Announcements

- Homework 10 is due next Wednesday, April 19.
- Homework 11 is due next Monday, April 24.

Last time

- Crystal structures
- Heat capacity

Today’s class

- Band theory of solids

in-class quiz (5 min)

For a specific metal, plotting C/T against T^2 yields a straight line with a slope of 1.66×10^{-4} J/mole·K^4. What is this metal?

A. K

B. Na

C. Au

D. Ag

E. Cu

Metal	Debye Temperature
K	91 K
Na	157 K
Au	162 K
Ag	227 K
Cu	347 K

in-class quiz (5 min)

$$C = \frac{12\pi^4}{5} R \left(\frac{T}{T_D}\right)^3 \Rightarrow \frac{C}{T} = \underbrace{\frac{12\pi^4}{5} R \frac{1}{T_D^3}}_{\text{slope}} T^2$$

$R = 8.31\ J \cdot mol^{-1} \cdot K^{-1}$

$T_D = 227\ K$

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Fermi function f(E)

- Read textbook section 10.5
- Definition: fraction of occupied states as a function of energy.

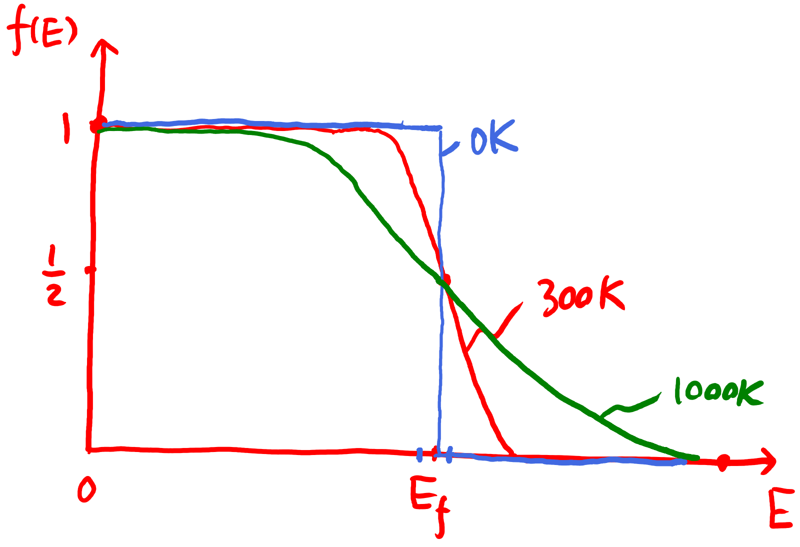
$$f(E) = \frac{1}{e^{(E - E_F)/kT} + 1}$$

E is the variable.
f(E) is T dependent.
E_F is Fermi energy, a constant for a given material.
E_F has a negligible change with temperature.

Element	Fermi Energy eV
Li	4.74
Na	3.24
K	2.12
Rb	1.85
Cs	1.59
Cu	7.00
Ag	5.49
Au	5.53
Be	14.3
Mg	7.08
Ca	4.69

Fermi function: shape, temperature dependence

$$f(E) = \frac{1}{e^{(E-E_f)/kT} + 1}$$



$T = 300K \Rightarrow kT = 0.025eV$, $E_f = 1eV$

$E = 0$, $f(E) = \frac{1}{e^{-E_f/kT}+1} = \frac{1}{e^{-40}+1} = 1$

$E = E_f$, $f(E) = \frac{1}{e^0 + 1} = \frac{1}{2}$

$E \gg E_f$, $f(E) = \frac{1}{e^{E/kT}+1} \doteq 0$

$T = 0K$, say $T = 10^{-15}K$, kT is extremly small

$E = 0$, $f(E) = \frac{1}{e^{-E_f/kT}+1} = \frac{1}{e^{-\infty}+1} \doteq 1$

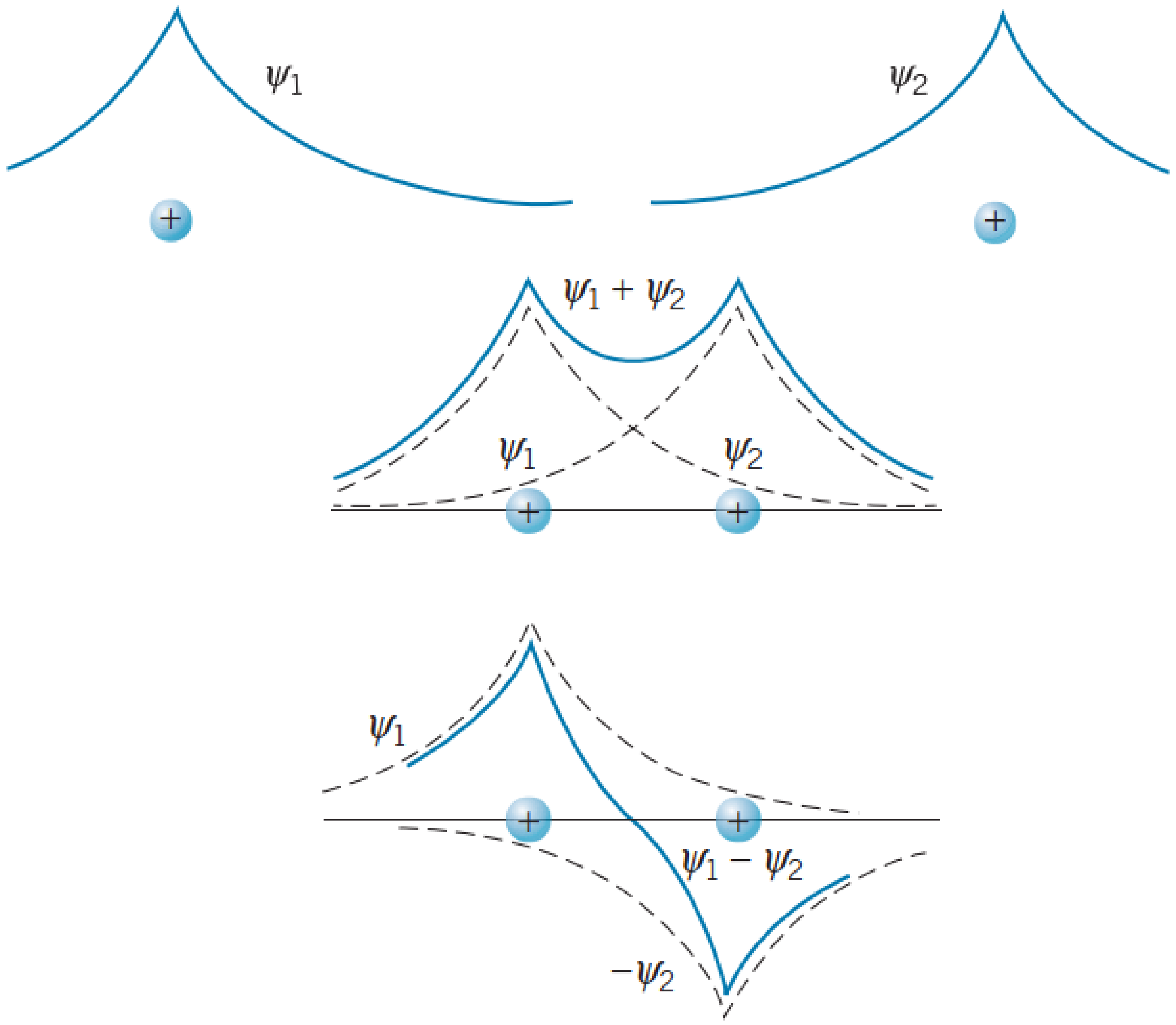
$E = E_f$, $f(E) = \frac{1}{e^0+1} = \frac{1}{2}$

$E \gg E_f$, $f(E) = \frac{1}{e^{E/kT}+1} = \frac{1}{e^{\infty}+1} = 0$

$E - E_f = 0.01eV$. $f(E) = \frac{1}{e^{0.01/kT}+1} = \frac{1}{e^{\infty}+1} = 0$

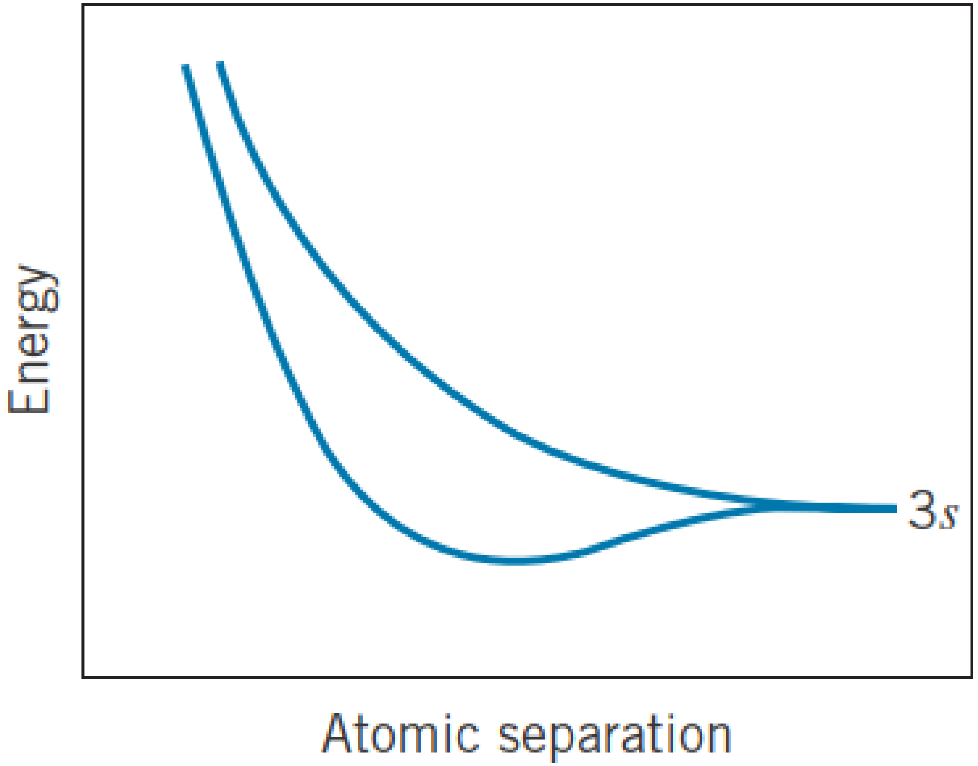
$E - E_f = -0.01eV$. $f(E) = \frac{1}{e^{-0.01/kT}+1} = \frac{1}{e^{-\infty}+1} = 1$

Wave functions begin to overlap as two identical atoms approach each other.



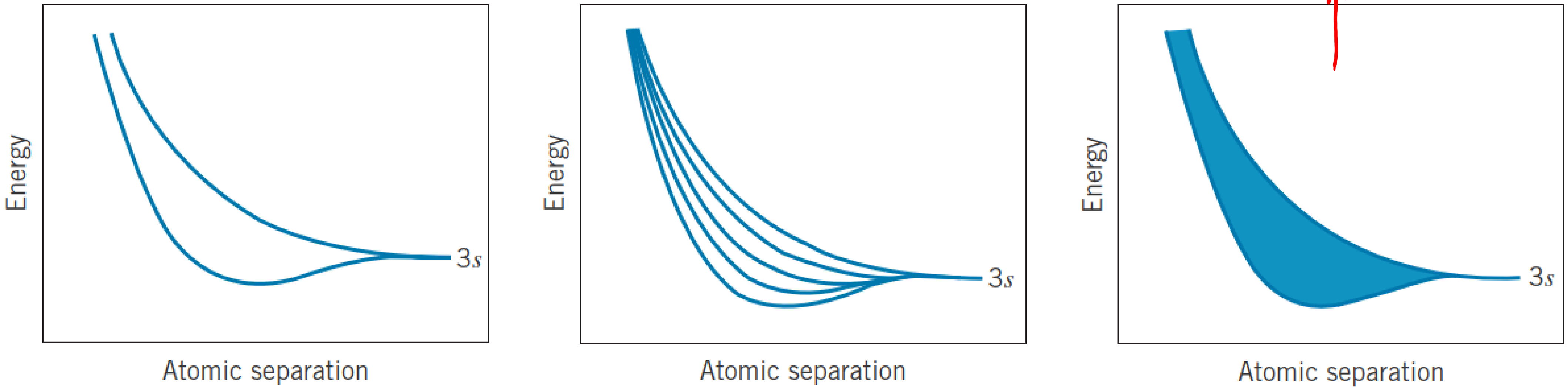
Split of energy levels

Energy level split when two identical atoms approach each other.



Energy band forms when many identical atoms approach each other.

1s band	2N
2s band	2N
2p band	6N
3p band	6N
n l band	$2(2l+1)N$ (m_s, m_l)



	2 atoms	5 atoms	N atoms
	2 levels	5 levels	N levels → band
each level # of electrons	2	2	2
total electrons / total capacity	4	10	2N

Energy bands in Na metal

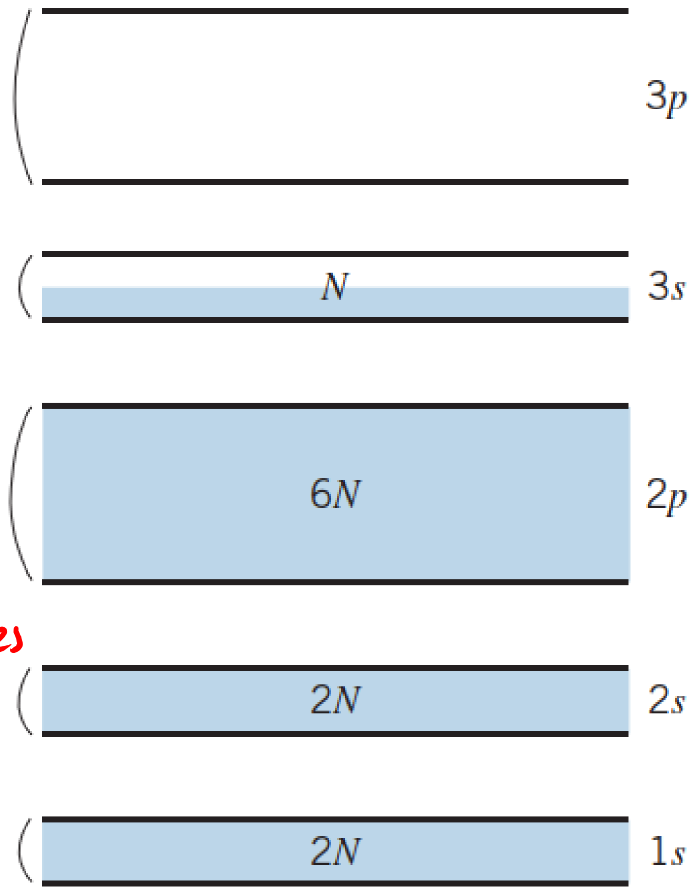
electron configuration
atomic theory

$1s^2 2s^2 2p^6 3s^1$ $11 e^-$

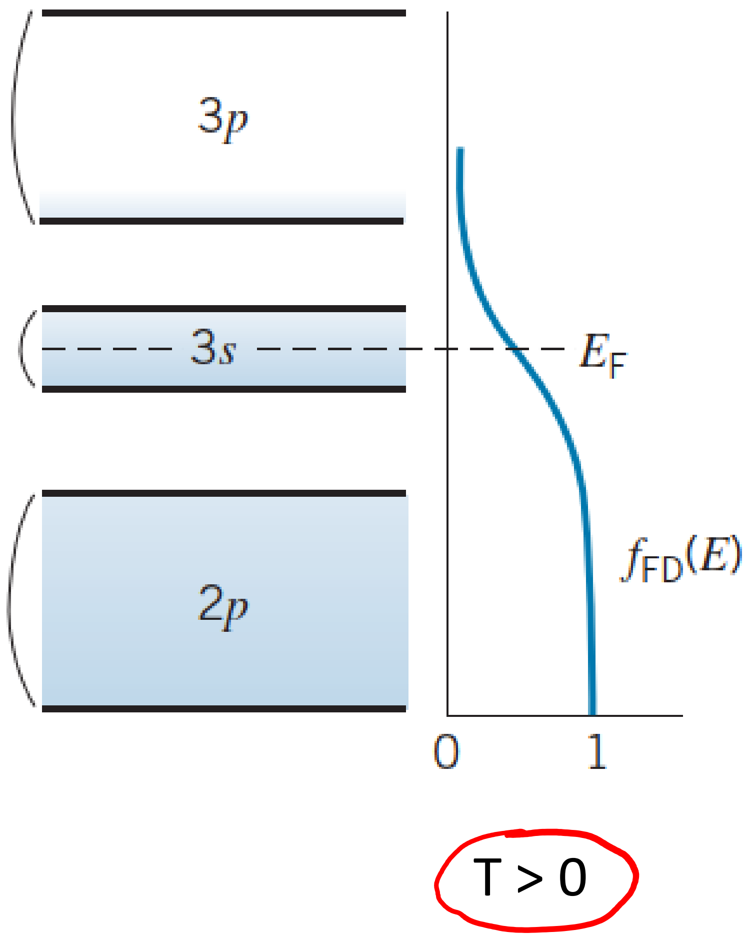
N atoms $11N e^-$

Na is a good conductor.

N relatively free 3s e^-s
can move to N unoccupied 3s states

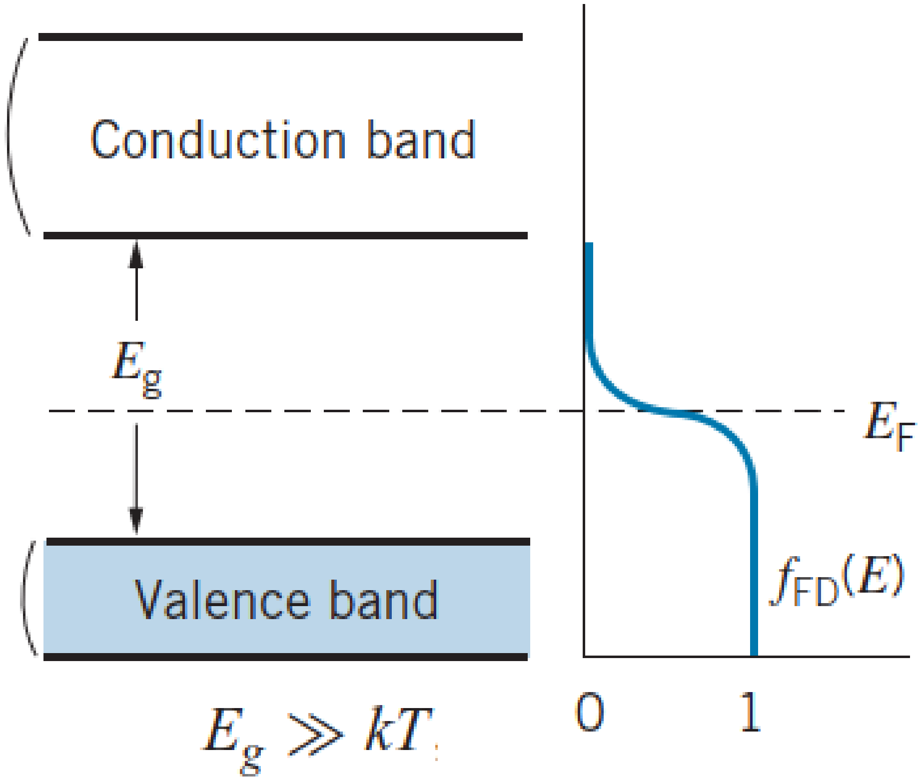


Fermi function spreads with thermal excitation

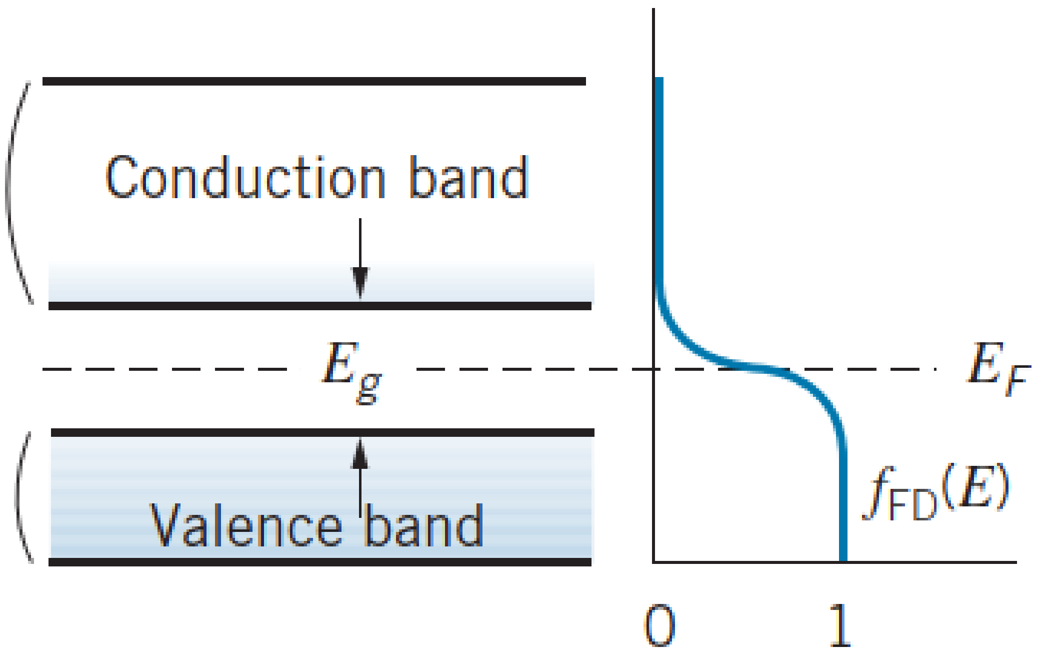


3p has some electrons. 2p is not completely full.

Insulator

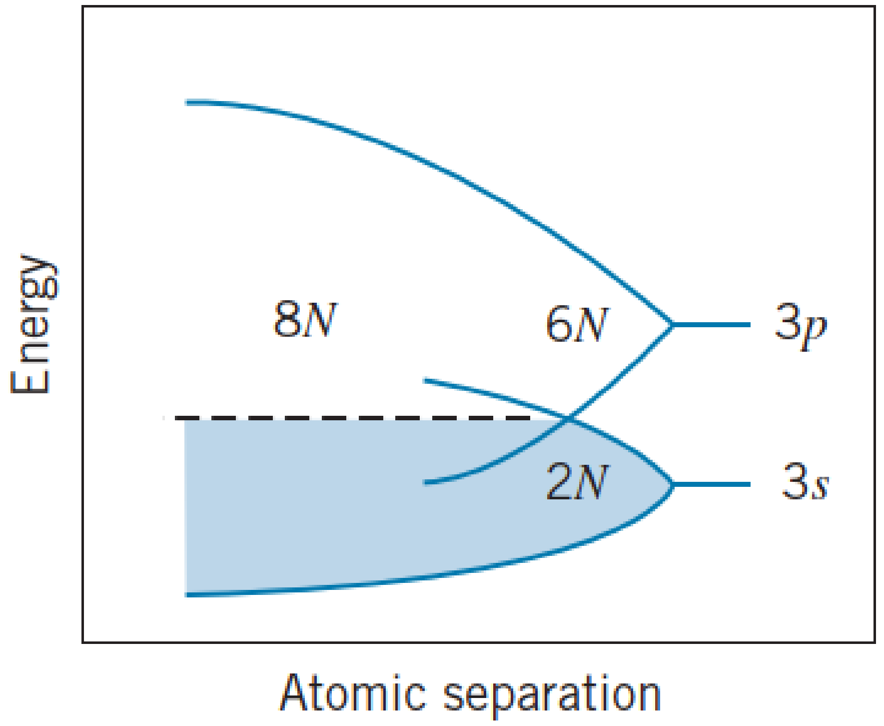


Semiconductor



Band structure in Mg metal

$1s^2 2s^2 2p^6 3s^2$



Band structure in C, Si, Ge