Neutron Scattering

Neutron scattering as a powerful tool in Solid State Chemistry. It is the technique of choice for condensed matter investigations in general because thermal/cold neutrons do not damage the investigated sample.

Why neutron?

- Wavelength in atomic distance
- No regular or rapid increase in the scattered intensities with the atomic number
- Different experimental results for different isotopes of the same element
 - $(b_{H} = -3.739 * 10^{-13} \text{cm} \qquad b_{D} = 6.671 * 10^{-13} \text{cm}$)
- Interaction between the magnetic moment of the neutron and that of atom
- Kinetic energy of thermal neutrons are in the same range of as the energies of lattice vibrations

Some properties of Neutron:

- It has no electric charge but has magnetic moment
- Subatomic particle with the mass of 1,674 .10⁻²⁷ kg
- Free neutrons are unstable but Bonded neutrons in a stable nuclei are stable
- Neutron Spin: ½
- Short range nuclear force(10⁻¹⁵m)
- $\lambda_{thermal} \sim 10^{-10} m$

Neutron Production :

- Research reactors
- □ Spallation sources

Research reactors :

- A kind of nuclear reactors but simpler than power reactors
- Mechanism: The "chain reaction"
- Neutron captured by Heavy elements and fission into lighter elements , under emission of neutrons , γ-rays and kinetic energy.

$$n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U$$

$${}^{236}_{92}U \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3n + 177MeV$$

Spallation sources :

- Spallation is a process in which fragments of materials (spall) are ejected from a body due to collision or stress
- The bullet: high energy species, such as proton(1 to 2 GeV)
- The target: heavy metal, such as Mercury and Tantalum
- 20 to 30 neutrons are generated per impact

Principle of Neutron Scattering :

- In Inelastic Scattering energy transfer from neutron to nucleus .
- In Elastic Scattering no energy transfer, neutron have the same energy after collusion.
- Mostly Inelastic Scattering for measuring structures and magnetic properties is used.
- Cold and thermal neutrons have wavelengths in the scale of atomic distances that makes them available for scattering experiments.

Some types of neutron scattering :

- □ Neutron triple axis spectrometry (TAS)
- Neutron backscattering
- □ Neutron time of flight scattering
- Neutron spin echo
- □ Neutron resonance spin echo

Comparison between X-Ray and Neutron Scattering

- □ Scattering experiments are in general similar to each other. Detecting the lattice structure.
- □ X-rays interact mainly with the electrons in the matter, Neutrons collide with the Nuclei via

the very short- range strong nuclear force and if there are unpaired electrons in the material, neutrons may also interact by a second mechanism: a dipole-dipole interaction between the magnetic moment of the neutron and the magnetic moment of the unpaired electron.

- □ Neutrons Penetrate deep into the matter than X-Ray radiation
- □ Neutron scattering is expensive and difficult to handle because of large facilities X-ray is cheap and easy to handle.
- □ Wavelength of X-rays and Neutrons can be both in the scale of atomic distances (~20-250pm)
- □ X-rays it is easiest to see atoms that have many electrons. However, Hydrogen, for example, which has only one electron, is not easy to see. With neutrons, nearly all kinds of atoms are visible.

How do we distinguish nuclear scattering from magnetic scattering?

- □ They normally occur at different wave vectors
- □ Magnetic scattering is temperature dependent while nuclear scattering is not
- □ Using polarized neutrons we could get spin flipping for magnetic scattering

<u>References</u>

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