

# SCATTERING NEUTRONS

When neutrons collide with a material, they are scattered by its atoms. Neutron detectors record the neutron's change in direction and collect a diffraction pattern. This works because the neutron wavelength is similar to the separation between atoms.

## Where Atoms Are

The positions and strengths of the peaks in the diffraction pattern are used to determine the atomic arrangement of the material.



In 1932 James Chadwick discovered the missing atomic particle. The particle, called a neutron, has no charge, the same mass as the proton and a spin. It therefore interacts with matter in a unique way.

Quantum mechanics tells us that particles can behave like light waves and vice versa, a principle known as wave-particle duality. A particle of energy,  $E$ , and mass,  $m$ , has a momentum,  $p$ , (where  $E=p^2/2m$ ) and an associated wavelength,  $\lambda$ , given by  $p=h/\lambda$ . Consequently a neutron near room temperature will typically have an energy of  $\sim 40\text{meV}$  and a wavelength of  $\sim 0.15\text{nm}$ .

The neutron may also lose or gain energy from the material during scattering. This may cause or cancel oscillations within the material called phonons. This is effective because neutron and phonon energies are similar.

## What Atoms Do

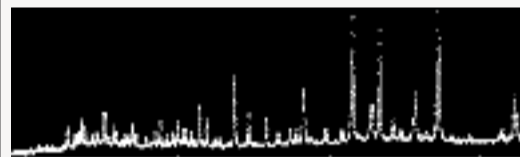
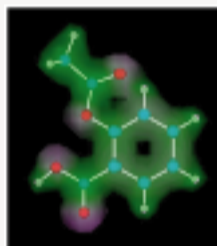
The inelastic scattering of neutrons is used to probe all kinds of dynamic processes in materials, including changes in the magnetic response.



The 1994 Nobel Prize for Physics was awarded to Clifford Schull and Bertram Brockhouse for pioneering work using neutron scattering to determine where atoms are and what they do.



Even hydrogen atoms may be located using neutron diffraction patterns, something which is difficult to do using x-rays.

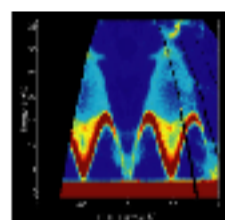


ISIS



ISIS, the world's most intense Spallation Neutron Source is 20 miles south of Oxford.

The neutron's spin can also interact with the spin arrangement of a magnetic material. Therefore, scattering experiments can also be used to determine the magnetic structures and magnetic responses of ferromagnets, anti-ferromagnets as well as more complex magnetic systems.

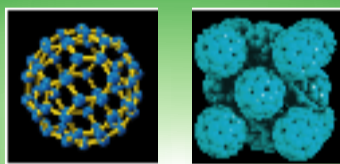


Characteristic inelastic neutron scattering signals are used to determine magnetic fluctuations.

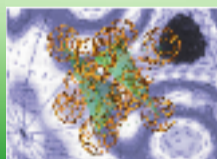


Neutrons are typically produced via nuclear fission in a nuclear reactor or through spallation, whereby a high energy proton chips neutrons from a heavy atom.

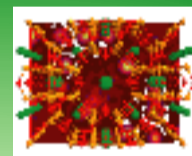
## Structure of $C_{60}$



The structure of carbon-60 was determined using neutron diffraction.



New batteries



Zeolites



Liquid Crystals

## Many Varied Applications

Physicists in Oxford work in many of these areas using neutron scattering facilities all over the world.



Superconductors



Water in proteins



Drug molecules

If you want to know more about Physics at Oxford see the web: <http://www.physics.ox.ac.uk/>