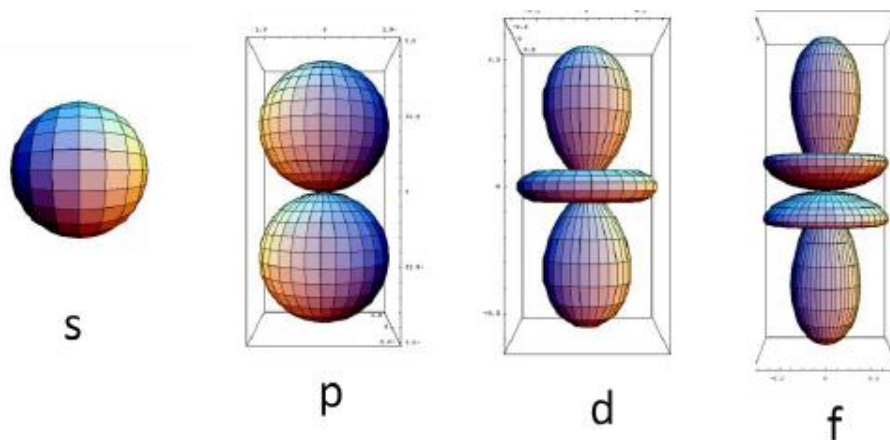


Homework 21

Electron orbitals.

We started discussing the structure of atoms. As we already know, atom consists of nucleus which includes positively charged protons and neutral particles – neutrons. The nucleus is surrounded by electron “clouds”. I deliberately not use the picture describing the electrons as negative particles orbiting the nucleus. The electron behavior cannot generally be described as this of a “solid” particle. In some experiments an electron behaves like a particle, in some experiments an electron behaves like a wave. The question “what is the electron?” is meaningless because it assumes that we are going to describe the electron in terms of something which is very well familiar to us through our everyday experience. But electron (or any particle, say, proton or neutron) is absolutely different from any object we can meet in everyday life. So we can just “project” the properties of electron to those belonging to different objects which are more familiar to us: particles and waves. We cannot use “regular” mechanics to describe the motion of electron. There is another theory which describes the behavior of microscopic particles. It is called “quantum mechanics”.

Wave nature of the electron does not allow us to locate it in space precisely, since a wave is an extended object and has no definite location. Instead, we can just describe the probability to meet the electron near certain point in space. Within this picture we can think of the electrons in an atom as of a “grey clouds” surrounding the nucleus. The clouds have different shape and the thicker is the “grayness” the higher is the probability to “meet” the electron. These clouds are called “atomic orbitals”. Electron orbitals in any atom of the periodic system at equilibrium conditions can be of the four shapes which are denoted by the characters: **s**, **p**, **d**, **f**. Historically, these notations came from the words: **s**harp, **p**rincipal, **d**iffusive, **f**undamental. These shapes are shown below:



Atomic orbitals.

If the electron cloud have spherical shape we will call this situation as “the electron occupies s-orbital”. There is a maximum number of electrons which occupy a certain orbital. For s-orbital this number is 2, for p-orbital it is 6, for d-orbital it is 10 and for f-orbital – 14. 2

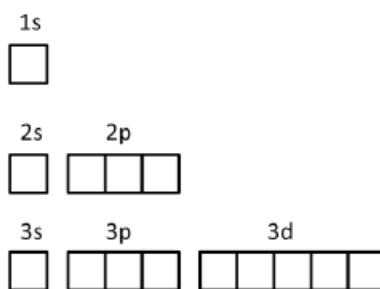
Electrons in an atom are attracted to the nucleus and repelled from each other, so their motion is very complicated. It was found that atomic orbitals group in shells. There are inner shells which are closer to the nucleus and outer shells which surround the inner shells. Each shell contains subshells. Each subshell contains orbitals of one type. The shells are denoted by numbers 1,2,3...The first shell contain only s-subshell; the second – s- and p-subshells, the third – s-,p- and d- subshells and the fourth – s-, p-, d- and f- subshells.

So, the first completed shell contain 2 electrons, the second – 8 electrons, the third – 18 electrons and the fourth – 32 electrons. As the outer subshell is complete, the electrons can “settle conveniently” which reduces potential energy of the atom. An atom with almost complete outer subshell “wants” to get the lacking electrons, while an atom with, for example, just one electron in the outer subshell would like to “get rid” of it. The orbital type and number of electron in the outer shell determines the chemical properties of the atom. If an atom with just one electron in the outer subshell, say, sodium (Na) atom will “meet” the atom with almost complete outer subshell, say, chlorine (Cl) it will gladly give his outer electron to chlorine, so the outer subshells of both atoms will became complete. But the atoms are charged now: sodium atom becomes a positive ion, since it is lacking one electron, while the chlorine atom is a negative atom since it has one extra electron. Then the ions electrically attract each other and form a two-atom molecule: NaCl. This is very well known substance – cooking salt. There are different ways to form a chemical bond – we will discuss them later.

There is a simple algorithm to determine electronic structure of an atom.

- First: we determine how many electrons are in the atom. The number of electrons is the atomic number z .
- Second: we start “filling” the shells and subshells keeping in mind the maximum number of electrons which can contain certain subshell.

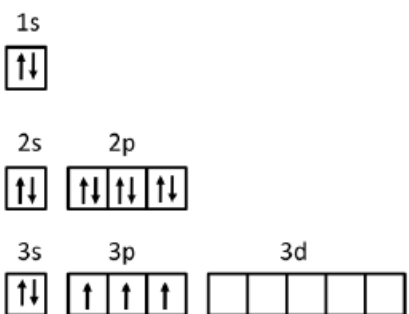
It is convenient to draw a block diagram:



Each cell can contain up to 2 electrons. We will denote these electrons as up and down arrows. For example take the atom of phosphorus (P). The atomic number of phosphorus is 15. So we have total 15 electrons to distribute among the cells of the diagram. We start from top, putting two electrons in each cell. This filling order of the cells is from top to bottom and from left to 3

right. This order is kept to the element 18 (Argon). After Ar this order is broken – but we will not discuss it at this time.

So we fill up first shell, s- and p- subshells of the second shell, s-subshell of the third shell. In the end we have 3 electrons left. We distribute them among empty cells of the p-subshell of the third shell. The result is shown below:



As long as the number of electrons is less than it is required to fill up a subshell, the electrons will spread among the empty cells of the subshell – they “feel more comfortable” this way.

A shorter form of writing the electronic structure is: $1s^2 2s^2 2p^6 3s^2 3p^3$. Here “big” numbers denote shell numbers, characters denote subshells, and superscripts denote number of electrons in the subshell.

Problem:

Write the electronic structure of sodium (Na), Fluorine (F) and Neon (Ne).