Structure of more complex elements and materials
Each elemental gas emits its own characteristic spectrum. This can be resolved by using a prism or a grating, taking advantage of the diffraction of light, which depends on the particular wavelength.
Multi-Electron Atoms

Z is the charge and determines the chemical characteristics of the element, e.g. Z=1 (Hydrogen) Z=47 (Silver). Electron transitions and photon emission is more complex and depends on Z and the shielding $S_n$ by inner electron shells.

$$E_n = - \left( Z - S_n \right)^2 \cdot \frac{13.6}{n^2} \approx - (Z - 1)^2 \cdot \frac{13.6}{n^2}$$

$$E_K = E_n - E_1 = - (Z - 1)^2 \cdot \frac{13.6}{n^2} + (Z - 1)^2 \cdot \frac{13.6}{1^2}$$

$$E_K = (Z - 1)^2 \cdot 13.6 \cdot \left( 1 - \frac{1}{n^2} \right) = \frac{hc}{\lambda_K}$$

$$\lambda_K = \frac{hc}{E_\gamma} = \frac{hc}{E_n - E_1}$$

K-transitions to n=1
X-ray transitions in high Z atoms

Ag  Z=47

-28.8 keV

-24.9 keV

-22.6 keV

Kα

Lαβγ (2.9 keV)

Kβ (24.9 keV)

Ag analysis

Kα (22.6 keV)
Example: Calculate the K and L x-ray lines for Ag

\[ E_K = (Z - 1)^2 \cdot 13.6\text{[eV]} \cdot \left(1 - \frac{1}{n_i^2}\right) \]

Ag: \( Z = 47 \)

\[ E_{K\alpha} = 46^2 \cdot 13.6\text{[eV]} \cdot \left(1 - \frac{1}{4}\right) = 21583\text{[eV]} \]

\[ E_{K\beta} = 46^2 \cdot 13.6\text{[eV]} \cdot \left(1 - \frac{1}{9}\right) = 25580\text{[eV]} \]

\[ E_L = (Z - 1)^2 \cdot 13.6\text{[eV]} \cdot \left(\frac{1}{2^2} - \frac{1}{n_i^2}\right) \]

\[ E_{L\alpha} = (46)^2 \cdot 13.6\text{[eV]} \cdot \left(\frac{1}{4} - \frac{1}{9}\right) = 3997\text{[eV]} \]
transition scheme with orbital momentum quantum number

Level splitting occurs due to elliptic orbitals. This introduces fine structure in the atomic light spectrum.
higher accuracy x-ray energies

<table>
<thead>
<tr>
<th>Z</th>
<th>Element</th>
<th>Kα₁</th>
<th>Kα₂</th>
<th>Kβ₁</th>
<th>Lα₁</th>
<th>Lα₂</th>
<th>Lβ₁</th>
<th>Lβ₂</th>
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<tbody>
<tr>
<td>47</td>
<td>Ag</td>
<td>22.163</td>
<td>21.990</td>
<td>24.942</td>
<td>2.984</td>
<td>2.978</td>
<td>3.151</td>
<td>3.348</td>
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</tbody>
</table>

Easy to obtain:  [http://www.med.harvard.edu/jpnm/physics/refs/xrayemis.html](http://www.med.harvard.edu/jpnm/physics/refs/xrayemis.html)
[http://www.csrri.iit.edu/mucal.html](http://www.csrri.iit.edu/mucal.html)

Typical spectra:  [http://ie.lbl.gov/xray/ag.htm](http://ie.lbl.gov/xray/ag.htm)
For using atomic spectroscopy methods we need to excite the atoms of the material that should be analyzed. The decay back to the atomic ground state configuration causes the emission of photons with characteristic energies which can be observed by spectroscopy methods!
Nuclear processes are with us all the time, they generate radiation by conversion of neutrons or protons, by emission of particles or by de-excitation of nuclear structure configurations generated by energy transfer to nuclei.
Natural Radioactivity