

7.3: The Hückel Parameterization

In the most simplified embodiment of the above orbital-level model, the following additional approximations are introduced.

Approximation 1: Diagonal Component

The diagonal values $\langle \chi_\mu | \frac{-\hbar^2}{2m_e} \nabla^2 + V | \chi_\mu \rangle$, which are usually denoted α_μ , are taken to be equal to the energy of an electron in the atomic orbital χ_μ and, as such, are evaluated in terms of atomic ionization energies (IP's) and electron affinities (EA's):

$$\langle \chi_\mu | \frac{-\hbar^2}{2m_e} \nabla^2 + V | \chi_\mu \rangle = -IP_\mu,$$

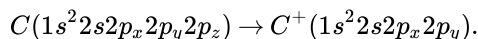
for atomic orbitals that are occupied in the atom, and

$$\langle \chi_\mu | \frac{-\hbar^2}{2m_e} \nabla^2 + V | \chi_\mu \rangle = -EA_\mu,$$

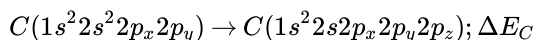
for atomic orbitals that are not occupied in the atom.

These approximations assume that contributions in V arising from coulombic attraction to nuclei other than the one on which χ_μ is located, and repulsions from the core, lone-pair, and valence electron clouds surrounding these other nuclei cancel to an extent that $\langle \chi_\mu | V | \chi_\mu \rangle$ contains only potentials from the atom on which χ_μ sits.

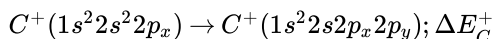
It should be noted that the IP's and EA's of valence-state orbitals are not identical to the experimentally measured IP's and EA's of the corresponding atom, but can be obtained from such information. For example, the 2p valence-state IP (VSIP) for a Carbon atom is the energy difference associated with the hypothetical process



If the energy differences for the "promotion" of C



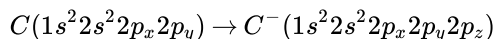
and for the promotion of C^+



are known, the desired VSIP is given by:

$$IP_{2p_z} = IP_C + \Delta E_C + -\Delta E_C^+.$$

The EA of the 2p orbital is obtained from the



energy gap, which means that $EA_{2p_z} = EA_C$. Some common IP's of valence 2p orbitals in eV are as follows: C (11.16), N (14.12), N^+ (28.71), O (17.70), O^+ (31.42), F^+ (37.28).

Approximation 2: Nearest Neighbors Approximation

The off-diagonal elements $\langle \chi_\nu | \frac{-\hbar^2}{2m_e} \nabla^2 + V | \chi_\mu \rangle$ are taken as zero if χ_μ and χ_ν belong to the same atom because the atomic orbitals are assumed to have been constructed to diagonalize the one-electron hamiltonian appropriate to an electron moving in that atom. They are set equal to a parameter denoted $\beta_{\mu,\nu}$ if χ_μ and χ_ν reside on neighboring atoms that are chemically bonded. If c_m and c_n reside on atoms that are not bonded neighbors, then the off-diagonal matrix element is set equal to zero.

Approximation 3: Off-Diagonal Component

The geometry dependence of the $\beta_{\mu,\nu}$ parameters is often approximated by assuming that $\beta_{\mu,\nu}$ is proportional to the overlap $S_{\mu,\nu}$ between the corresponding atomic orbitals:

$$\beta_{\mu,\nu} = \beta_{\mu,\nu}^o S_{\mu,\nu}.$$

Here $\beta_{\mu,\nu}^0$ is a constant (having energy units) characteristic of the bonding interaction between χ_μ and χ_ν ; its value is usually determined by forcing the molecular orbital energies obtained from such a qualitative orbital treatment to yield experimentally correct ionization potentials, bond dissociation energies, or electronic transition energies.

It is sometimes assumed that the overlap matrix S is the identity matrix. This means that overlap between the orbitals is neglected

The three approximations above form the basis of the so-called **Hückel model**. Its implementation requires knowledge of the atomic α_μ and $\beta_{\mu,\nu}^0$ values, which are eventually expressed in terms of experimental data, as well as a means of calculating the geometry dependence of the $\beta_{\mu,\nu}$'s (e.g., some method for computing overlap matrices $S_{\mu,\nu}$).

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