EE 213 Spring 2002
Homework #2.

Problem #1.

1. \( t_{Be} = 30.5 \text{ nm} \)
   \( t_{Au} = 35 \text{ nm} \)
   \( t_{Si} = 30.5 \text{ nm} \)

A) We could do the calculation from Na to Na, but it seems to check at the lower energies and the higher energies (if needed)
   so we start with the Na Kα X-ray.

There are 3 layers where X-rays get absorbed.

- Be window: \( e^{-\mu t_{Be}} \) (\( \mu \) dead layers)
- Au metal: \( e^{-\mu_{Au} t_{Au}} \) (\( \mu_{Au} \) some doping)
- Si dead layer: \( e^{-\mu_{Si} t_{Si}} \)

Once the get through these layers, they have to be absorbed in the active layers to get detected.

- Probability of absorption: \( 1 - e^{-\mu_{Si} t_{Si}} \)

- Total transmission

\[
T = e^{-\mu_{Be} t_{Be}} e^{-\mu_{Au} t_{Au}} e^{-\mu_{Si} t_{Si}} (1 - e^{-\mu_{Si} t_{Si}})
\]
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Problem #1 (cont.)

1. cont.

so let's look at the Na Kα line, the lowest energy one and most likely to be absorbed in the first 3 layers. E_{Xα}(Na) =

in X-ray absorption tables of NIST, you are given the mean absorption coeff. (μ_A) in cm²/gm

\[ \text{Density of the material} \]

\[ P_{Be} = 1.85 \text{gm/cm}^2 \Rightarrow \mu_{Be} = 1.94 \times 10^{-3} \text{gm/cm}^2 \]
\[ P_{Au} = 19.3 \text{gm/cm}^2 \Rightarrow \mu_{Au} = 6.76 \times 10^{-5} \text{gm/cm}^2 \]
\[ P_{Si} = 2.33 \text{gm/cm}^2 \Rightarrow \mu_{Si} = 7.1 \times 10^{-5} \text{gm/cm}^2 \]

don't bother with active layers yet.

from the NIST tables for E_{Xα} = 1041 eV = 1.041 keV, Na Kα
then look up in NIST tables the mean absorb. coeff. for that energy

\[ \text{(μ)} \text{ cm}^2/\text{gm} \]

you may need Be \( 5.7 \times 10^2 \)
\[ \text{Au} \quad 4.4 \times 10^3 \]
\[ \text{Si} \quad 1.48 \times 10^3 \]

\[ a_{Na} = e^{-A_{Na}} \]
\[ = 0.99 \]

so claim of 90% not true!!
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problem #1 cont

1. cont B. Oxygen Kα X-rays

E_{Kα} = 525 eV from Stehren tables.

The main Lyman series occurs below 1 keV on the NIST tables. And you can
roughly extrapolate and find that

\( \frac{\%}{\%} \sim 10^4 \text{ cm}^2/\text{gm for Be, Au, Si at \sim 5000 \text{ eV} } \)

\( \frac{\%}{\%} \) Pt in oxygen Kα

\[ \begin{align*}
&\text{Be} \quad 19.25 \\
&\text{Au} \quad 2.25 \\
&\text{Si} \quad 6.8
\end{align*} \]

\[ T_0 = e^{-19.25 - 2.25 - 6.8 (\text{m})} = e^{-28.3} \approx 0 ! \]

\[ \text{[Oxygen Kα cannot be detected]} \]
I am afraid that I gave you incomplete information in this problem. I left out the sample thickness and distance the detector was from the sample. So I will describe this problem, but below is the strategy to be taken to solve the problem. Note that the Cliff-Lorimer K factors are only for thin films, you would need the film thickness to figure out the absorption intensities.

Also, the weight concentration is different than the number (atomic) concentration.

\[ S = N \text{ J} \text{ S} \text{ Y} F \]

\[ \frac{N_A}{N_B} = \frac{S_A (6YF)_B}{S_B (6YF)_A} \] \quad \frac{M_A}{M_B} = \frac{N_A A_A}{N_B A_B} \]

\[ C_A = \frac{C_A}{M_A} = \frac{1}{\sum_{j} M_j} \cdot \frac{N_j A_j}{M_A} = \frac{S_j (6YF)_j}{S_B (6YF)_B} \]

In each Kα X-ray, you had to figure out the transmion function of the detector for that X-ray.
2) If we need to make the measure for absorption of the emitted X-ray in the film, we need to add the absorption correction factor.

\[
\frac{M_j}{M_0} = \frac{S_j}{S_0} \frac{(\Delta \lambda)_{j}}{(\Delta \lambda)_{0}} f_a f_j
\]

where \( f_a/ f_j = \frac{1 - (\Delta \lambda)_{A}/(\Delta \lambda)_{j}}{1 - (\Delta \lambda)_{A}/(\Delta \lambda)_{0}} \)

and \( y = \frac{1}{\omega_0} = \sqrt{2} \) in this case.

The secondary fluorescence correction is not needed here.

We proceed by assume no absorption correction. To get the first guess at \( C_j \), then we have to determine \( P \) and recalculate \( (\Delta \lambda)_{A}/(\Delta \lambda)_{0} \) noting that

\[
(P_A)_{\text{sample}} = (P_A)_{\text{AIBA}} \sum_j (P_A)_{\text{AIBA}} C_j
\]

and iterate.
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problem 3.

\[ E_0 = 2 \text{ MeV}, \quad ^4\text{He}^+ \]
\[ \Theta = 165^\circ \]
\[ \beta_{\text{out}} = 15^\circ, \quad \beta_{\text{in}} = 0^\circ \]

Si film on top, so peak is due to the scattering from front and back surface of the Si film.

width of peak, \( \Delta E = 0.15 \text{ MeV} \)

\[ t_{\text{Si}} = \frac{\Delta E}{[S]} \]

where \( [S] = K_{\text{Si}} \left( \frac{dE}{dx} \right) \frac{1}{\left( \frac{dE}{dx} \right)_{\text{out}}} + \left( \frac{dE}{dx} \right)_{\text{in}} \)

\[ [S] = K_{\text{Si}} \left( \frac{dE}{dx} \right)_{\text{out}} + \left( \frac{dE}{dx} \right)_{\text{in}} \]

assuming little change in \( E \) within the Si film

\[ K_{\text{Si}} = 0.62, \quad \frac{dE}{dx} = 2.38 \times 10^2 \text{ MeV} / \text{cm} \] since only 10% energy change.

\[ [S] = 3.99 \times 10^3 \text{ MeV} / \text{cm} \]

\[ t_{\text{Si}} = 0.15 \text{ MeV} / 3.99 \times 10^3 \text{ MeV} / \text{cm} = 0.38 \mu\text{m} = t_{\text{Si}} = 380 \text{ Å} / \]
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Problem 3 (cont)

Now to find out what the substrate is:
it is 3800 Å beneath front interface of Si film.

we measure the 50% point of the rise to be

\[ E_z \approx 1.74 \text{ MeV} \]

\[ E_z = 1.74 \text{ MeV} + 0.15 \text{ MeV} \]

\[ E_B = 1.89 \text{ MeV} \]

\[ k_z = \frac{1.89}{2.0} = 0.94 = k_z \]

If we look at graphs from lecture notes for K vs α
at θ = 160° we see that K = 0.62

Since K won't be much different at θ = 165°,
we conclude substrate is Ta //