Chemical Bonding in Superconductivity and Superfluidity

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The diverse classes and numerous types of materials that exist in a superstate, i.e. attain superconductivity, or superfluidity, have a common type of chemical bonding. A delocalizable coordinate covalent bond type exists in these materials. Chemically such systems contain an electron pair donor orbital, and at least one degenerate, or equivalent multiple site, electron pair acceptor orbital. The electronic entropy of such formed coordinate covalent bonds is greater than the electronic entropies of the parent species. This is true when the orbital volume of the formed delocalized coordinate covalent bond is greater than the orbital volumes of the donor and acceptor orbitals of the parent species. In terms of the normalized Gibbs-Helmholtz equation the entropy change, ΔS_n , of the electron system then increases, and necessarily the free energy change, ΔG_n , decreases. The increase in ΔS_n must be sufficiently large so that ΔG_n and the chemical potential, μ, become negative. This leads to the formation of a boson state. The occupation number of the Bose-Einstein function is defined for negative values of μ. A system for which ΔG is negative in principle is capable of doing 'useful' work. Persistent electrical currents in superconductors, and superfluidity in He-4, are examples of 'useful' work. These are to be expected. A negative value of μ can only occur when an attractive potential in the system can, and does, exist. This 'attractive potential' is a manifestation of the formation of a coordinate covalent bond that exists in a superstate system. Classical bonding orbitals in MgB_2 can explain superconductivity in this material. The concept of coordinate covalent bonding is likewise applicable to high temperature superconductors such as cuprates. The superstate systems discussed satisfy these requirements. These principles should be useful in the rational design and synthesis of other high temperature superconductors.