$$\langle x_1^2 \rangle_A = \langle \psi_A | x_1^2 | \psi_A \rangle = \frac{1}{2}\left[\langle x^2\rangle_a + \langle x^2\rangle_b\right] = \langle x_2^2\rangle_A$$

$$\psi_A = \frac{1}{\sqrt{2}}\left[\psi_a(x_1)\psi_b(x_2) - \psi_b(x_1)\psi_a(x_2)\right]$$

$$\langle x_1 x_2 \rangle_A = \langle x\rangle_a \langle x\rangle_b - |\langle x\rangle_{ab}|^2$$

$$\Rightarrow \langle \Delta x^2\rangle_A = \underbrace{\langle x^2\rangle_a + \langle x^2\rangle_b - 2\langle x\rangle_a\langle x\rangle_b}_{\langle \Delta x^2\rangle_c} + 2|\langle x\rangle_{ab}|^2$$

$$= \langle \Delta x^2\rangle_c + 2|\langle x\rangle_{ab}|^2$$

$$\langle \Delta x^2\rangle_S \leq \langle \Delta x^2\rangle_c \leq \langle \Delta x^2\rangle_A$$

$\langle \Delta x^2\rangle_S$: spin antisymmetric, spin-0 singlet $\left(\frac{\uparrow\downarrow - \downarrow\uparrow}{\sqrt{2}}\right)$

$\langle \Delta x^2\rangle_A$: spin symmetric, spin-1 triplet

Electric (coulomb) binding.

Metallic Binding

Ashcroft & Mermin figure 19.3

Covalent bond expands until there is appreciable electron density throughout interstitial regions in direct space, and band overlap in k-space.

⇒ Drude Model treat electrons like free a gas with Maxwell-Boltzmann statistics.

⇒ Sommerfeld Model. - free electron gas but with Fermi-Dirac statistics.

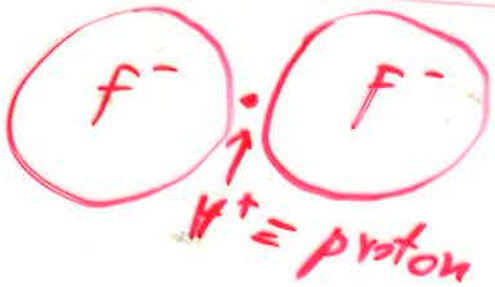
→ electron kinetic energy is lower than in an isolated atom.

Hydrogen Binding

special case

H^+ is <u>really</u> small

e.g. <u>DNA</u>



Elastic waves in Xtals → more in Ch 4 & 5.

In general, very complicated.

Even for cubic system, only special directions (1,0,0) & (1,1,0), (1,1,1), have energy propagation $\vec{k}$ along (longitudinal[1]) & perpendicular (transverse[2]) to particle motion.

↑ polarizations