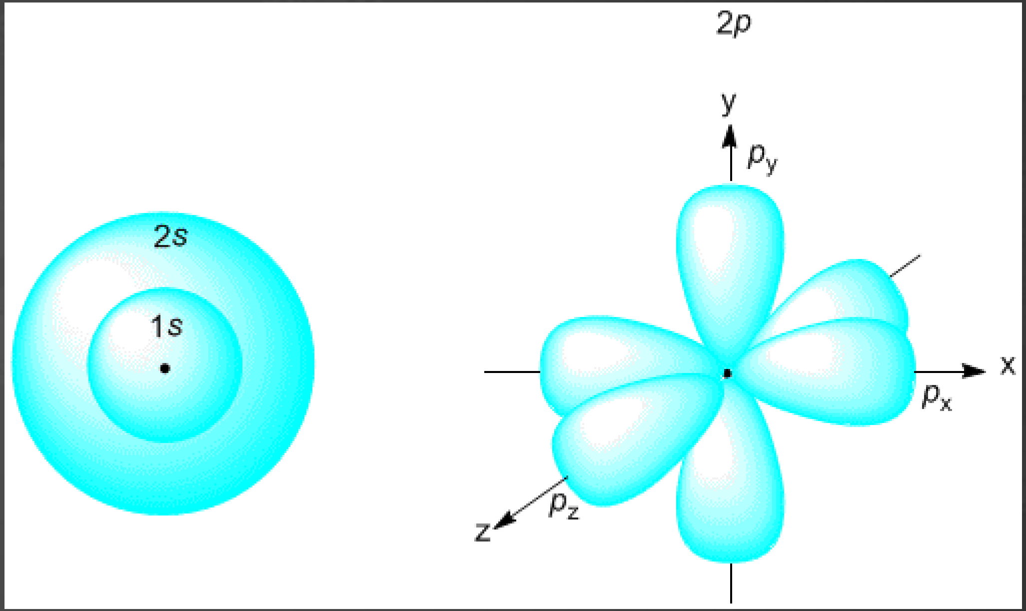


An electron must occupy an orbit around the nucleus that is consistent with the whole number of wavelength - n is a whole number.
The numbering starts from the nucleus.
We will call these orbits "shells". Each shell has a number starting from the nucleus. This number is called **principal quantum number**.

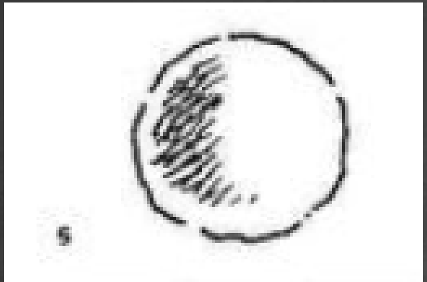


Electron as a wave - Schrödinger atomic model

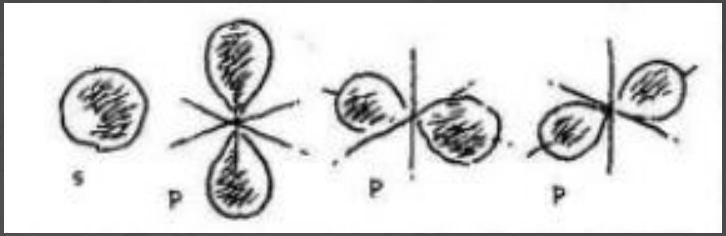
- Schrodinger described electron movement in space using mathematical models for a wave
- The model describes probability of finding an electron-wave in a certain point around the nucleus
- There are still orbitals in this model, they represent the space around a nucleus where an electron can be found with the probability of 95%
- All calculations were done for a single electron



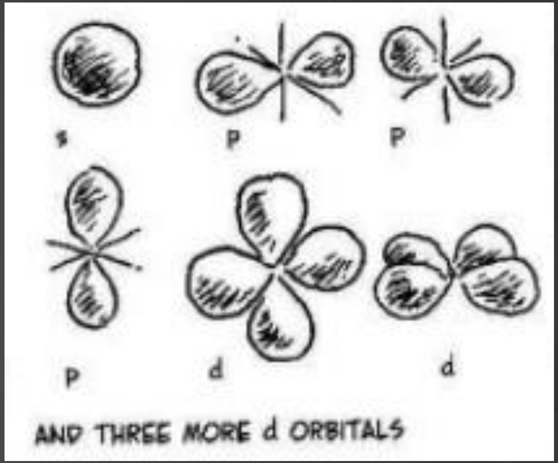
Shell 1



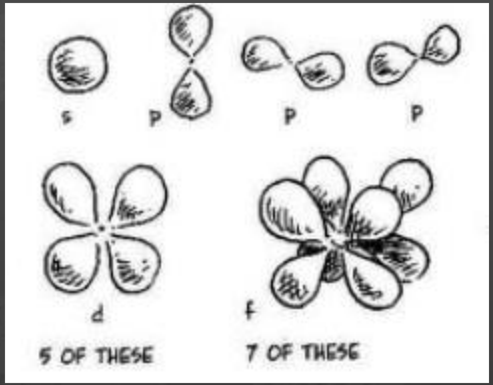
Shell 2

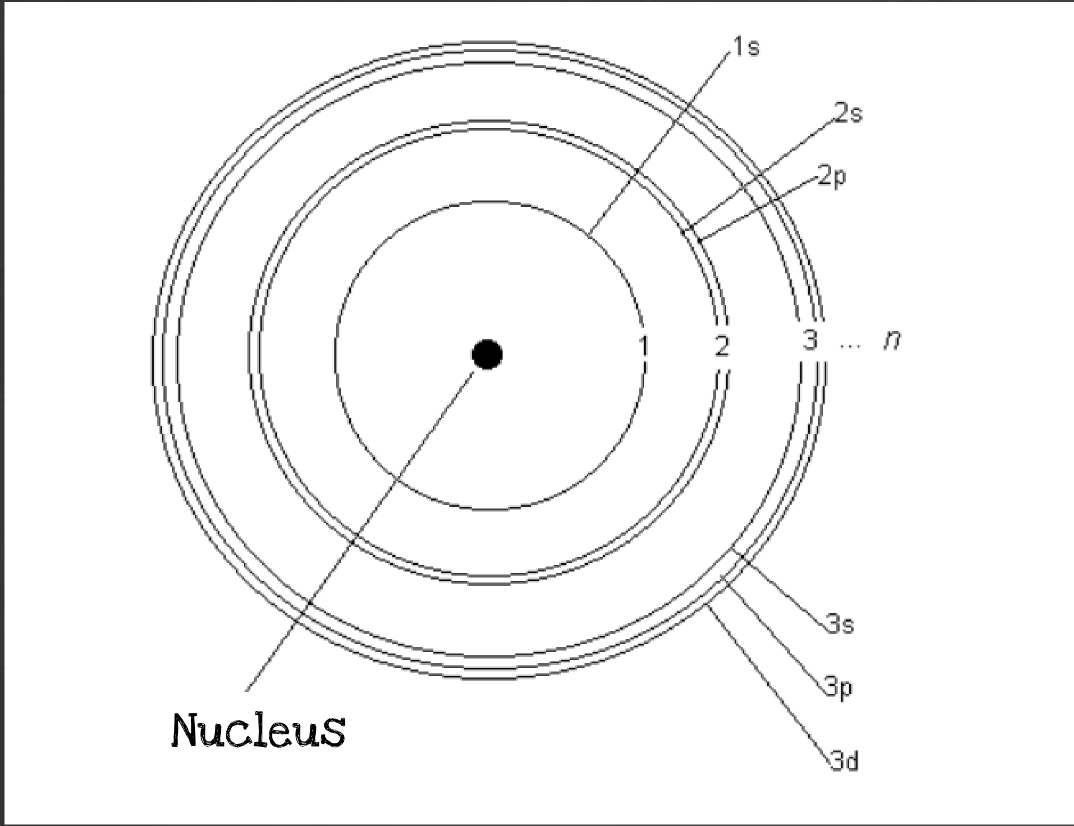


Shell 3



Shell 4





Shells become more complex when they get further away from nucleus. Starting with the 2nd shell they get "subshells".

You can think of these orbitals as energy sublevels.

Different sublevels are called s, p, d, and f. These subshells are made of orbitals and each orbital can hold **up to two electrons**

- The number of electrons is equal to the number of protons.
- Electrons inhabit the closest to the nucleus shells and orbitals.
- Each shell and each orbital can hold just a certain number of electrons.
- **The maximum number of electrons that each shell can have is $2n^2$**

Shells and Subshells

- The number of subshells within any level is equal n (the shell number)

Shell number (n)	Sub-shell
1	s
2	s, p
3	s, p, d
4	s, p, d, f

Sub-shell	Number of orbitals	Maximum number of electrons
s	1	2
p	3	6
d	5	10
f	7	14

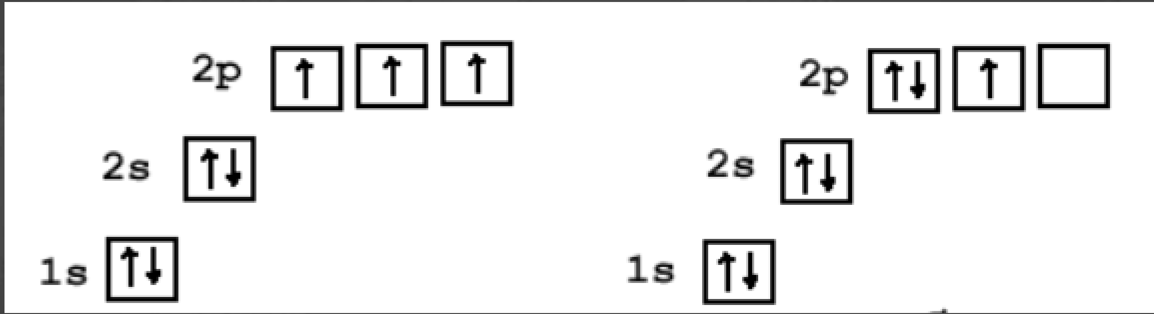
Rules of filling electrons' shells

1. Decide the total number of electrons to be placed (it should be equal to the number of protons, which is its atomic number)
2. Add electrons to each orbital starting with that of the lowest energy level and keeping in mind that we cannot place more than 2 electrons on each orbital
3. According to Hund's rule, all orbitals will be singly occupied before any is doubly occupied.

This will be an *atomic electron configuration*

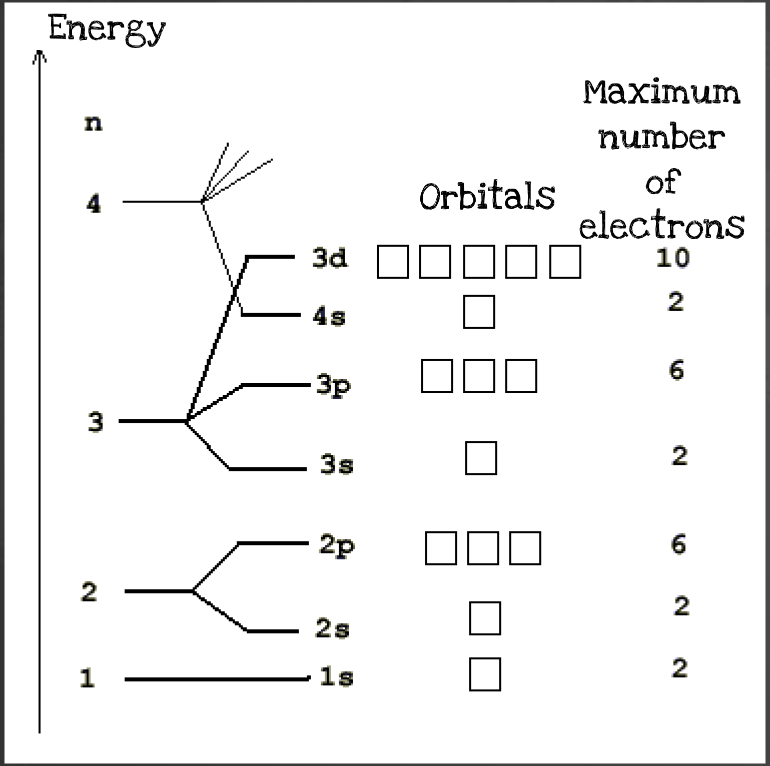
Orbital diagram

- Hund's rule states that: Every orbital in a sublevel is singly occupied before any orbital is doubly occupied. All of the electrons in singly occupied orbitals have the same spin (to maximize total spin).

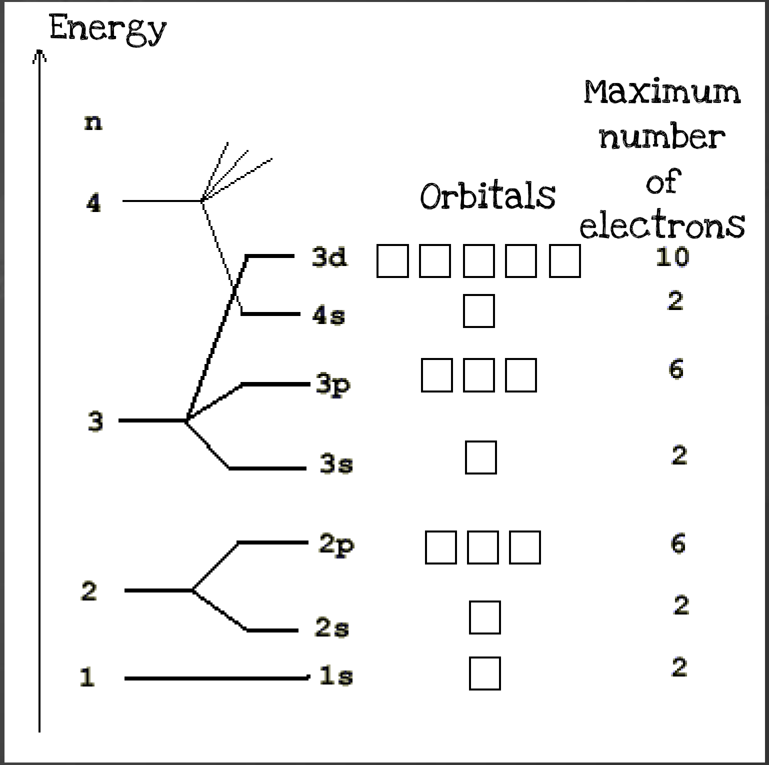


These are two versions of nitrogen electron orbital diagrams.
Which one is correct?

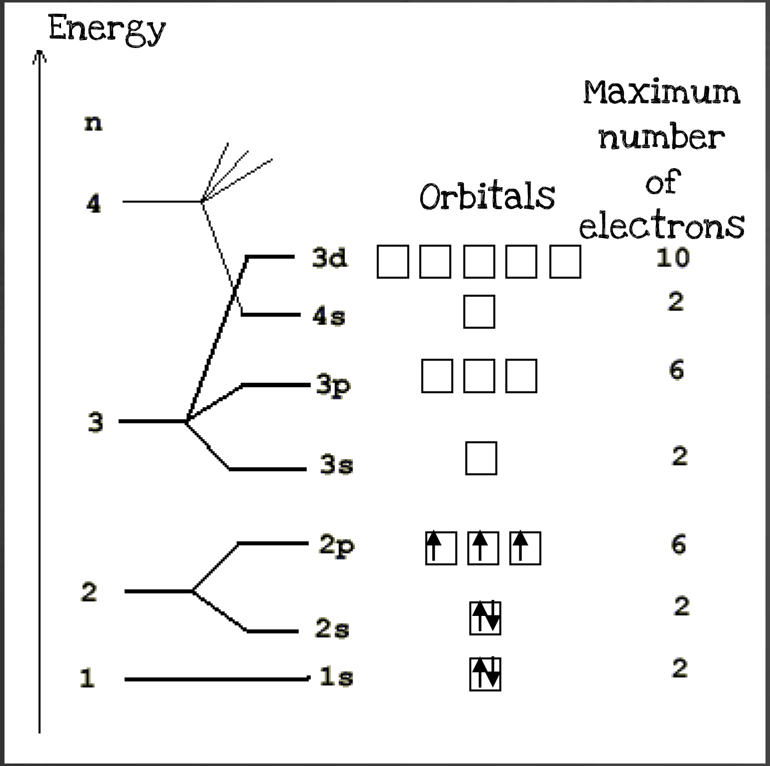
$_{7}N$


Energy
n
4
3
2
1
Orbitals
Maximum number of electrons
3d
4s
3p
3s
2p
2s
1s
10
2
6
2
6
2
2

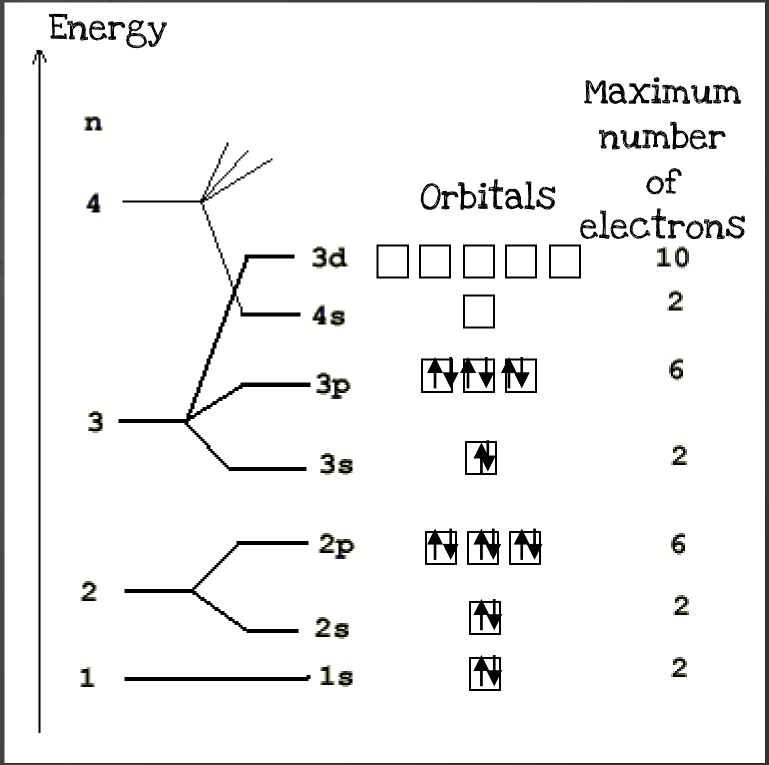
$_{18}Ar$


Energy
n
4
3
2
1
Orbitals
Maximum number of electrons
3d
4s
3p
3s
2p
2s
1s
10
2
6
2
6
2
2

$_{7}N$


Energy
n
4
3
2
1
Orbitals
Maximum number of electrons
3d 10
4s 2
3p 6
3s 2
2p 6
2s 2
1s 2

$_{18}Ar$


Energy
n
4
3
2
1
Orbitals
Maximum number of electrons
3d 10
4s 2
3p 6
3s 2
2p 6
2s 2
1s 2

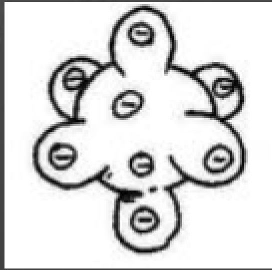
The outer most electrons, called **valence electrons**, account for most chemical reactions

E.g. in its interactions with other atoms nitrogen can accept 3 electrons to complete its outer shell.

A complete outer shell is energetically more advantageous than an incomplete one.

Take a look at the element with n=18

18. Argon, Ar, Ne$3s^2\,3p^6$

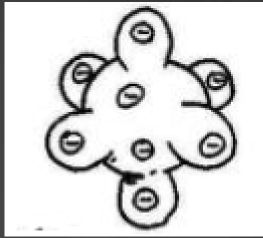


It has a complete outer shell and is called "non-active"

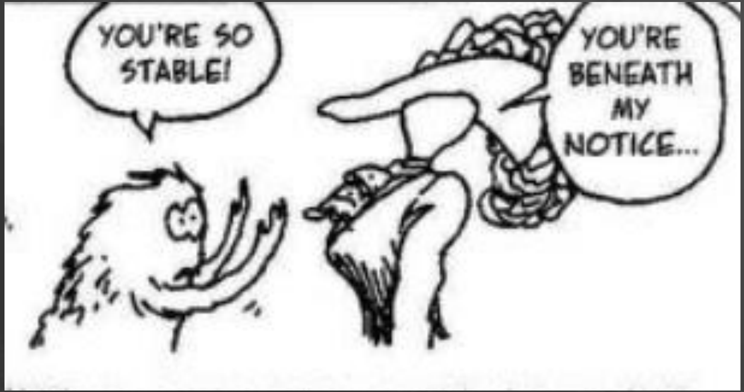
It is one of "noble" gases

Similarly, Neon has an outer shell completed with the 8 electrons:

10. Neon, Ne, $1s^2 2s^2 2p^6$

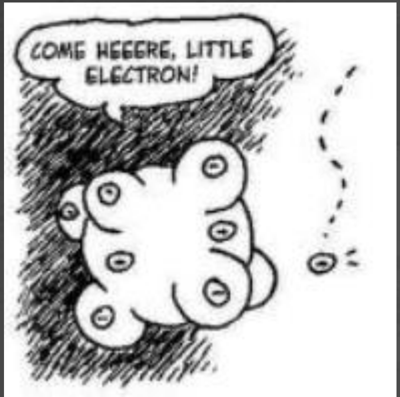


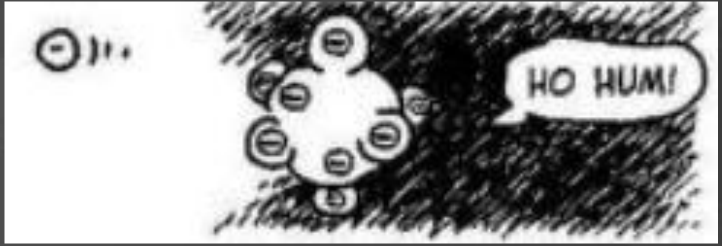
Just like real nobility, the noble gases are the envy of the common elements. Everyone wants that full complement of 8 outer electrons.



We call it the **<u>RULE OF EIGTH</u>**: at atom tends to pick up or give away just enough electrons to make eight in its outer shell - AN **<u>ELECTRON OCTET</u>**.

Electron donor and electron acceptor properties of atoms are related to the octet rule





The donors tend to achieve the octet by giving up the electrons from their outer shell and the electron acceptors tend to get octet by accepting the electrons to their outer shells

Donors are atoms that just start filling their outer shells and strong acceptors almost finished building their octets

Let's look at $_{11}Na$ and $_{9}F$:

F: $1s^2\underline{2s^22p^5}$
Na: $1s^22s^22p^6\underline{3s^1}$