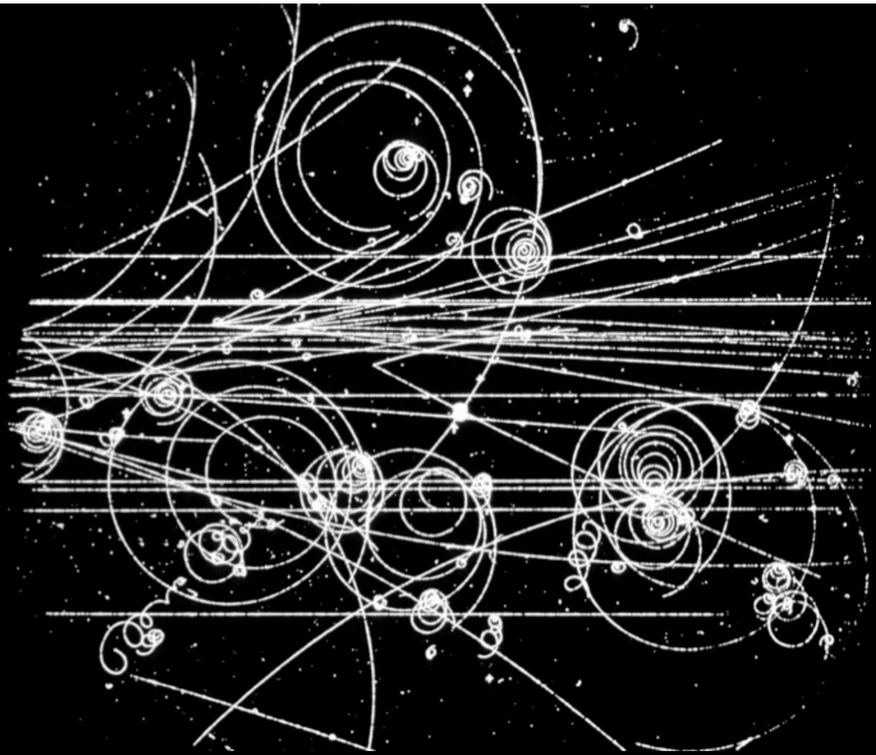
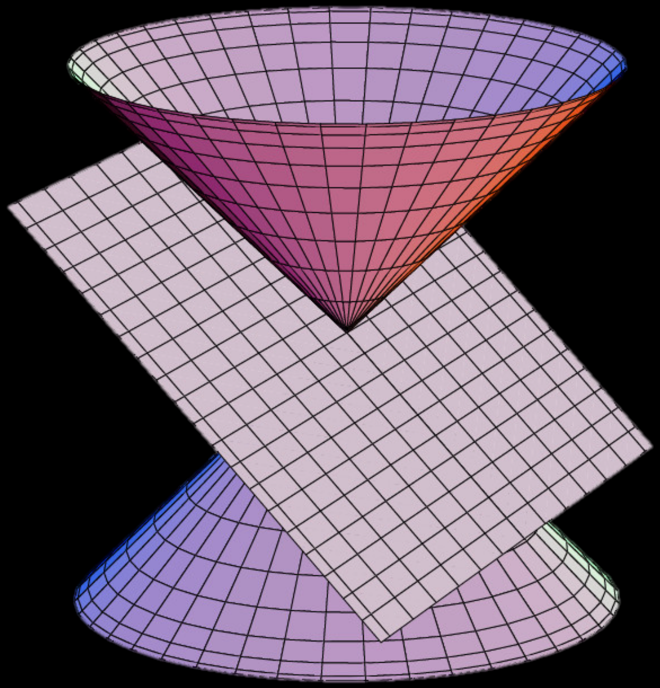
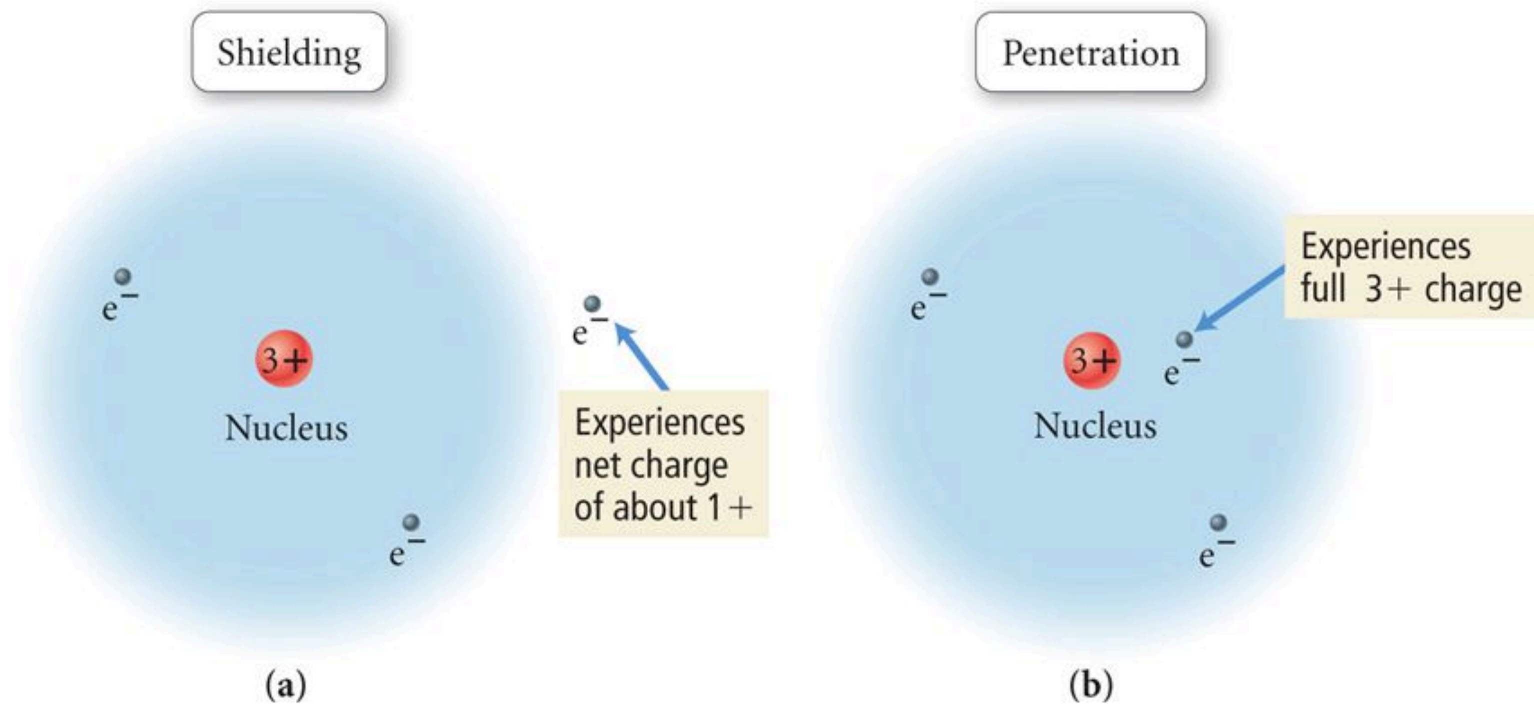




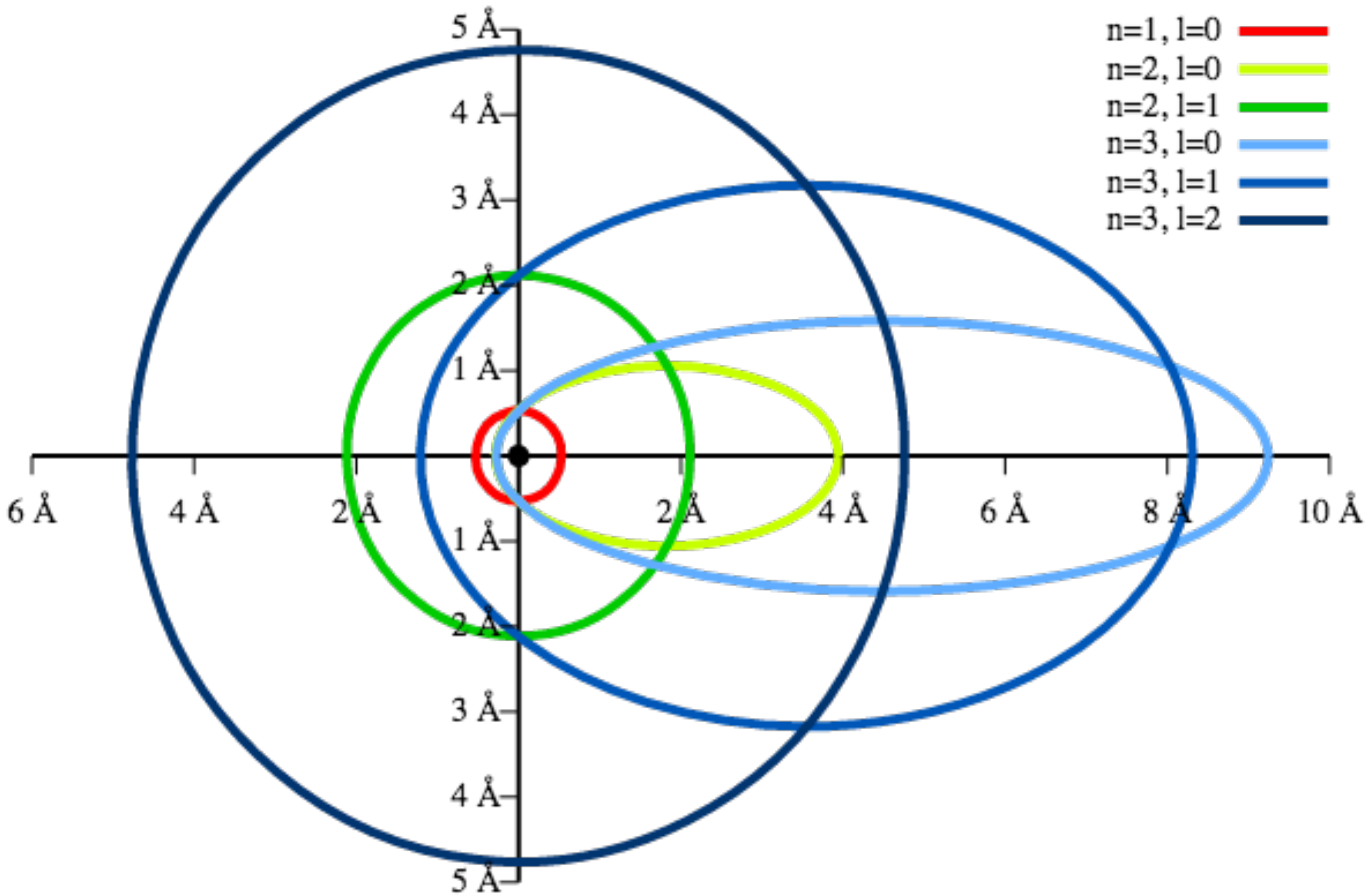
Modern Physics (Phys. IV): 2704

Professor Jasper Halekas
Van Allen 70
MWF 12:30-1:20 Lecture

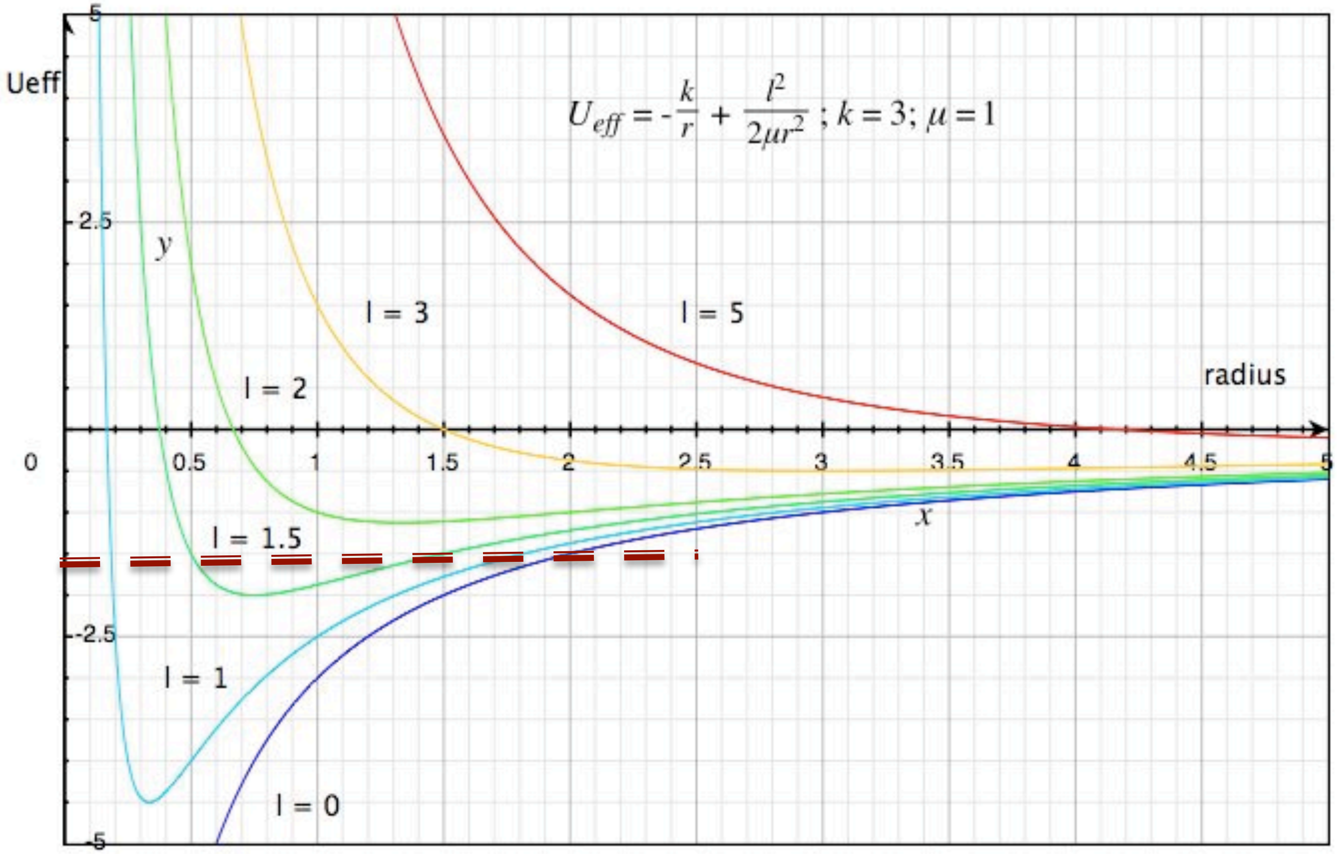
Penetration and Shielding



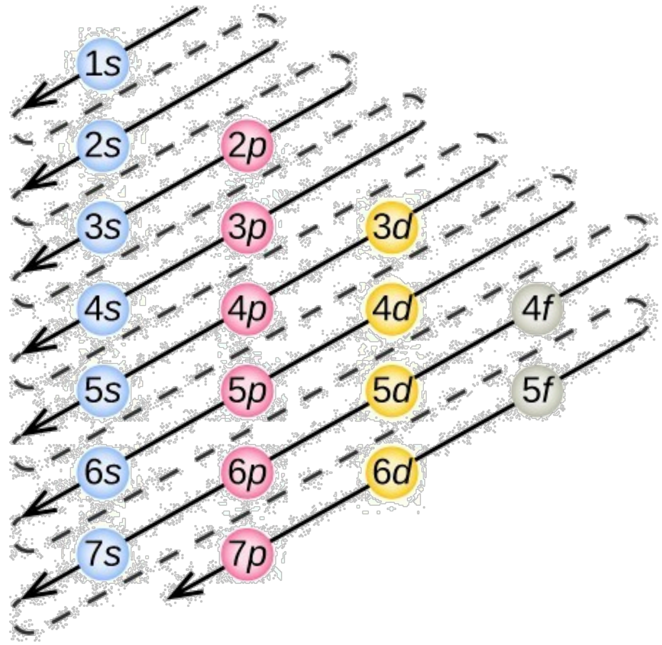
Penetrating Orbits



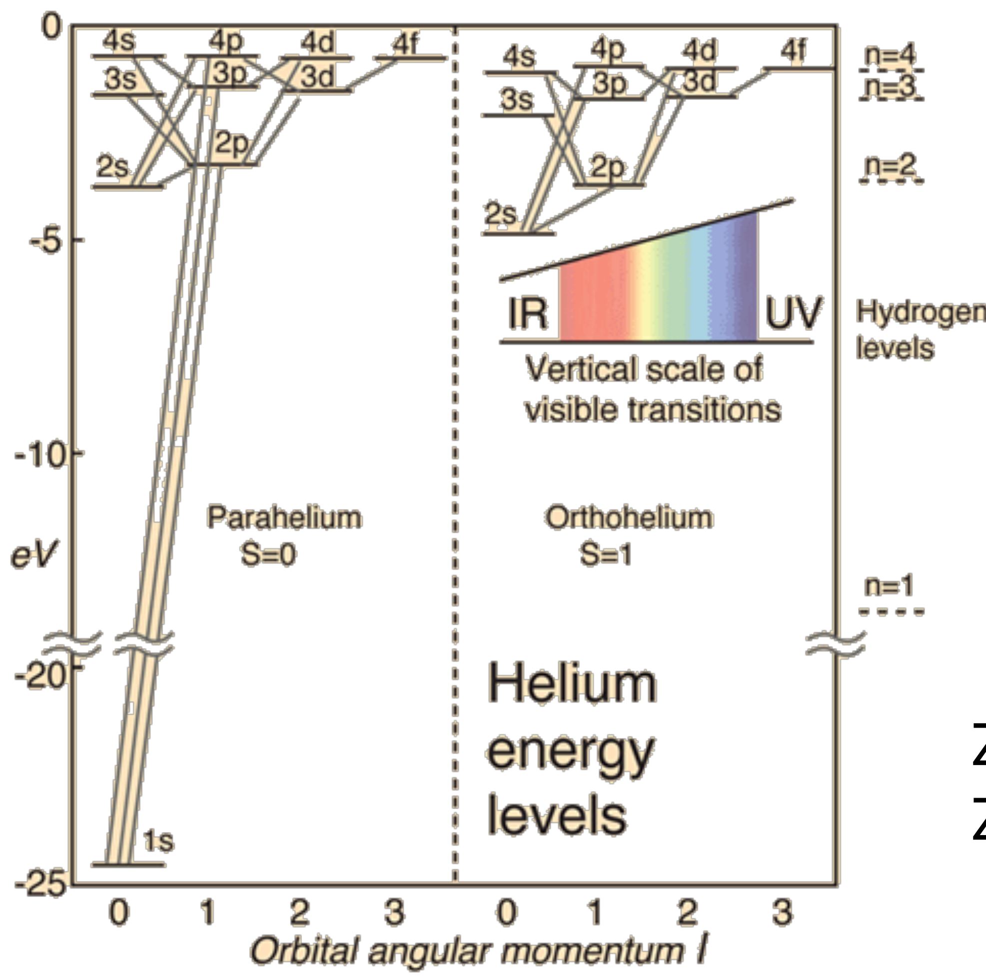
Effective Radial Potential



Energy Levels



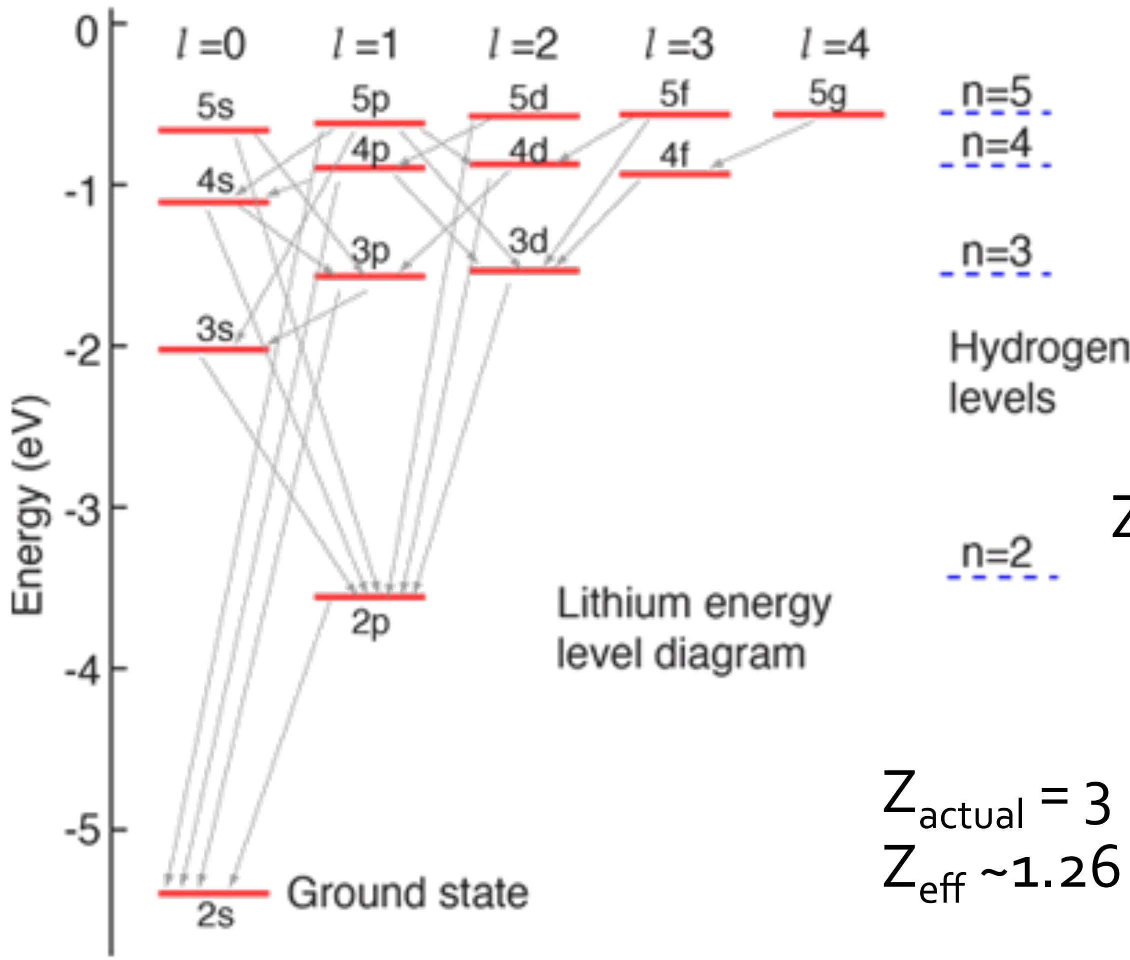
Helium (Z=2) Transitions



$Z_{actual} = 2$

$Z_{eff} \sim 1.37$ (1s)

Lithium (Z=3) Transitions



Z_{eff} ~1.02 (2p)

Z_{actual} = 3

Z_{eff} ~1.26 (2s)

Lithium

-e (1s)
+3e   -e (2s)
-e (1s)

perfect screening $Z_{eff} = 1$

$$E_{2s} = -13.6 \cdot Z_{eff}^2 / n^2$$

$$= -13.6 \cdot 1/4 = -3.4$$

E_{2s} actually -5.4

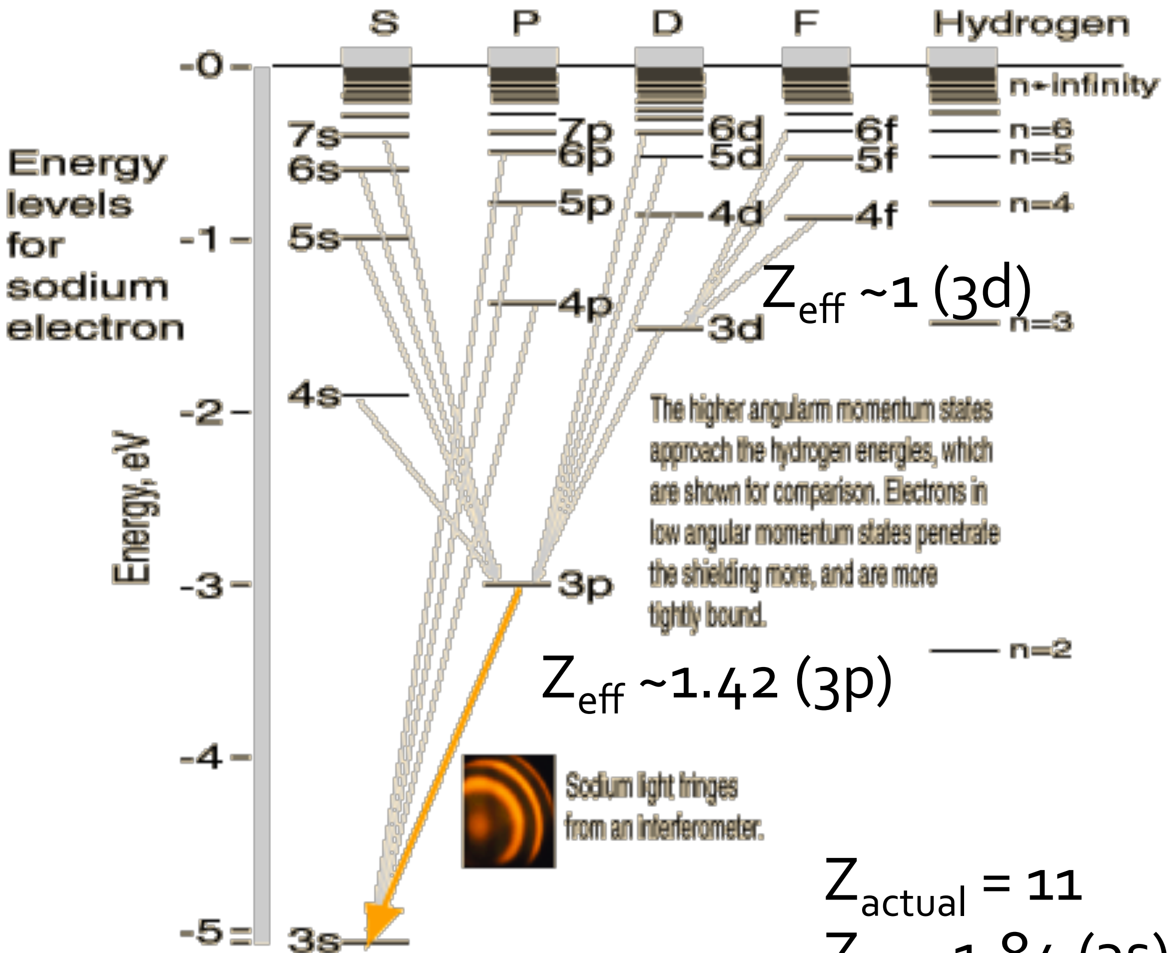
$$\Rightarrow Z_{eff} = 1.26$$

Not perfect screening, but close

- $E_{2p} = -3.55$

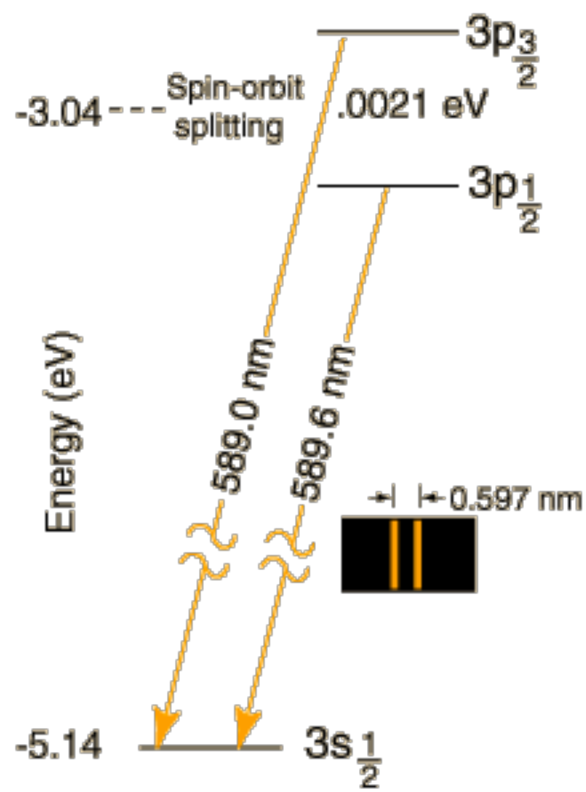
Much closer to perfect screening since less penetration (more "circular" orbit)

Sodium (Z=11) Transitions



Z_{eff} ~1 (3d)

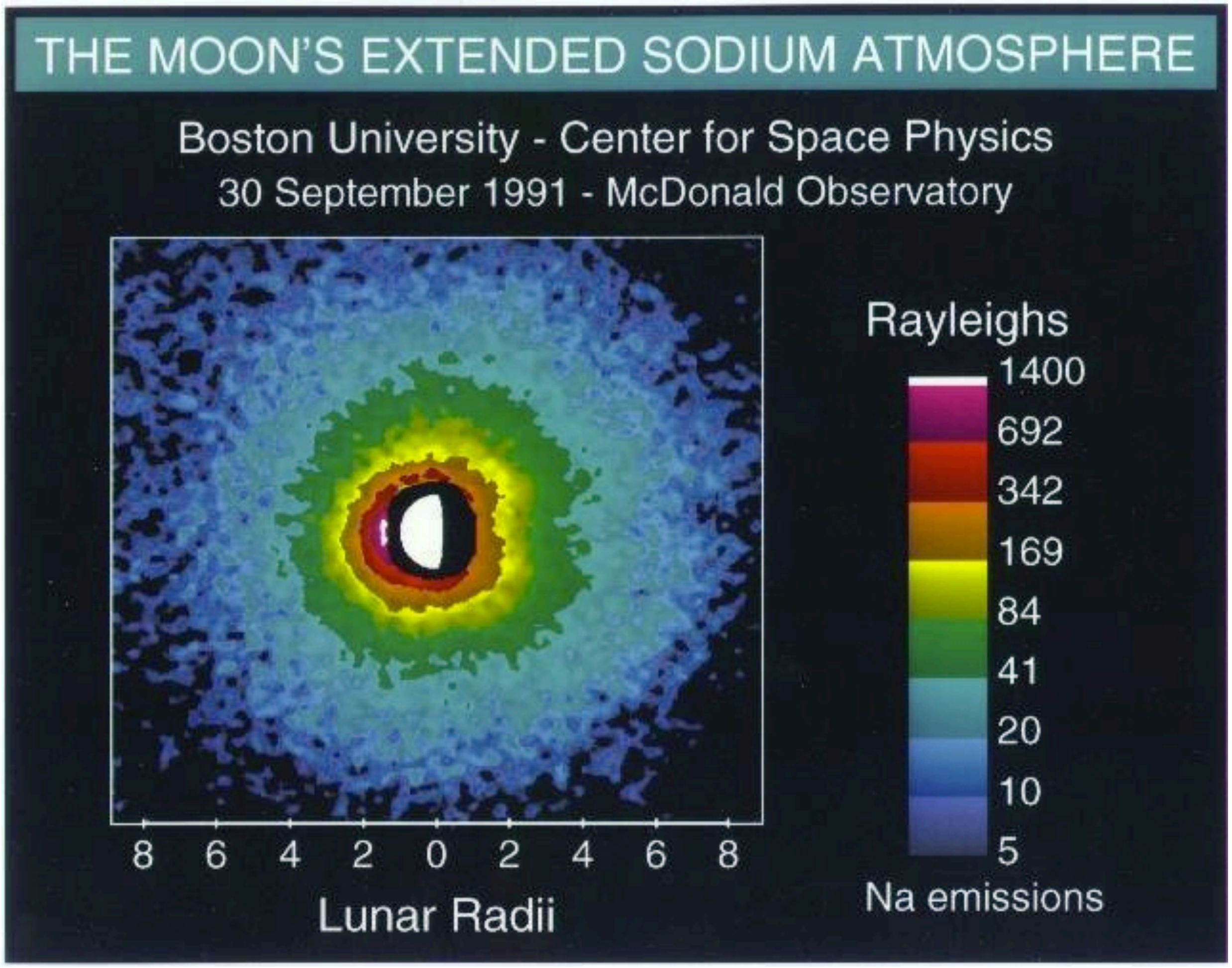
Z_{eff} ~1.42 (3p)



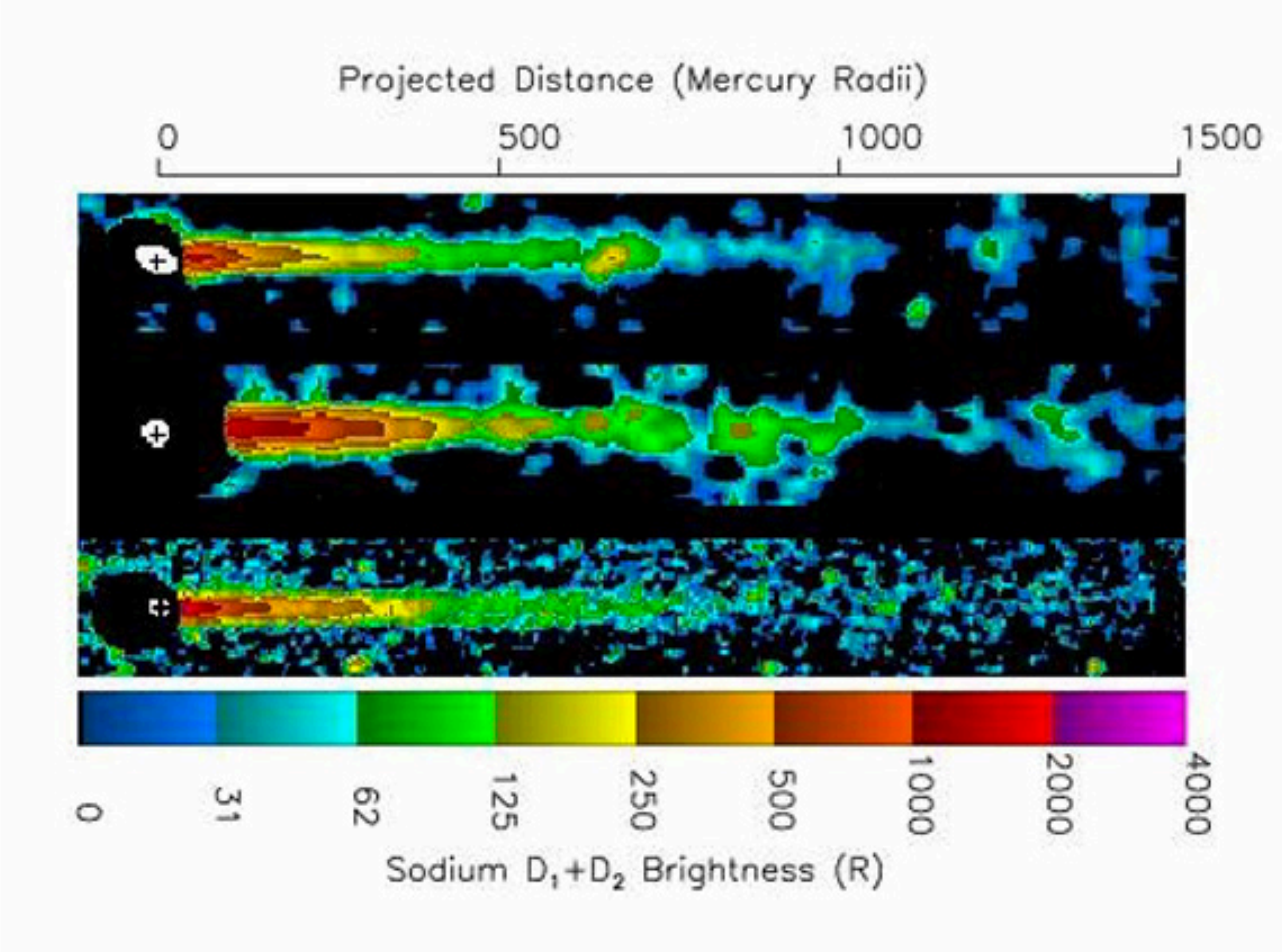
Z_{actual} = 11

Z_{eff} ~1.84 (3s)

Sodium Emission from the Moon



Sodium Emission from Mercury



Concept Check

- Consider an atom of Chlorine (Z = 17, outer shell 3s2 3p5) and an atom of Potassium (Z = 19, outer shell 4s1). Which atom would you predict would be easier to ionize?

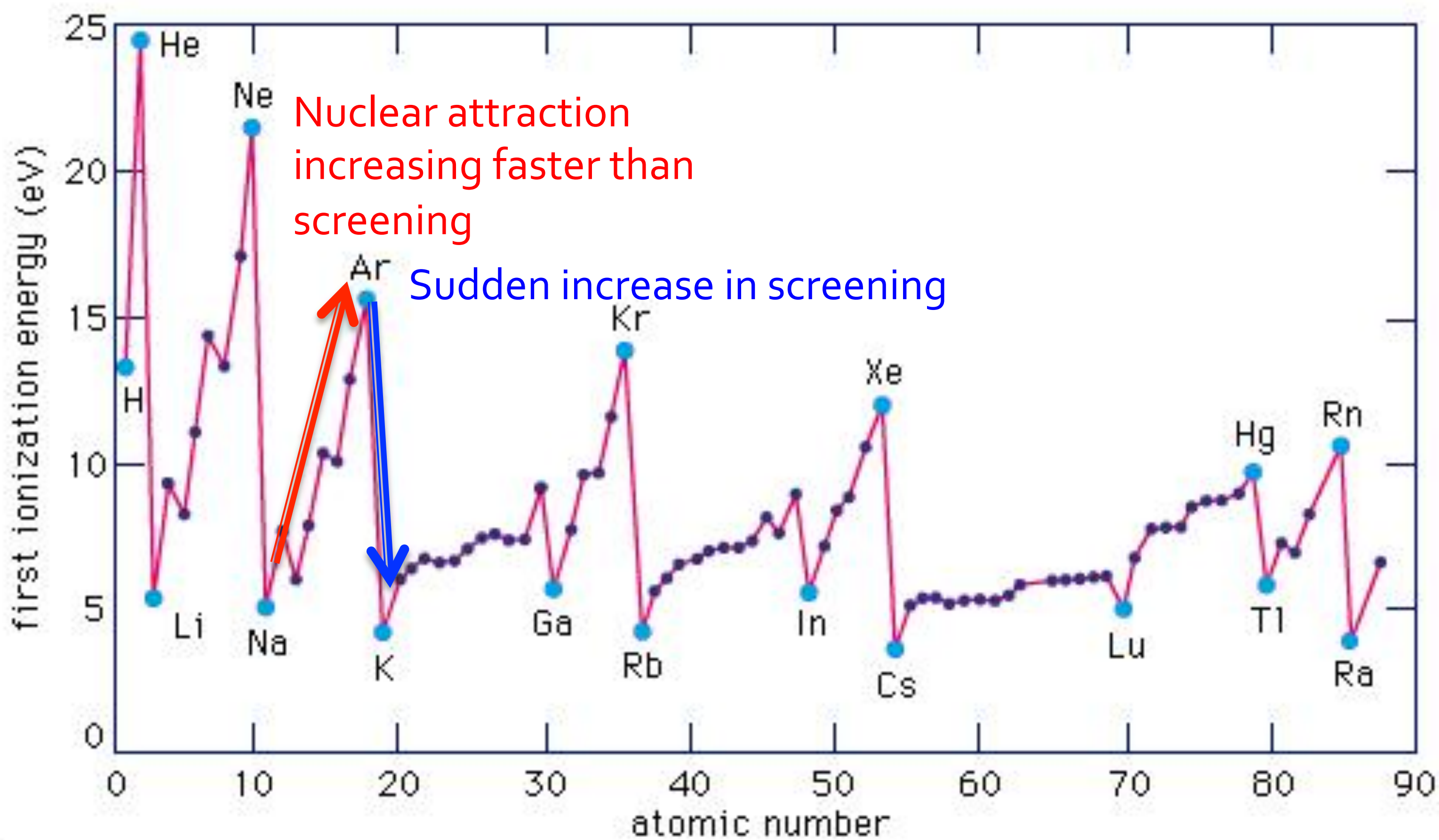
A. Chlorine
B. Potassium
C. Both similar
D. No way to predict

Concept Check

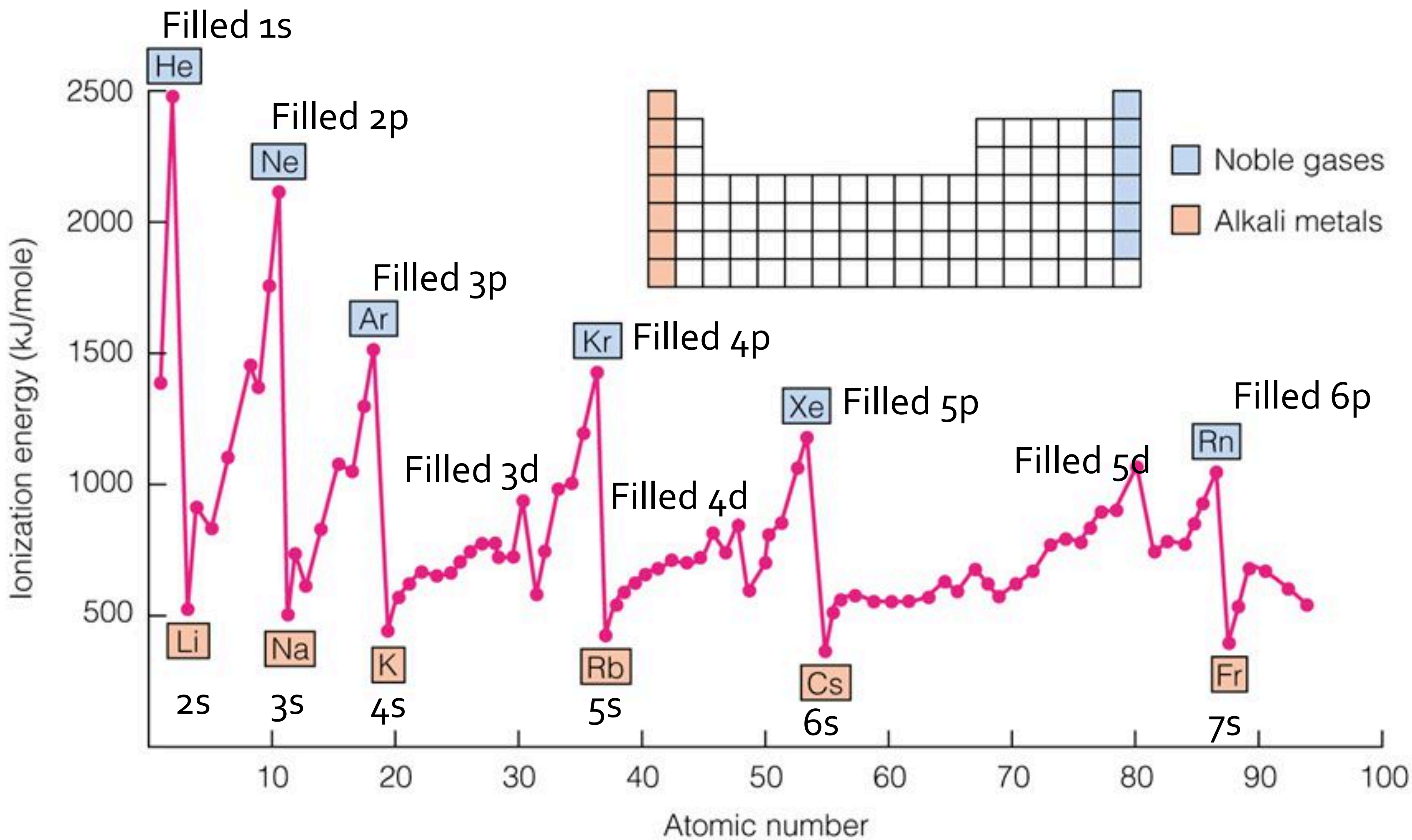
- Consider an atom of Chlorine (Z = 17, outer shell 3s2 3p5) and an atom of Potassium (Z = 19, outer shell 4s1). Which atom would you predict would be easier to ionize?

A. Chlorine
B. Potassium
C. Both similar
D. No way to predict

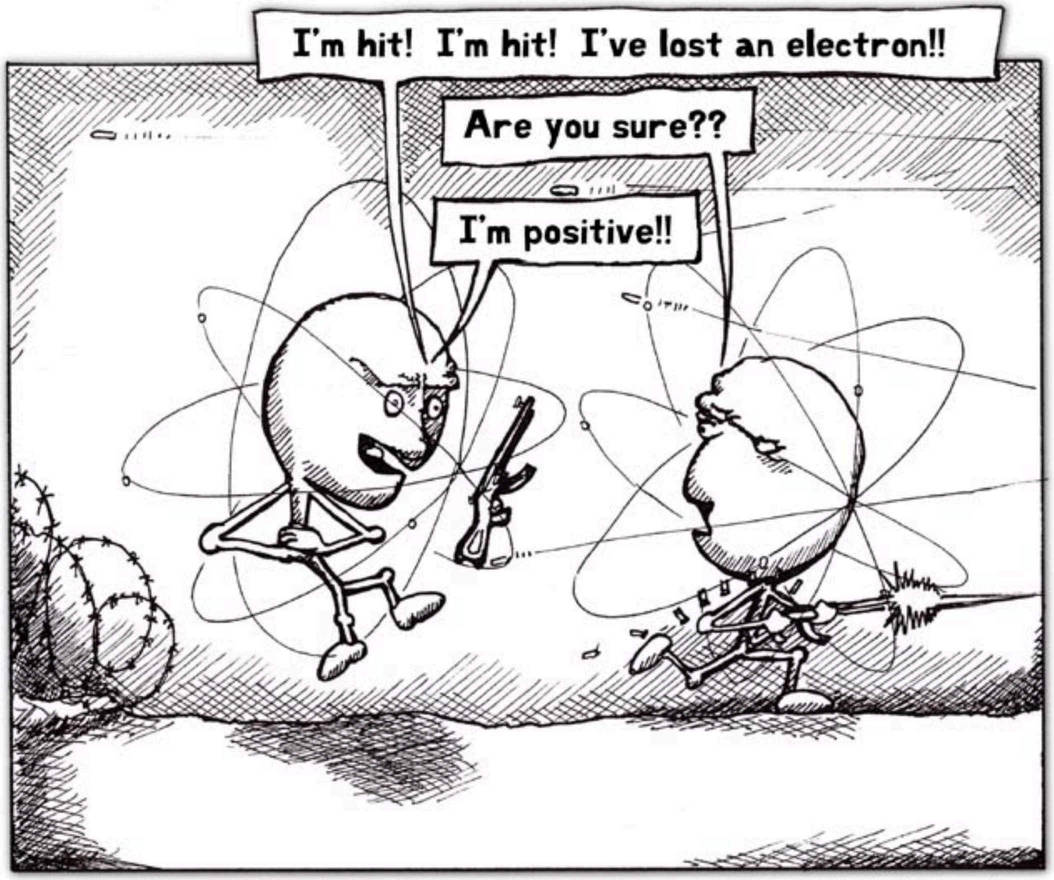
First Ionization Potential Vs. Z



First Ionization Potential Vs. Z

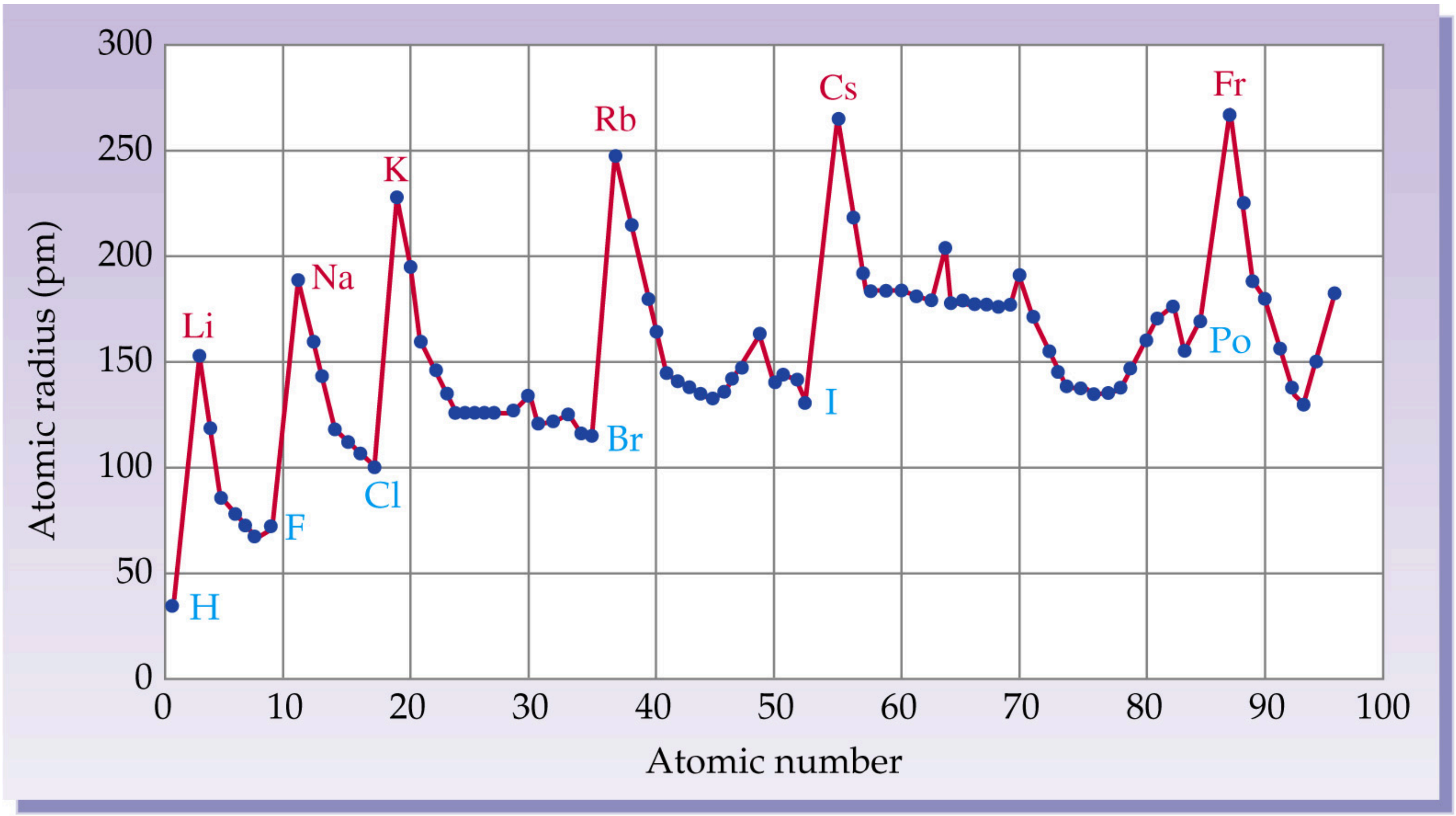


Ionization

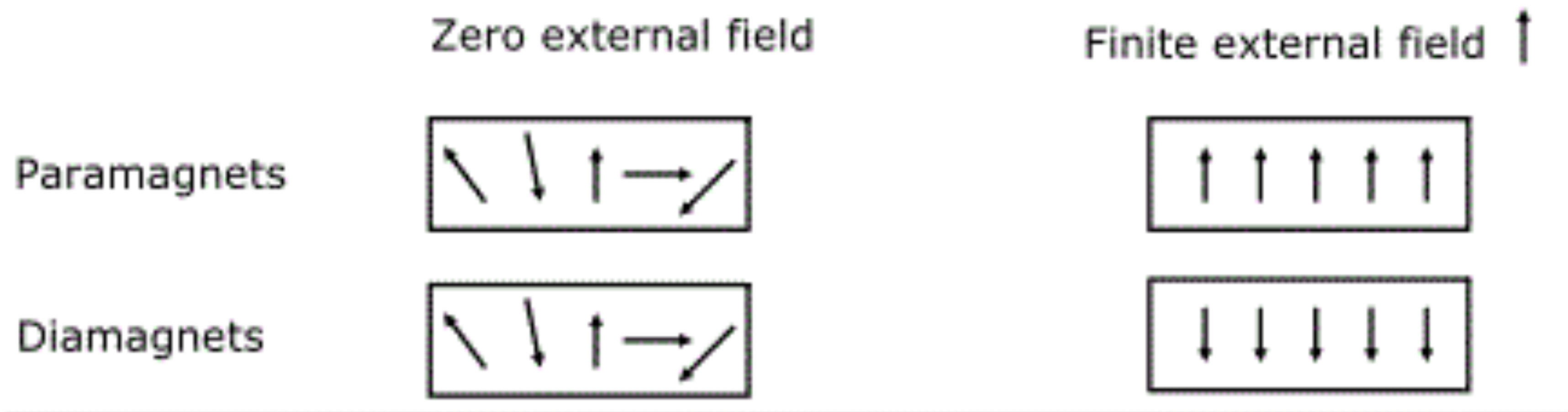


Another casualty in the War of the Atoms

Atomic Radius Vs. Z



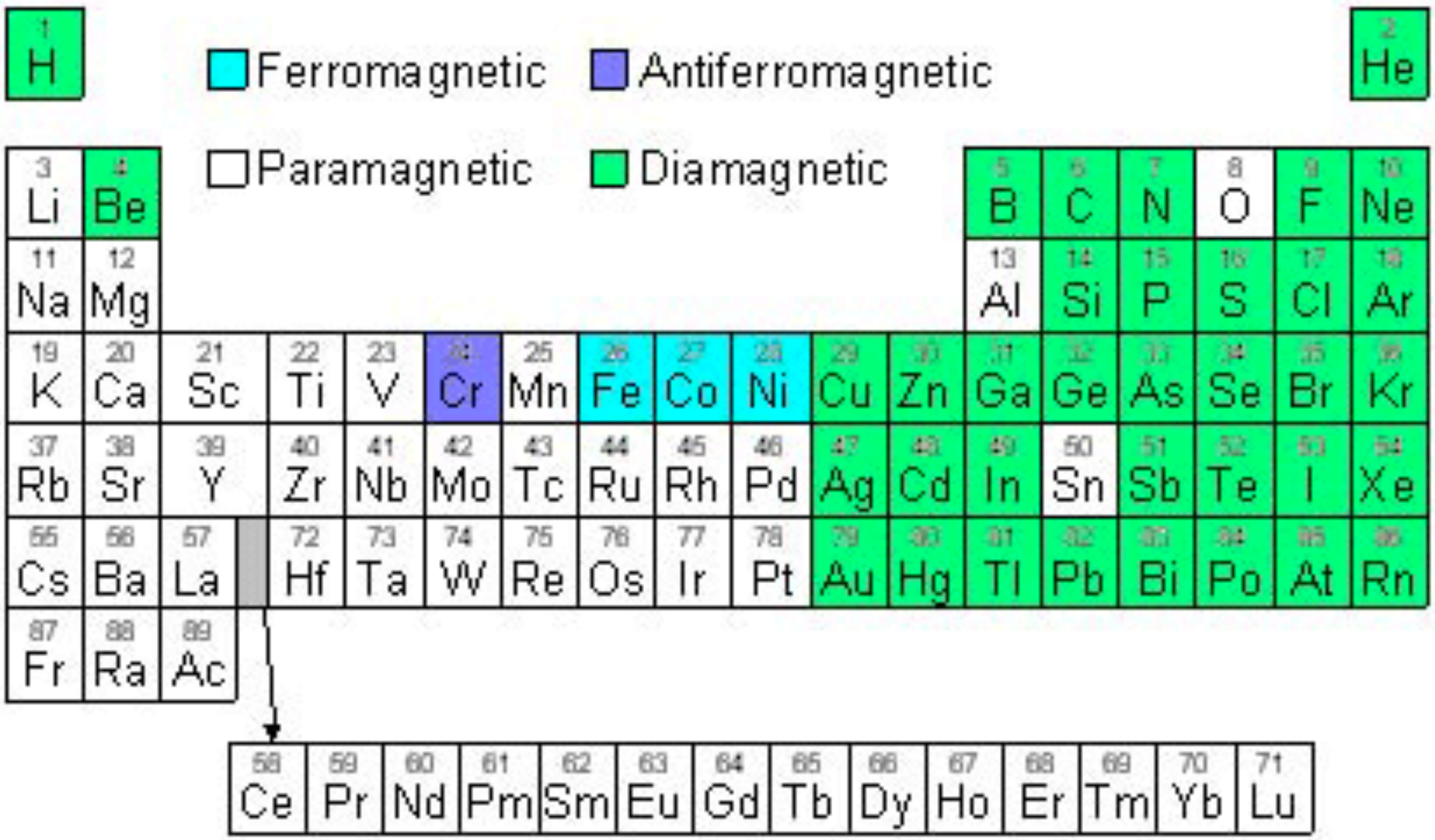
Paramagnetism and Diamagnetism



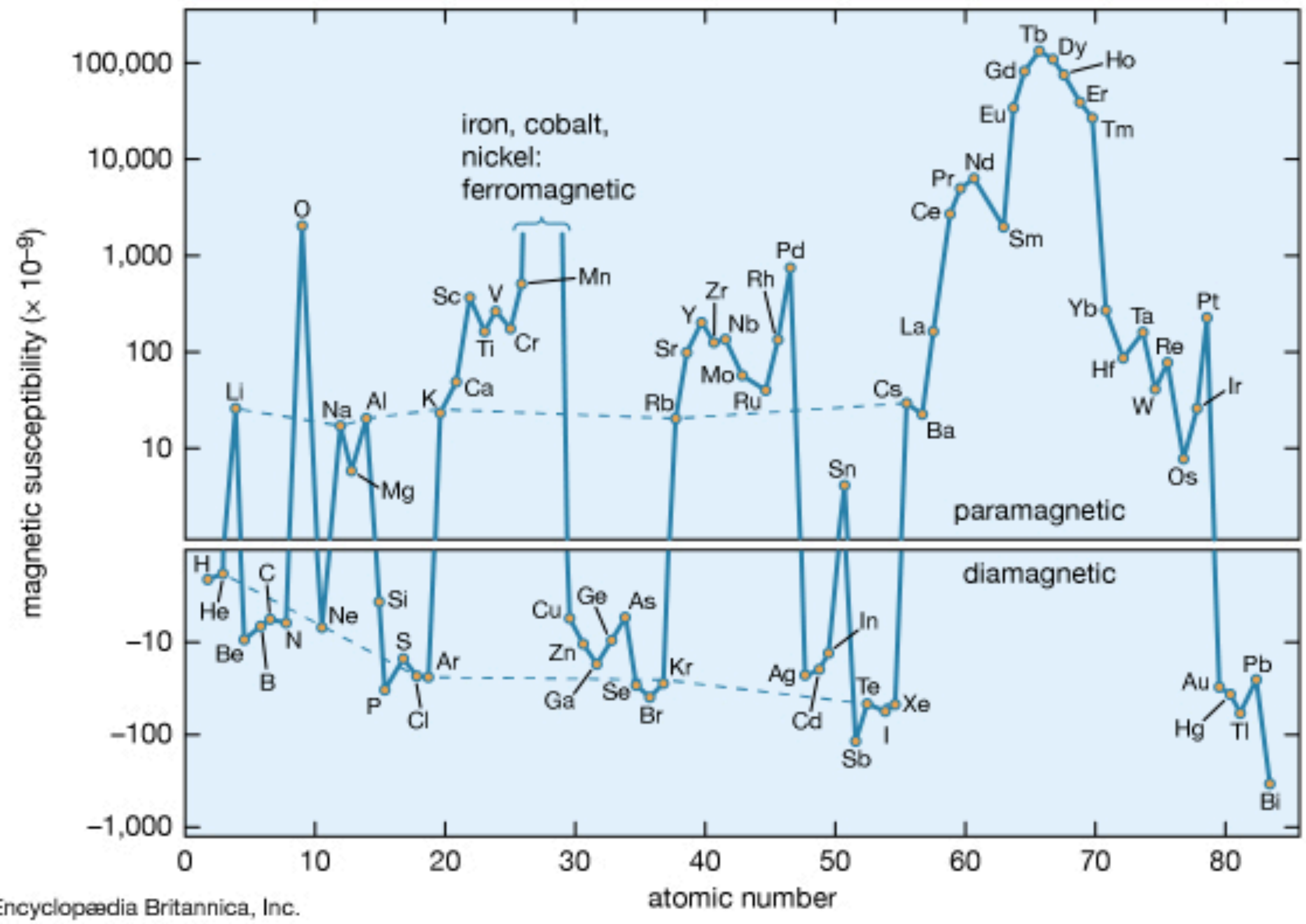
Paramagnetism: Caused by atoms with a net magnetic dipole moment – in these atoms, the intrinsic magnetic moment aligns with the external field

Diamagnetism: Caused by atoms with mostly filled orbitals – in these atoms, induction effects oppose the external applied magnetic field

Magnetism and Periodic Table

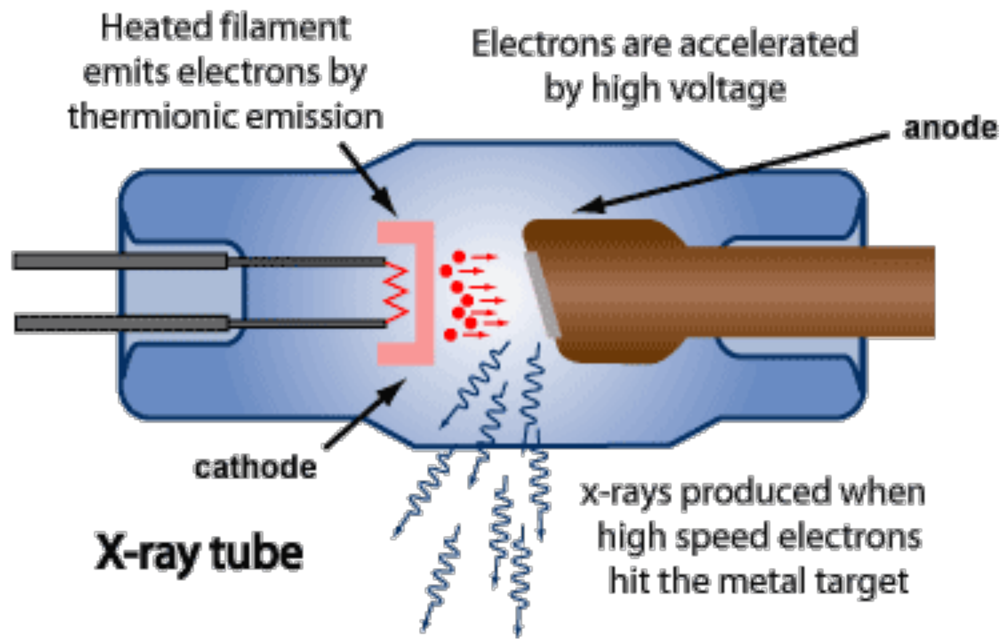


Magnetic Susceptibility Vs. Z

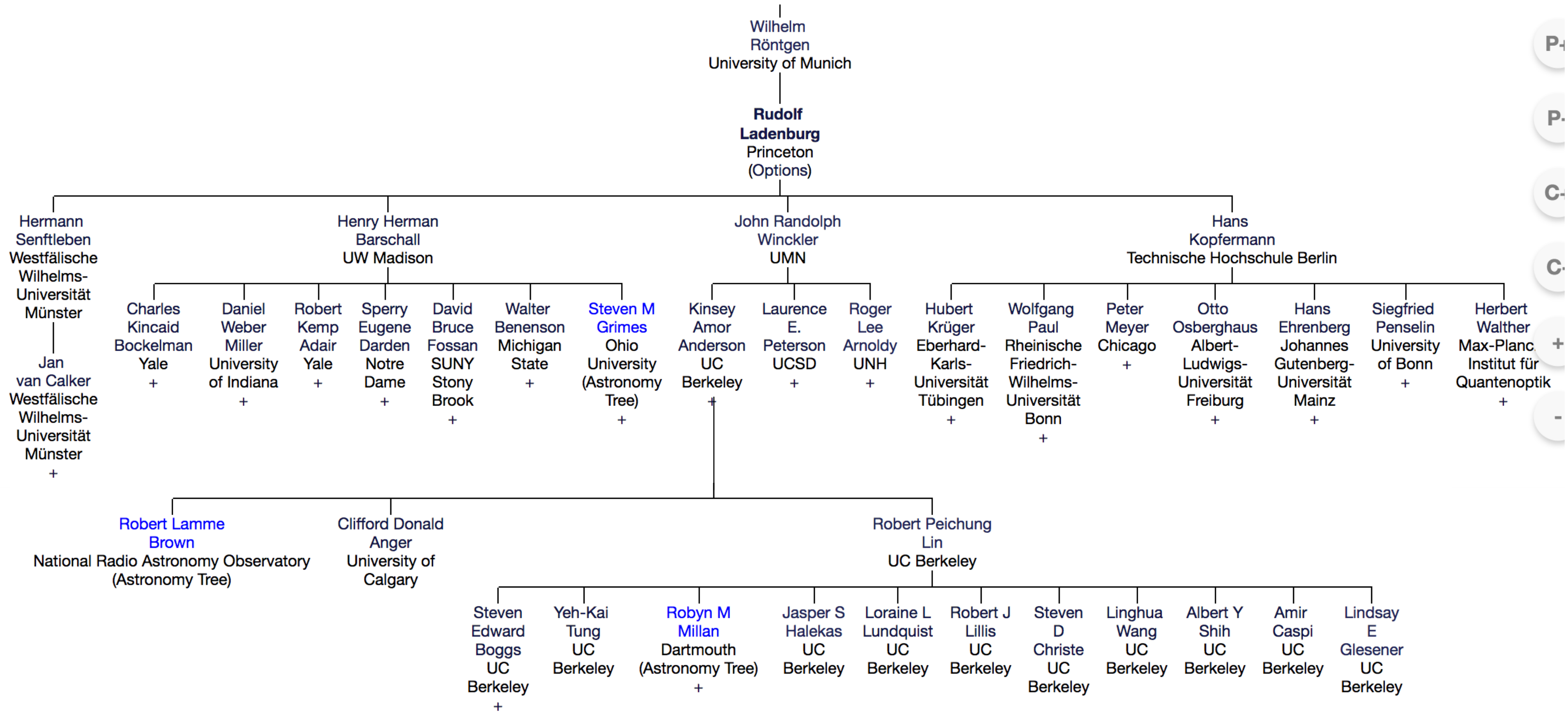


© Encyclopædia Britannica, Inc.

Röntgen's X-Ray Tube

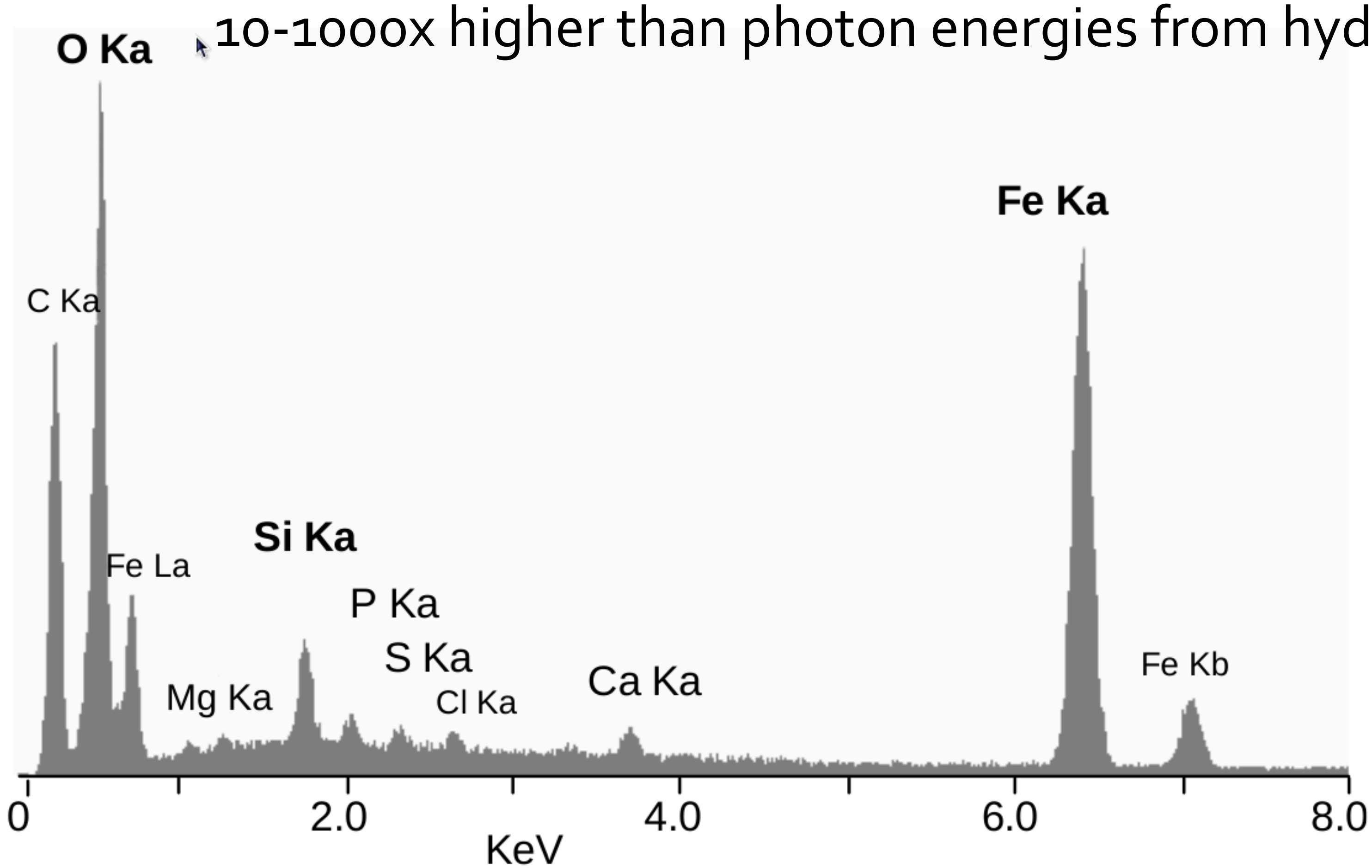


Academic Family Tree



X-Ray Energies

10-1000x higher than photon energies from hydrogen!



Concept Check

- Imagine an electron collides with a high-Z element and removes one of its 1s electrons. To an electron in the 2s orbital, what is the new apparent effective nuclear charge?

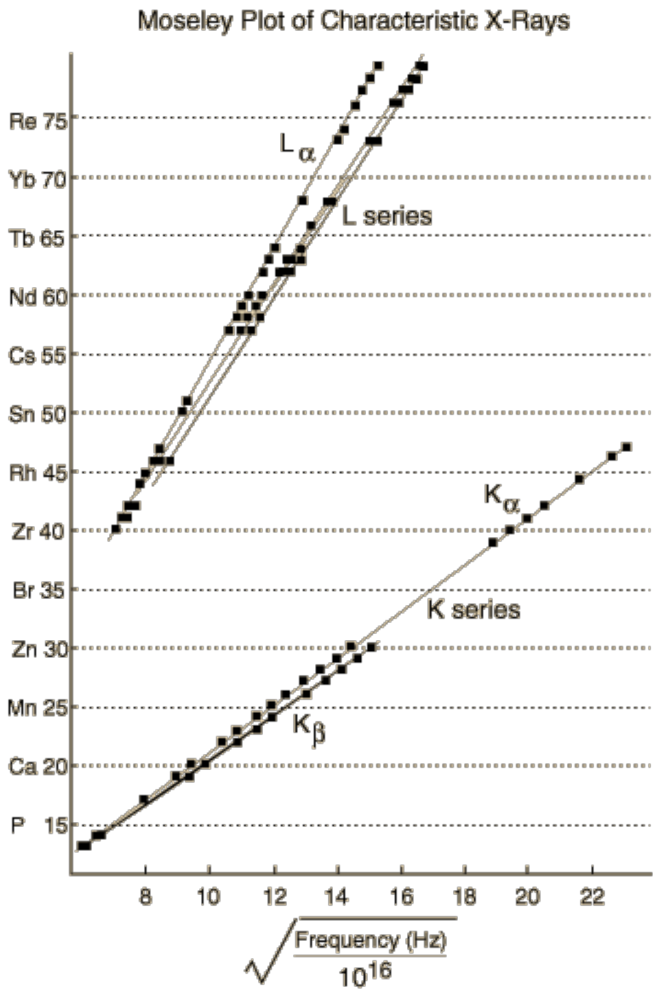
- $Z_{eff} \sim Z$
- $Z_{eff} \sim 1$
- $Z_{eff} \sim Z-1$
- $Z_{eff} \sim Z-2$

Concept Check

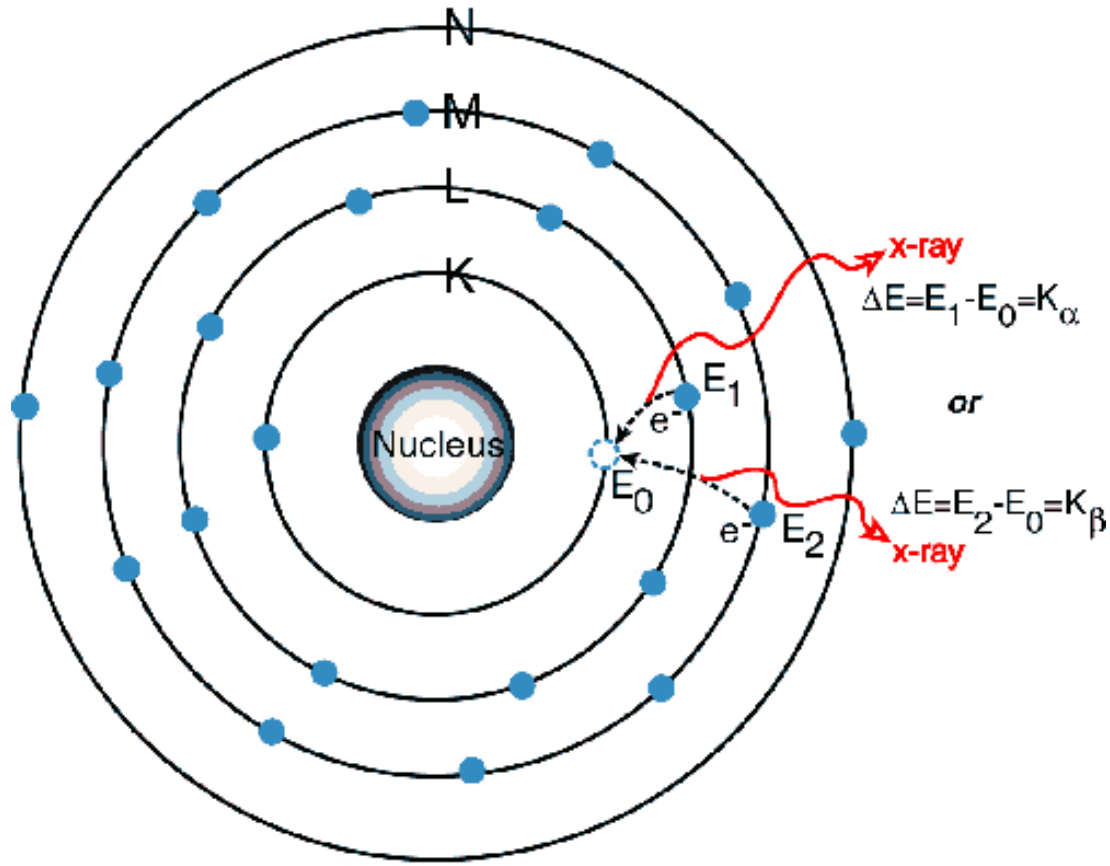
- Imagine an electron collides with a high-Z element and removes one of its 1s electrons. To an electron in the 2s orbital, what is the new apparent effective nuclear charge?

- $Z_{eff} \sim Z$
- $Z_{eff} \sim 1$
- $Z_{eff} \sim Z-1$
- $Z_{eff} \sim Z-2$

Characteristic X-Rays



Adapted from Moseley's original data (H. G. J. Moseley, Philos. Mag. (6) 27:703, 1914)



K X-Rays

$$\Delta E = -13.6 \, (Z-1)^2 \left(\frac{1}{n^2} - 1\right)$$

$K\alpha$: $\Delta E = -13.6 \, (Z-1)^2 \left(\frac{1}{4} - 1\right)$
$= 10.2 \, (Z-1)^2$

O : $Z = 8 \Rightarrow \Delta E_{K\alpha} \sim 500$ eV
Fe ; $Z = 26 \Rightarrow \Delta E_{K\alpha} \sim 6.4$ keV

$K\beta$: $\Delta E = -13.6 \, (Z-1)^2 \left(1/9 - 1\right)$

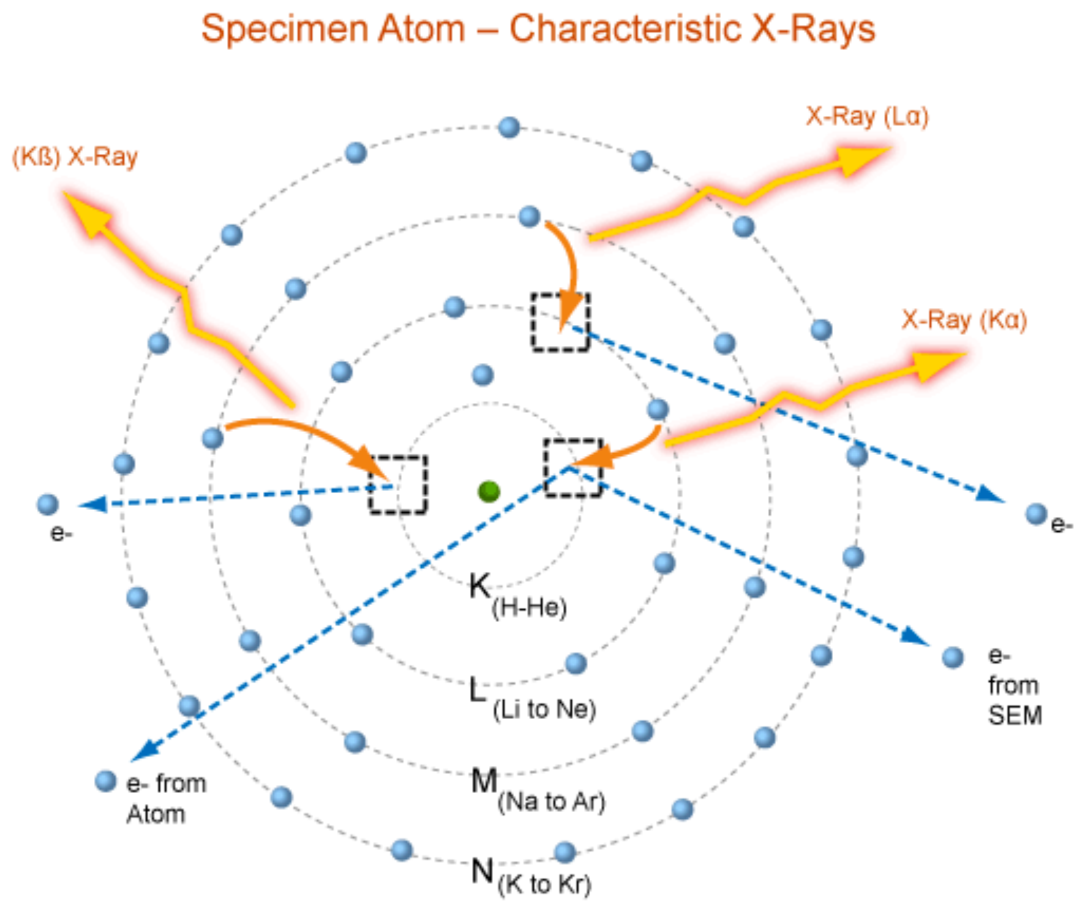
L : $\Delta E = -13.6 \, (Z-7.4)^2 \left(\frac{1}{n^2} - 1/2^2\right)$

Note : Perfect screening
would give $Z-9$
1s, 2s, 2p filled less one

$L\alpha$: $\Delta E = -13.6 \, (Z-7.4)^2 \left(\frac{1}{3^2} - 1/2^2\right)$
$L\beta$: $\Delta E = -13.6 \, (Z-7.4)^2 \left(\frac{1}{4^2} - 1/2^2\right)$

etc.

K and L X-Rays



Specimen Atom – Characteristic X-Rays
(Kß) X-Ray
X-Ray (Lα)
X-Ray (Kα)
e-
e-
K (H-He)
L (Li to Ne)
M (Na to Ar)
N (K to Kr)
e- from Atom
e- from SEM

X-Ray Spectroscopy