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The Solid-State Hard-Ball Model and Young's Modulus

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Introduction

Tungsten is a ferri-type paramagnetic metal in that its paramagnetism obeys the Neél ferrimagnetic formula in fitting susceptibility data χ from low of 5K to high of 300K [1] and 1800K [2]. The magnetic susceptibility data of VI B elements, Cr, Mo, and W are increasing with temperature, quite different from that of V B elements, V, Nb, and Ta that have decreasing trend with temperature [3]. This means that the electronic configurations of elements play important role in their properties, e.g., Young's moduli of VI B are greater than that of V B. χ inverse is equal to the inverse of the diamagnetic χ Curie [1], plus the inverse of the paramagnetic χ Pauli, and plus the inverse of the diamagnetic χ lattice/phonon. The inverse of the diamagnetic χ_{Curie} has the form of T/C where T is in K, and the negative C is also in K; the inverse of the paramagnetic χ_{Pauli} is independent of T, and hence a constant; while the inverse of the diamagnetic $\chi_{lattice/phonon}$ has the form of $-b/(T-\theta_p)$ in which b and θ_p are respectively positive and negative parameters. According to the above discussion, for W χ increases with T, the inverse of χ decreases with T, therefore $\chi_{Curie\text{-}diamagnetic}$ dominates χ since it is a negative value; while for V B elements $\chi_{lattice/phonon}$ dominates χ. The diamagnetic χ_{Curie} comes from the demagnetizing field in the vacancy (0.32) of W in-between the hard ball arrangement (0.68) of atoms in the lattice [1]. The ratio of 0.32 to 0.68 is near the absolute value of that of atoms with the anti-direction (-0.985) to para-direction spins (1.985) by the calculation in the Neél ferrimagnetic formula. Thus one can say that VI B elements obey more likely the hard ball model than do VB elements. It also tells that those with high Young's modulus fit the hard ball model more than those with low Young's modulus and the phonon effect is greater with lower modulus than with higher modulus, and reversely in this case.

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