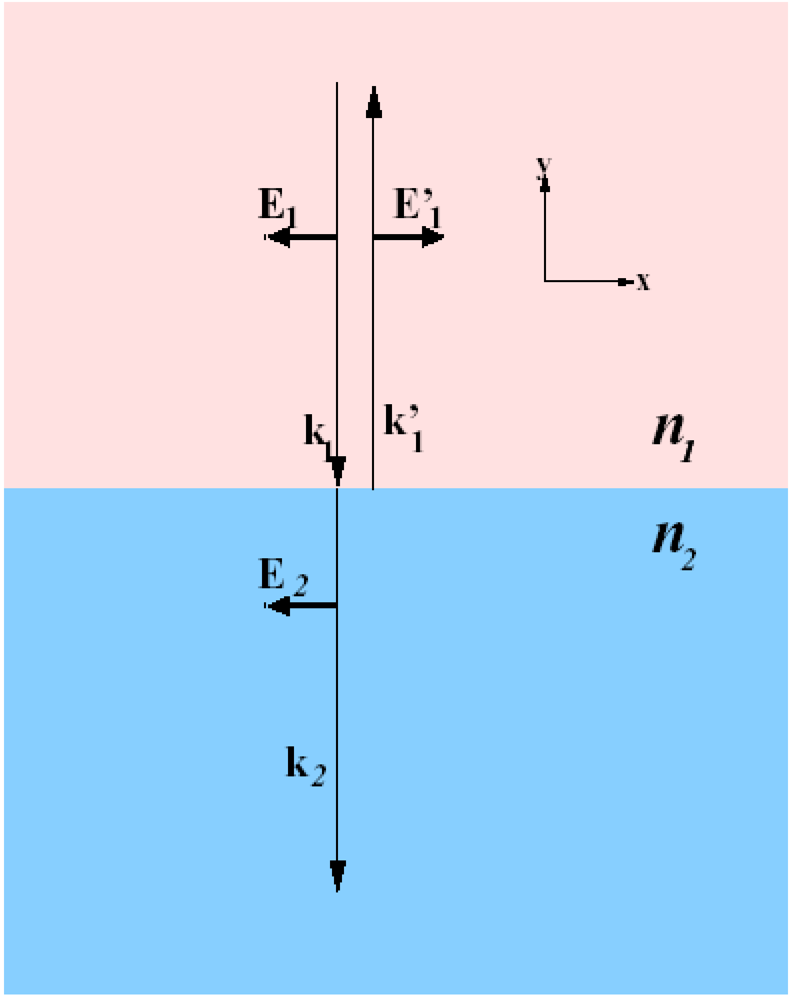
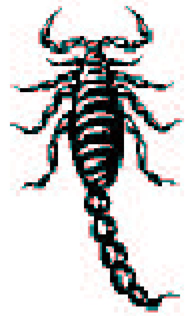
Announcements

1. Third exam – may turn in reworked exams by Wednesday. Additional presentations???
2. Slight change in syllabus
3. Remember to bring your evaluation pin #'s and Thinkpad's to lab this week.
4. Today's topics – atomic, molecular, and solid state physics


E1
E'1
y
x
k1
k'1
n1
n2
E 2
k 2



29	4/21/03	Materials physics	42 & 43	42.4,32,43.3,9	4/23/03
30	4/23/03	Nuclear Physics	44.1-44.8	44.14,25,32,44	4/25/03
31	4/25/03	Nuclear processes	45.1-45.7	45.5,6,16,19	4/28/03
32	4/28/03	Nuclear processes	45.1-45.7	45.22,25,28	4/30/03
	4/30/03	Review			
	5/6/03	Final Exam (2 PM)			

The physics of atoms –

Features are described by solutions to the matter wave equation – Schrödinger equation:

$$-i\hbar \frac{\partial}{\partial t}\Psi(\mathbf{r},t) = \left[-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial \mathbf{r}^2} + V(\mathbf{r})\right]\Psi(\mathbf{r},t)$$

"reduced" mass of electron and proton

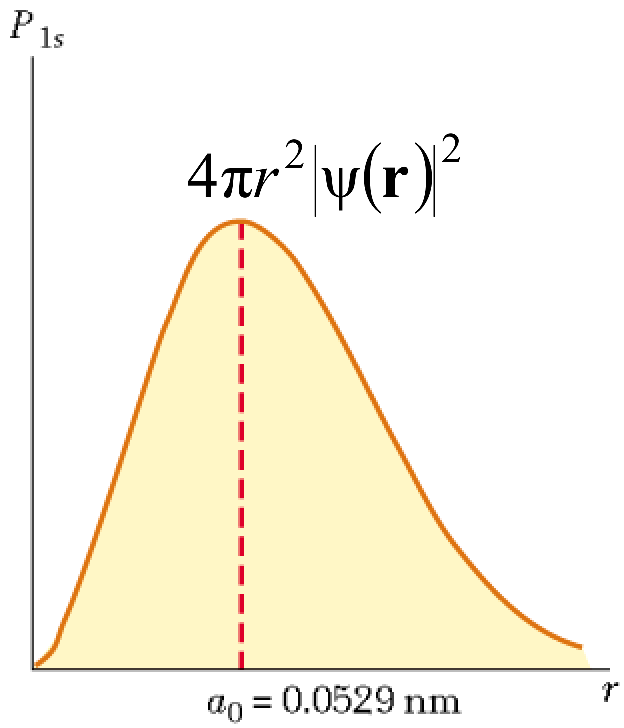
$$-\frac{Ze^2}{4\pi\varepsilon_0 r}$$

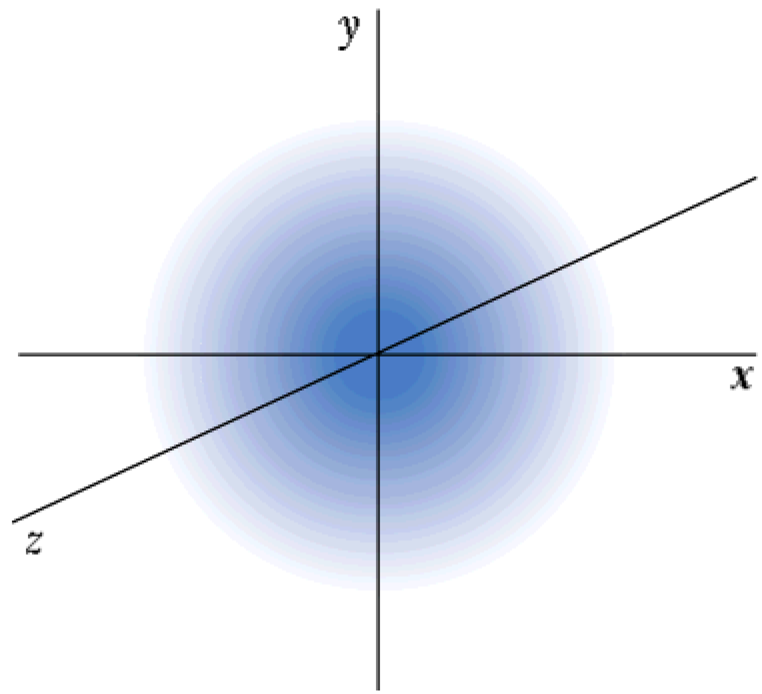
Stationary-state wavefunctions: $\Psi(\mathbf{r},t) = \psi(\mathbf{r})e^{-iEt/\hbar}$

Solutions: $E_n = -\frac{Z^2e^2}{8\pi\varepsilon_0 a_0}\frac{1}{n^2} = -13.6\frac{Z^2}{n^2}\text{ eV}$

$$a_0 = \frac{4\pi\varepsilon_0\hbar^2}{me^2} = 0.0529\text{ nm}$$

Form of probability density for ground state (n = 1)



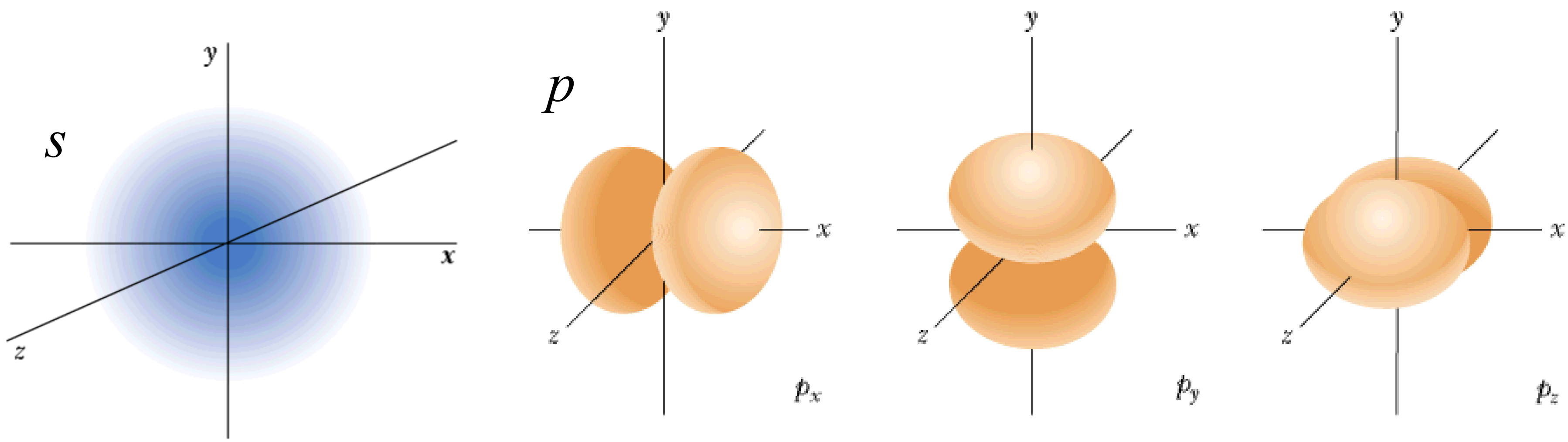


Angular degrees of freedom

-- since the force between the electron and nucleus depends only on distance and not on angle, angular momentum **L ≡ r x p** is conserved. Quantum numbers associated with angular momentum: $\mathbf{L}^2 = \hbar^2 \ell(\ell+1)$ $\quad\quad \ell = 0,1,2,\ldots.(n-1)$

$L_z = \hbar m$ $\quad\quad -\ell \leq m \leq \ell$ total of $2\ell+1$ states

Notation: $\ell = 0 \Rightarrow s, \quad 1 \Rightarrow p, \quad 2 \Rightarrow d$



Summary of results for H-atom:

$$E_n = -13.6\frac{Z^2}{n^2}\,\text{eV}$$

Balmer series

spectra

degeneracy associated with each n: $2n^2$

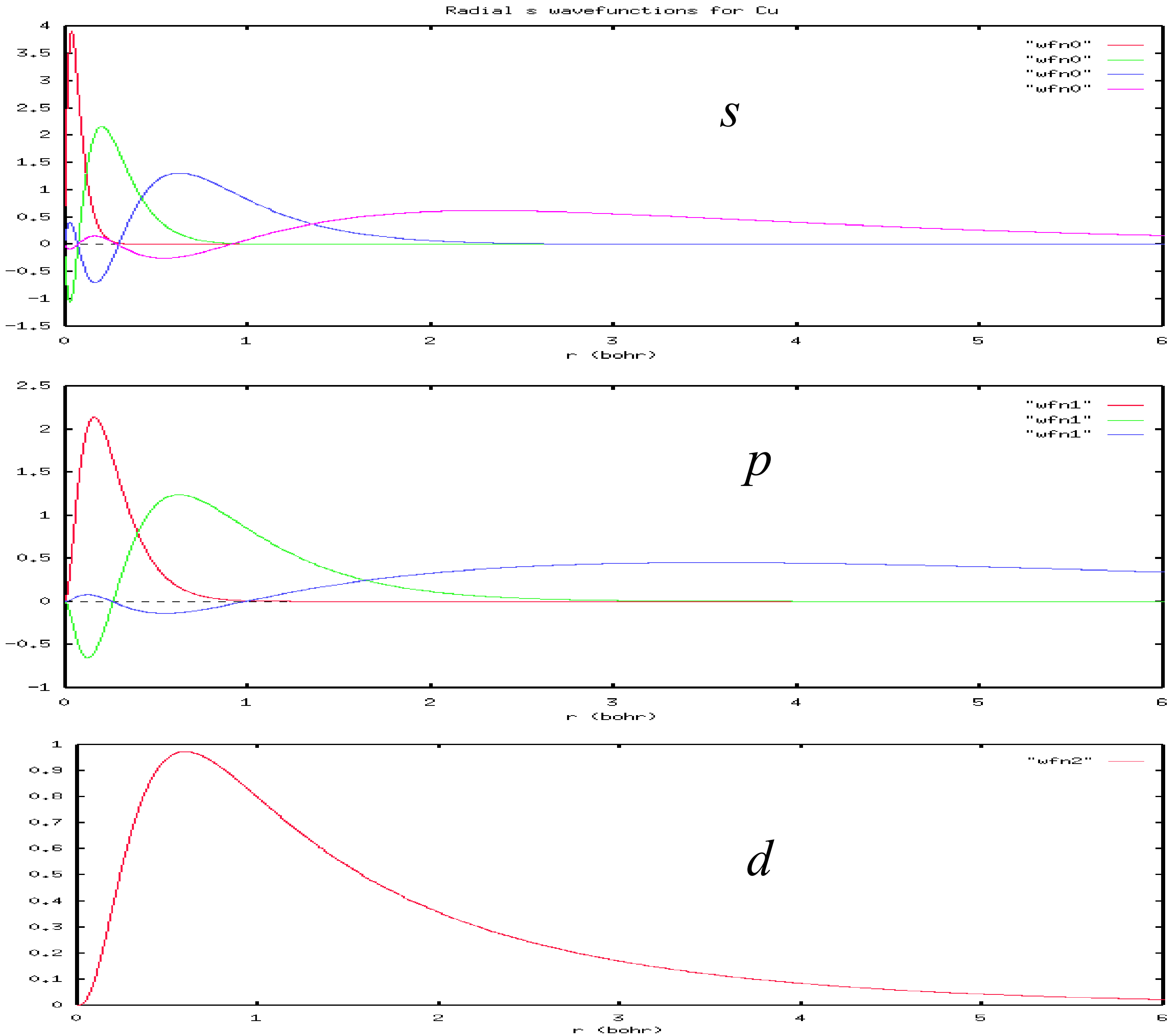
Atomic states of atoms throughout periodic table:

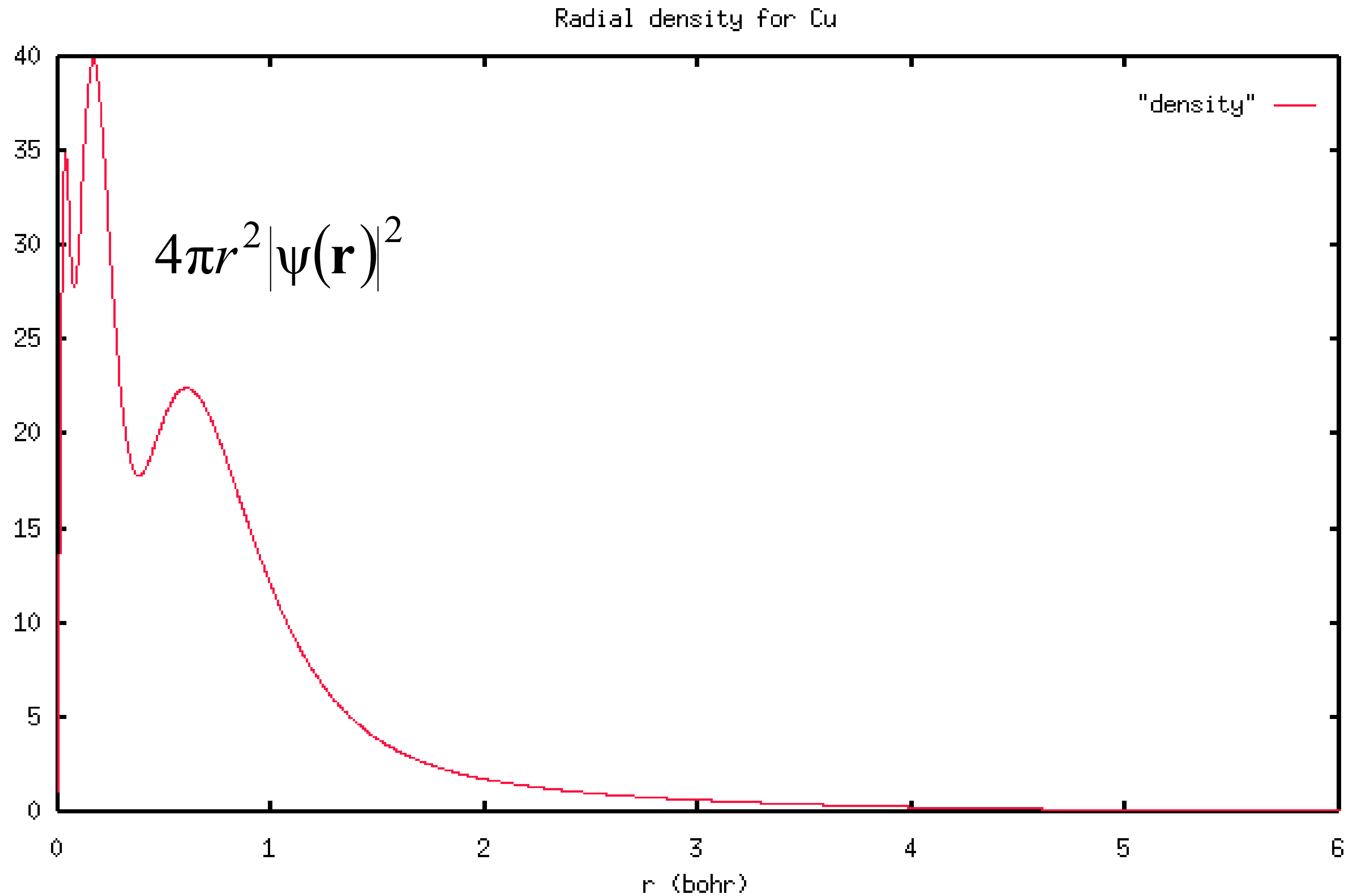
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 As	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac															

$$E\psi(\mathbf{r}) = \left[-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial \mathbf{r}^2} + V(\mathbf{r}) \right]\psi(\mathbf{r})$$

effective potential for an electron in atom

Example: Cu (Z=29) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$




Radial density for Cu
"density"
$4\pi r^2|\psi(\mathbf{r})|^2$
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
r (bohr)

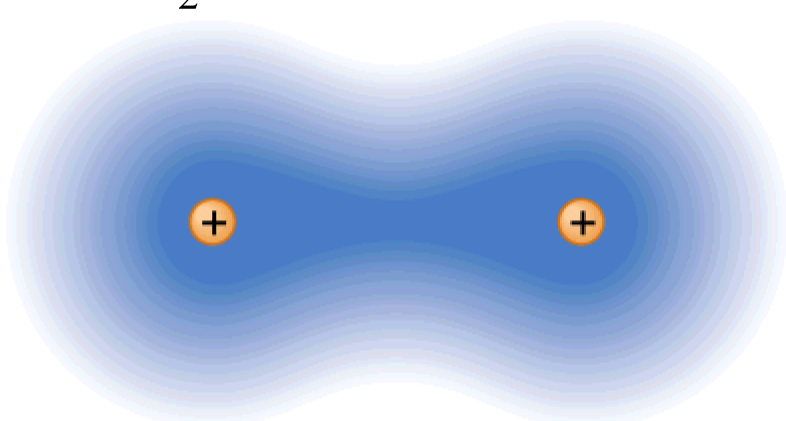
Physics of molecules and solids

$$E\psi(\mathbf{r}) = \left[-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial \mathbf{r}^2} + V(\mathbf{r}) \right]\psi(\mathbf{r})$$

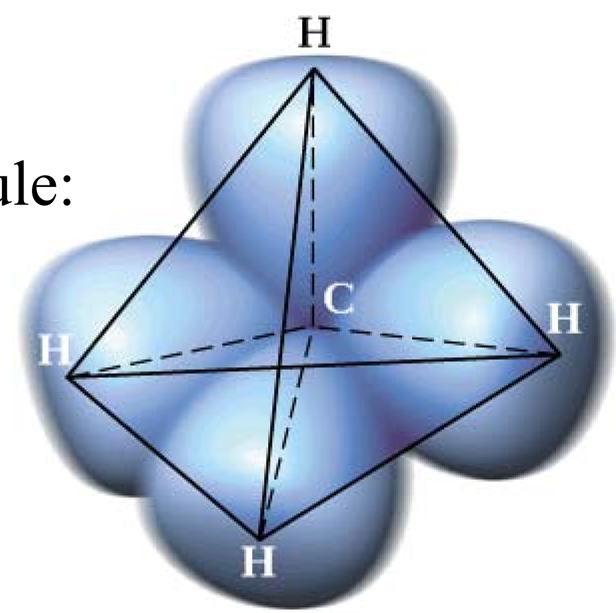
effective potential for electron in molecule or solid

Example: electron density associated with

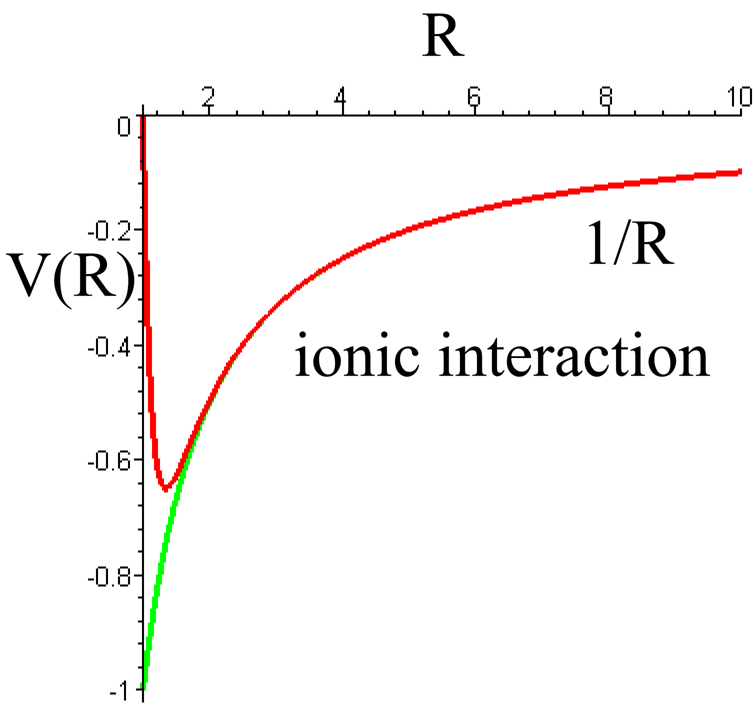
H_2 molecule:

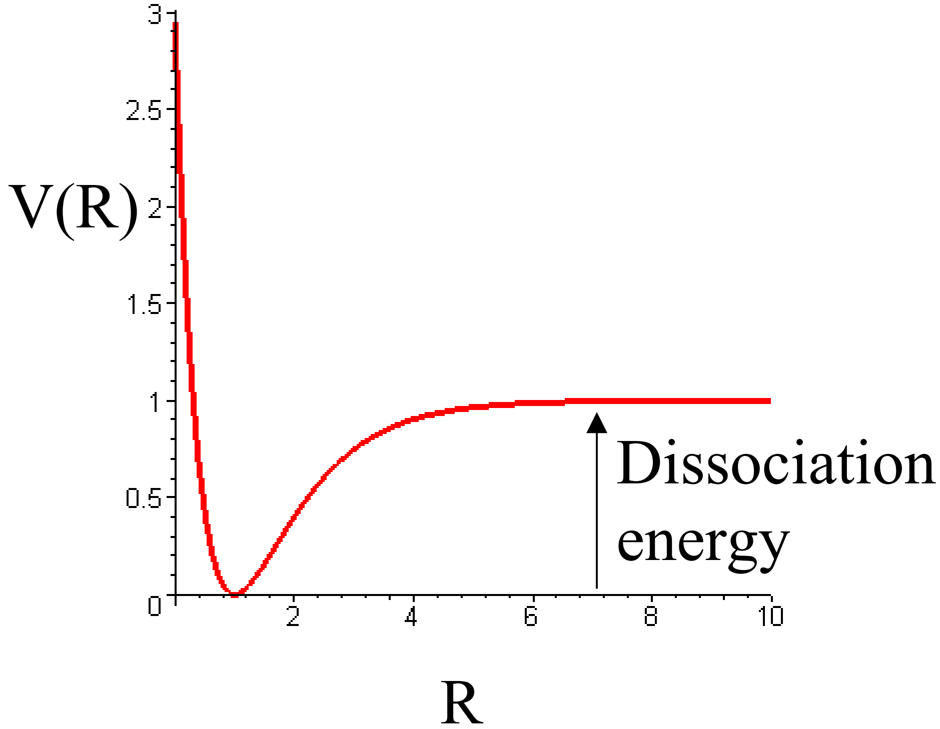


CH_4 molecule:



Molecular binding of nuclei due to electron “glue”:



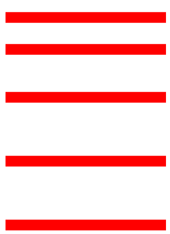


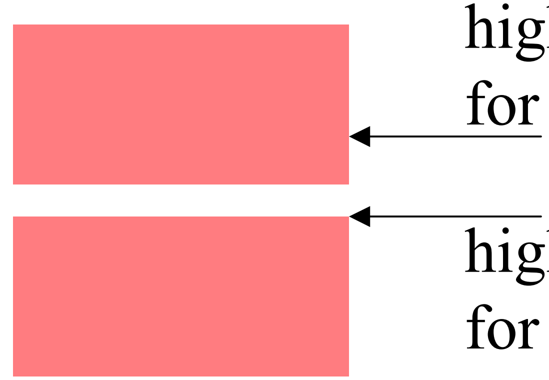
Physics of solids

$$E\psi(\mathbf{r}) = \left[-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial \mathbf{r}^2} + V(\mathbf{r})\right]\psi(\mathbf{r})$$

effective potential for electron in molecule or solid

Energy spectrum of atom or molecule :



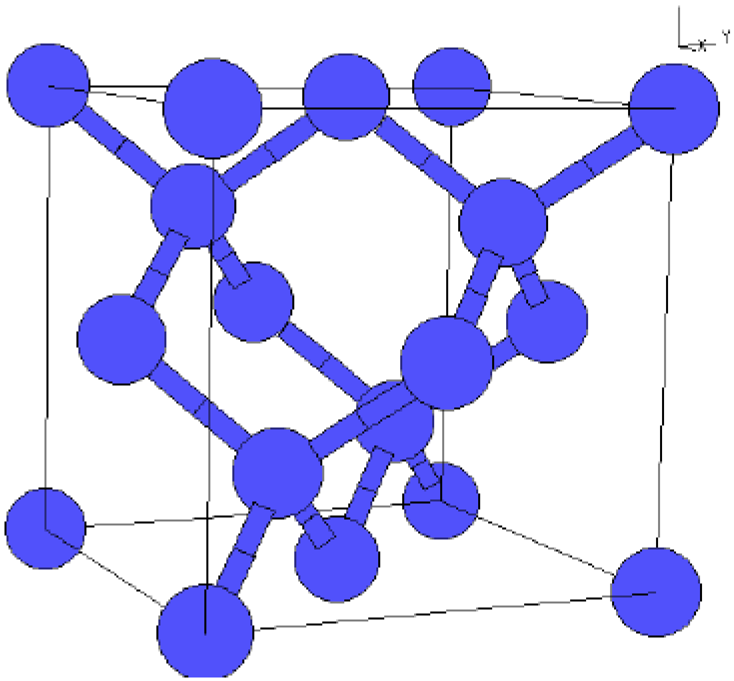


highest filled state for metal

highest filled state for insulator

Example: 2 materials made of pure carbon:

diamond (insulator)



graphite (semi-metal)