Physics with Neutrons I

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Exercise sheet 7

https://wiki.mlz-garching.de/n-lecture06:index

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1. Imaging Basics

In neutron imaging, the transmission of neutron through a sample is determined, which can be used to distinguish between different materials. In many experiments it is sufficient only to consider the neutron absorption in a material. However, there are other cases where this is completely wrong. One prominent example is the comparison between water (Hydrogen) and iron. The respective absorption cross sections are: $\sigma_{abs}^{H} = 0.3326$barn, $\sigma_{abs}^{Fe} = 2.56$barn (for thermal neutrons). In measurements, though, water shows a clearly stronger neutron attenuation. What other factors besides absorption have to be considered? What are their impact on an imaging experiment?

2. Bragg-Imaging

Neutron interaction with matter is generally energy dependent. Scattering and absorption typically increase with increasing neutron wavelength.

- What does this mean for the samples used in an experiment?

- Despite neutrons passing through the sample, the measurement results might be different if we rotate the sample by 180°. What is causing this discrepancy? (Hint: the effect is strongest if we use a broad spectrum of neutrons)

Beside the general trend of neutron attenuation (see Figure below) there might appear sudden jumps at certain energies, which are caused by coherent scattering. These features are used in Bragg imaging, by taking measurements with neutrons slightly above and below a jump energy and comparing the results.

- Why are there no features in the Water curve?

- What is determining the lowest Energy of such a jump. (Hint: it's called Bragg imaging)

- Calculate the lowest jump energy for iron.
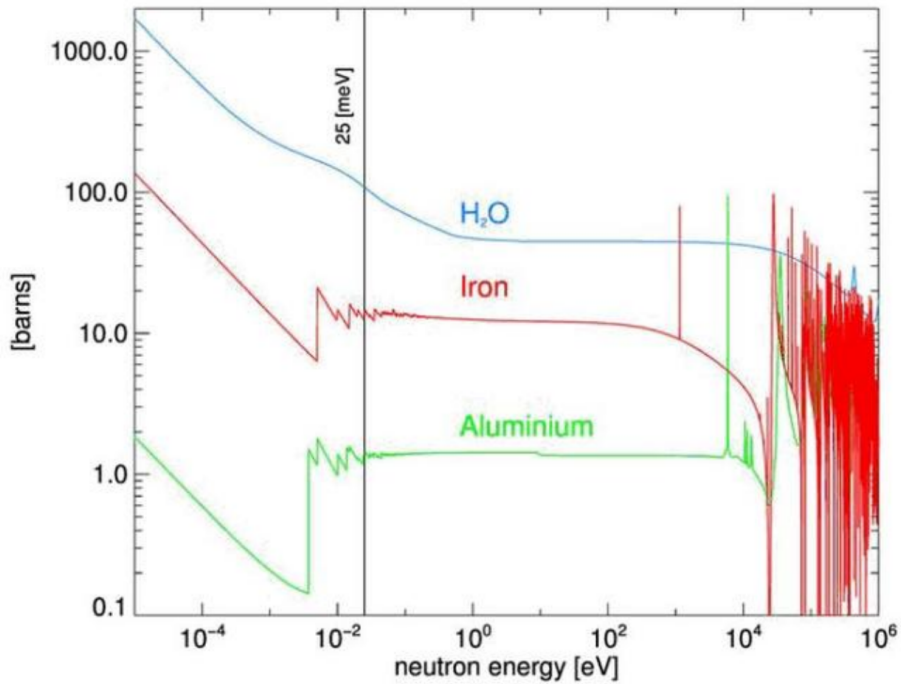
3. Patterson Function

Probably the biggest problem in all scattering experiments is the phase problem: we can only measure the scattering intensity (which is real) instead of the scattering function (which is complex). A way of getting around this problem is the Patterson function which is defined by the Fourier transform of the scattering Intensity:

$$P(\vec{r}) = FT\left(I(\vec{q})\right)$$

which can be obtained by experiment.

The equivalent definition in real space is given by the self correlation of the crystal structure:

$$P(\vec{r}) = \rho(\vec{r}) \otimes \rho(-\vec{r})$$

where ρ is the scattering length density (or electron density in case of X-rays).

Shown below is a possible structure of a brombenzene crystal, which will be used to test the Patterson method from a real space perspective
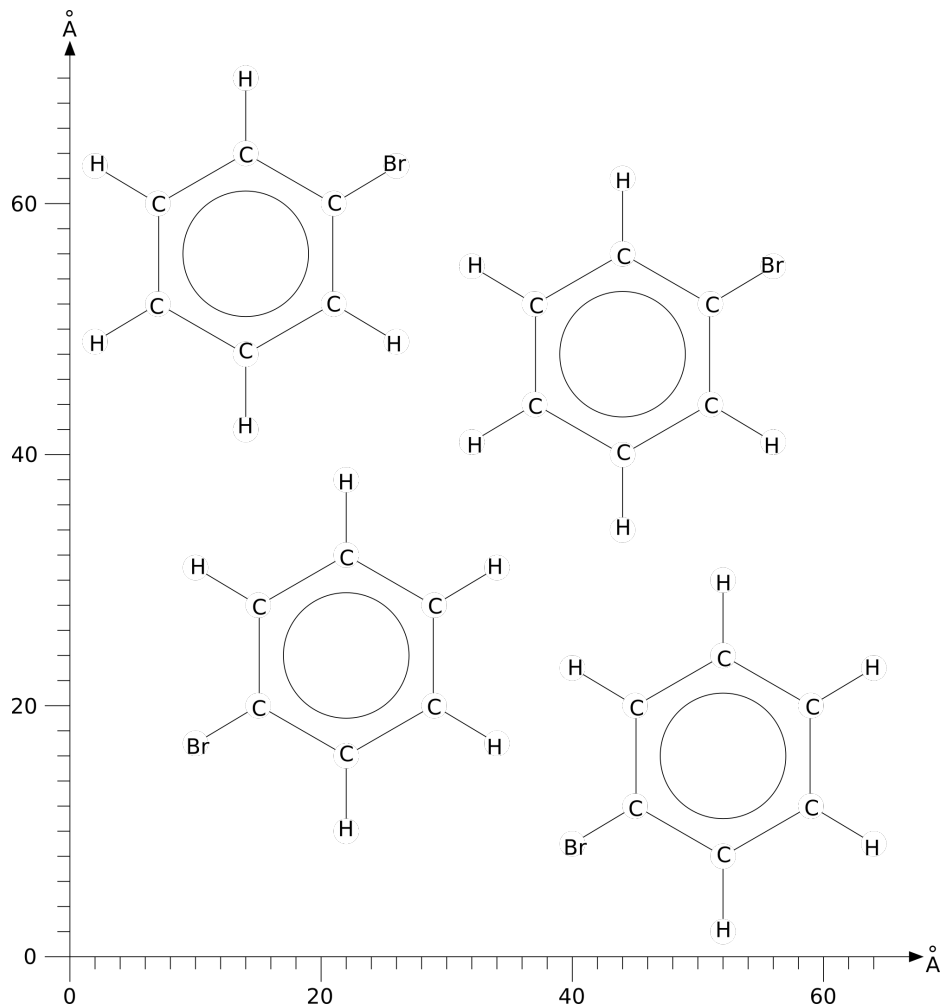
- Choose a unit cell.

- Calculate (compute) the Patterson function for the unit cell (take the positions from the image and assume point like atoms).

- Interpretation of a Patterson function becomes very much easier if one can obtain it for nearly identical crystals by comparing them to each other. Assume a substitution of Br by H (which does noch change the crystal structure) and calculate the Patterson function again.

- Instead of the atomic substitution, could the effect used in Bragg edge imaging be used to change the scattering cross section of one specific atom in the crystal?

- Subtract one Patterson function from the other and interpret the result.