X-RAY PRODUCTION

X-Rays are produced by sending high energy electrons into a material.
ACCELERATED CHARGES GIVE OFF RADIATION

The electrons when they encounter the large electric field of the nucleus are accelerated.

The energy the electron looses is radiated as x-ray photons.

The process of producing x-rays in this way is called Bremsstrahlung.
Figure 7–1. The bremsstrahlung interaction.
The smooth parts of the curves represent the Bremsstrahlung x-rays.
Note the large peaks in the curves at about 60 pm and 70 pm.

The x-rays giving these peaks are produced by a different process.

We will explain this process using the energy levels of the Bohr Model but not hydrogen.
Generic Energy Level Diagram

from the N shell

<table>
<thead>
<tr>
<th>( \ell )</th>
<th>( j (\ell \pm 1/2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>5/2</td>
</tr>
<tr>
<td>2</td>
<td>3/2</td>
</tr>
<tr>
<td>1</td>
<td>1/2</td>
</tr>
</tbody>
</table>

M shell  \( n=3 \)

L shell  \( n=2 \)

K shell  \( n=1 \)

\( L_\alpha_2 \)

\( L_\beta_1 \)

\( L_\alpha_1 \)

\( K_\alpha_2 \)

\( K_\alpha_1 \)

\( K'_\beta_1 \)

\( K'_\beta_2 \)

<table>
<thead>
<tr>
<th>( \ell )</th>
<th>( j (\ell \pm 1/2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3/2</td>
</tr>
<tr>
<td>1</td>
<td>1/2</td>
</tr>
<tr>
<td>0</td>
<td>1/2</td>
</tr>
</tbody>
</table>
The figure shows the possible energy levels for an atom. The electron can be in one of those levels. Photons are given off or absorbed when the electron transfer from one to another.

For many electron atoms we assume the inner shells or lower energy levels fill first.

In the figure the

\( n = 1 \) level will have 2 electrons as we saw

\( n = 2 \) level will have 8 electrons

e tc.
NOTE THAT WHEN DISCUSSING X-RAYS THE LEVELS ARE ASSIGNED SYMBOLS K, L, M, N, etc.

The levels are called:

For level $n = 1$ K shell

For level $n = 2$ L shell

For level $n = 3$ M shell

etc.

When electrons are shot with high energy towards a metal Bremsstrahlung x–rays are produced AND electrons interact with the electrons of the metal and eject electrons from the K, L, M, and other shells.
Electrons in the atom then fall from the upper levels to fill the vacancy left by the electron that was ejected.

The atom thus looses energy and the lost energy is given off as a high energy x-ray photon.

The energy of the x-ray given off will be

\[ E \text{ (x-ray)} = E_u - E_l \]

where \( E_u \) is the energy of the upper level and \( E_l \) is the energy of the lower level.
WAVELENGTH OF THE X-RAYS

We can use the Bohr model and what we learned from the Pauli Principle to obtain the wavelengths of the x-rays.

Start with the Rydberg equation

\[ \frac{1}{\lambda} = Z^2 R \left( \frac{1}{n_l^2} - \frac{1}{n_u^2} \right) \]

If high energy electron ejects electron from K level another atomic electron will transfer down to fill the \( n = 1 \) level. If this is from the \( n = 2 \) level we will...
obtain the $K_\alpha$ x–ray.

Remember that Pauli dictates that there are two electrons in the $n = 1$ level.

Therefore when the transition from the upper level ($n = 2$) to the $n = 1$ level occurs there is the charge on the nucleus AND the charge of the remaining electron in the $n = 1$ level.

For $Z$ we must use the net charge

$(Z - 1)$.

Thus
\[
\frac{1}{\lambda_{K\alpha}} = R(Z - 1)^2 \left( \frac{1}{1^2} - \frac{1}{2^2} \right)
\]

Or for transitions from any upper state

\[n = 1, 2, 3, 4, \ldots\]

We get

\[
\frac{1}{\lambda_{K\alpha}} = R(Z - 1)^2 \left( \frac{1}{1^2} - \frac{1}{n_u^2} \right)
\]

Or

\[
\frac{1}{\lambda_{K\alpha}} = R(Z - 1)^2 \left( 1 - \frac{1}{n_u^2} \right)
\]