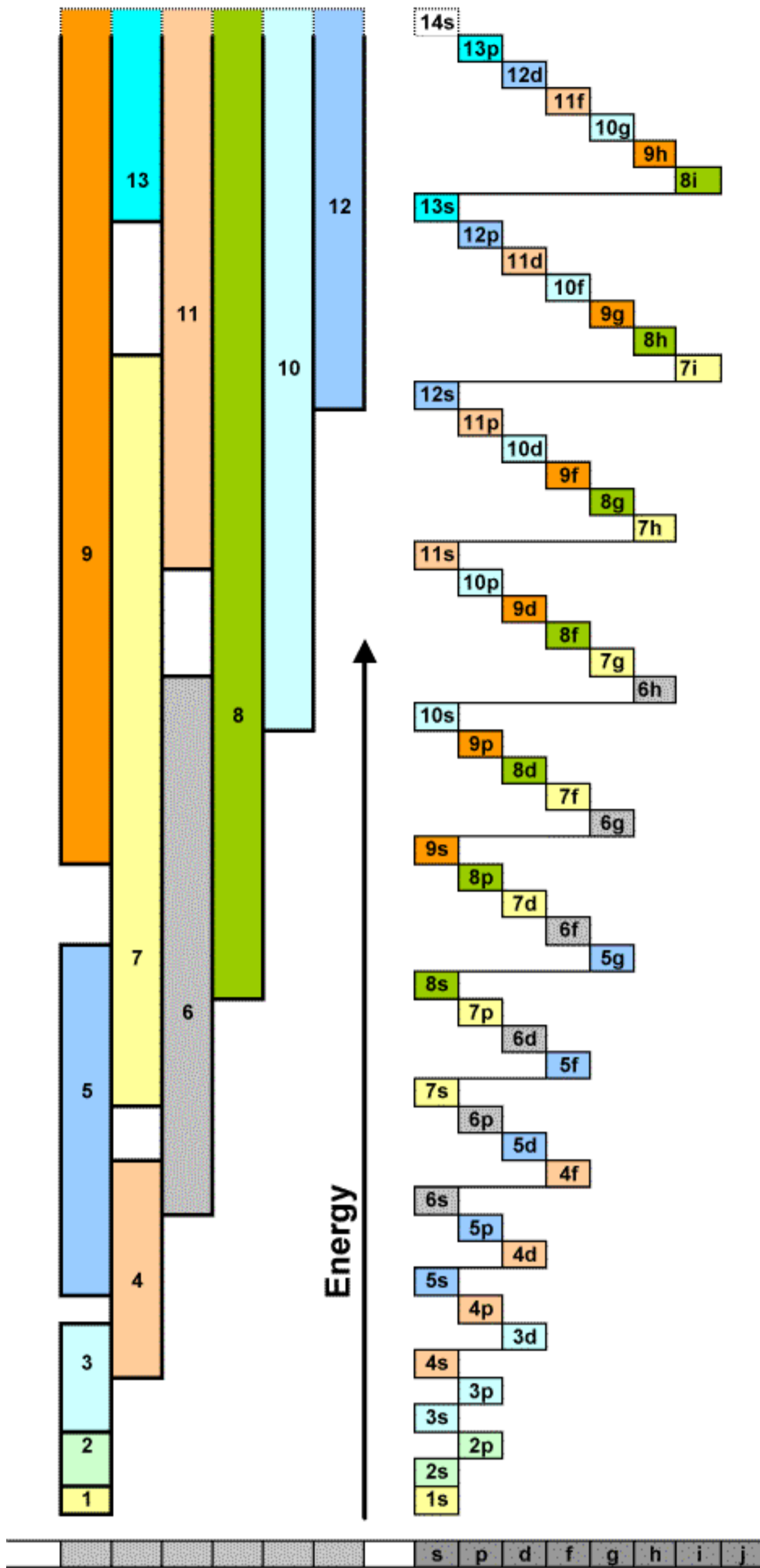


Approximate order of atomic orbital energy levels

Aufbau Principles

(from German Aufbauprinzip, "building-up principle"), rationalization of the distribution of electrons among energy levels in the ground (most stable) states of atoms. The principle, formulated by the Danish physicist Niels Bohr about 1920, is an application of the laws of quantum mechanics to the properties of electrons subject to the electric field created by the positive charge on the nucleus of an atom and the negative charge on other electrons that are bound to the nucleus. The building-up denoted by the name of the principle is a **hypothetical** process in which the electrons are regarded as entering, one by one, this electric field and assuming their most stable conditions with respect to it.



Aufbau principles determine the order in which atomic orbitals are filled as the atomic number is increased. For the hydrogen atom, the order of increasing orbital energy is given by $1s < 2s = 2p < 3s = 3p = 3d$, etc. The dependence of energy on n alone leads to extensive degeneracy, which is however removed for orbitals in many-electron atoms. Thus $2s$ lies below $2p$, as already observed in helium. Similarly, $3s$, $3p$ and $3d$ increase energy in that order, and so on. The $4s$ is lowered sufficiently that it becomes comparable to $3d$. The general ordering of atomic orbitals is summarized in the following scheme:

$$1s < 2s < 2p < 3s < 3p < 4s \sim 3d < 4p < 5s \sim 4d < 5p < 6s \sim 4f \sim 5d < 6p < 7s \sim 5f < 6d$$

and illustrated in Fig. 1 below. This provides enough orbitals to fill the ground states of all the atoms in the extended periodic table. For orbitals designated as comparable in energy, e.g., $4s \sim 3d$, the actual order depends which other orbitals are occupied. The sequence of orbitals pictured above increases in the order $n + \frac{1}{2}l$, except that $l = 4$ (rather than 3) is used for an f-orbital.

