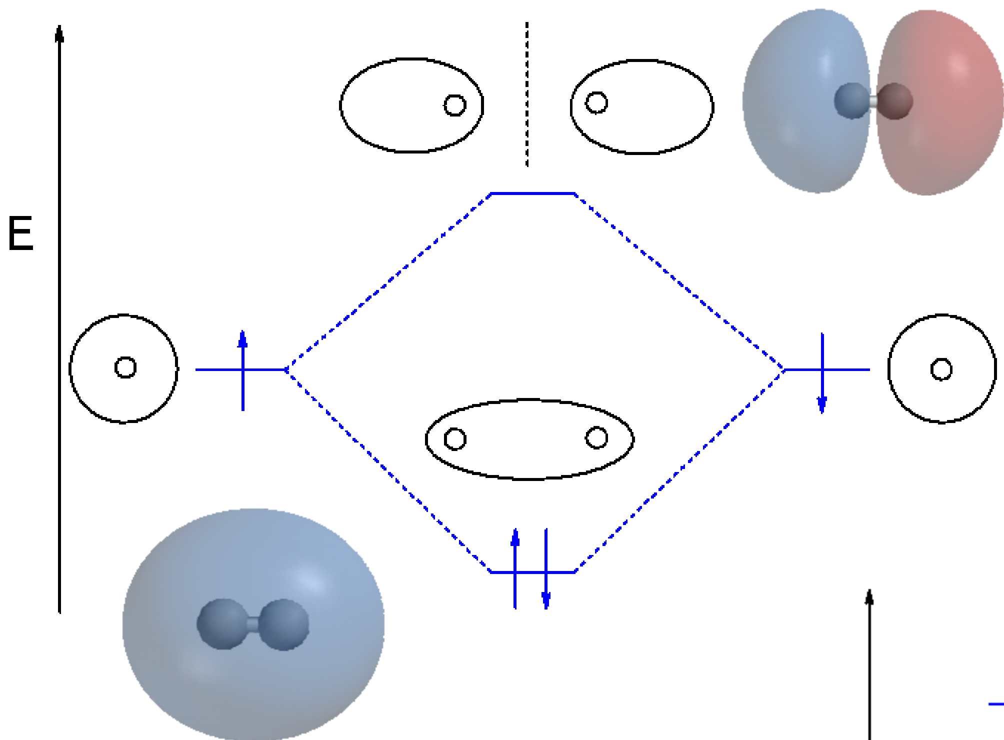
# Introduction to electronic band structure

It has been know for long time that different materials can conduct electricity. Macroscopically, those can also be formally subdivided into metals, semiconductors and insulators according to the degree of conductivity. We shall shed some light onto microscopic origins of difference in electron conductivity.

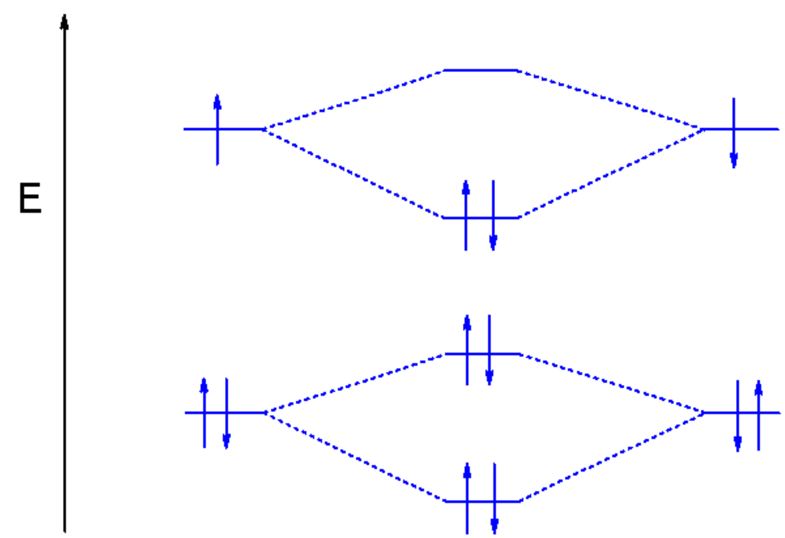
Now, we will try (as we always do in CM course) to connect macroscopically observed picture with microscopic properties.

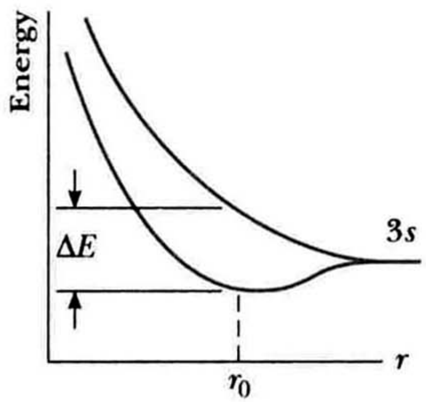
# Bohr model, electron spin and Hydrogen Molecular orbitals

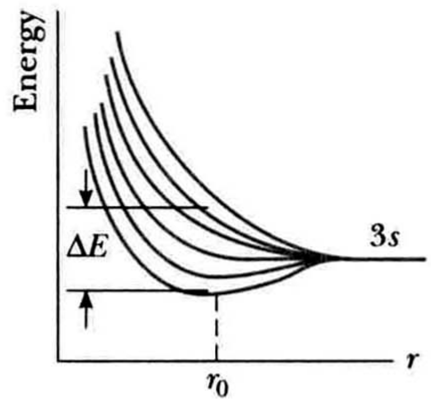


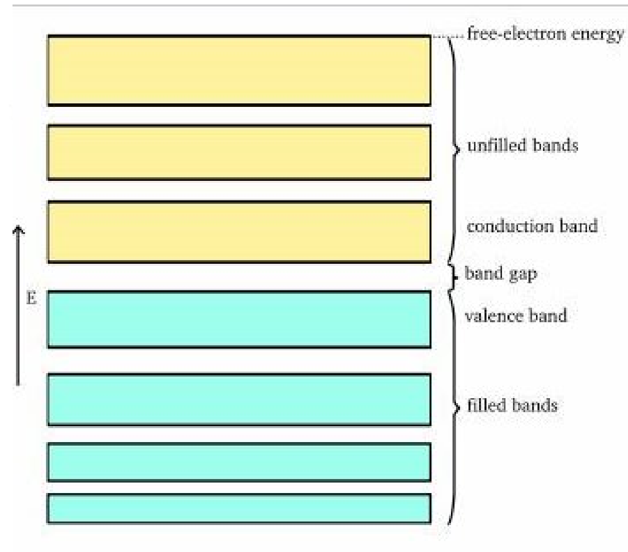

Electrons are spatially confined in bonding orbitals. What happens to the orbitals as we increase the number of atoms/molecules? We can see pattern emerging of energy levels behaviour.

dilithium

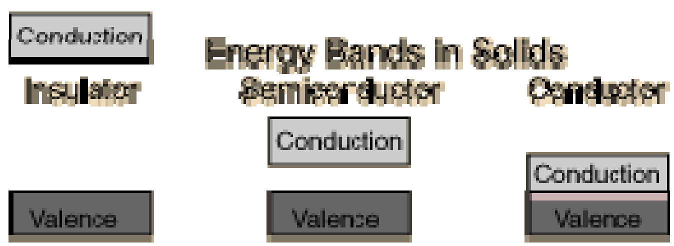




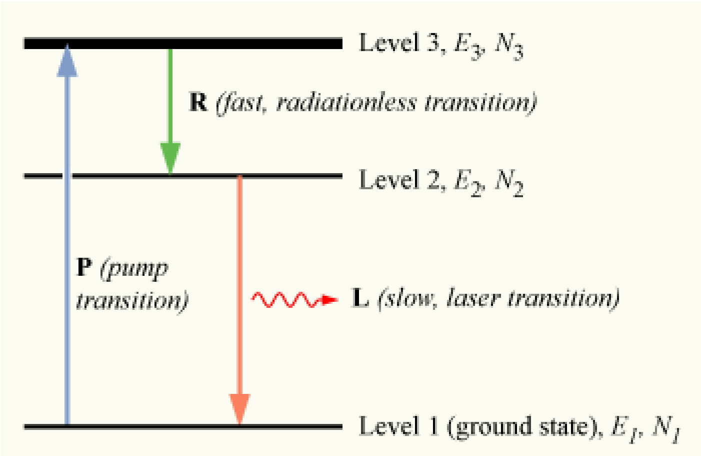

Thus we can see that as number of atoms in a system is increasing, the number of orbitals is also increasing and they form bands.

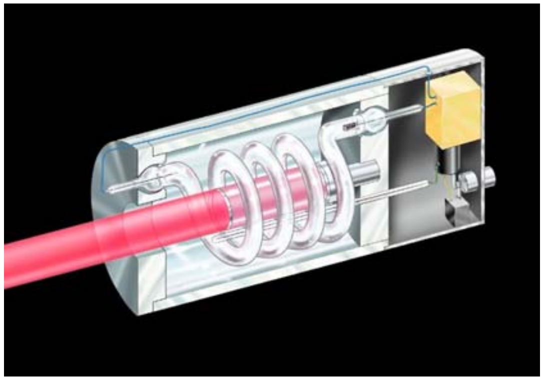



We shall only consider the highest occupied and the lowest unoccupied bands. The bottom filled band is called Valence band, while the top unfilled band is called Conduction band. Electrons found in Conduction band become spatially delocalised and are thus able to participate in electrical current flow.

## Insulator Energy Bands

Band theory of solids is quite powerful and, for example, enables one to make a conclusion about electronic conductivity of a material by how the material looks like! Glass that is transparent to visible light is clearly an insulator. The visible light photons do not have enough energy to bridge the band gap and get the electrons up to an available energy level in the conduction band. The visible properties of glass can also give some insight into the effects of "doping" on the properties of solids. A very small percentage of impurity atoms in the glass can give it color by providing specific available energy levels which absorb certain colors of visible light (e. g. stained glass).
Doping of insulators can dramatically change their optical properties, but is not enough to overcome the large band gap to make them good conductors of electricity. Still, they can be used for lasers (e. g. ruby, see below).



## Semiconductor Energy Bands

Semiconductors are effectively insulators at $T = 0$ K, but at higher temperatures a finite number of electrons can reach the conduction band and provide some current. In doped semiconductors, extra energy levels can be added. Doping can have drastic effect on their electrical conductivity and is the basis for solid state electronics.


# Concept of Electrons and Holes