TRANSVERSE AND ZERO FIELD μSR IN COPPER

Introduction:

This experiment uses muons to mimic the behaviour of protons. Both adopt interstitial sites in a metal lattice:

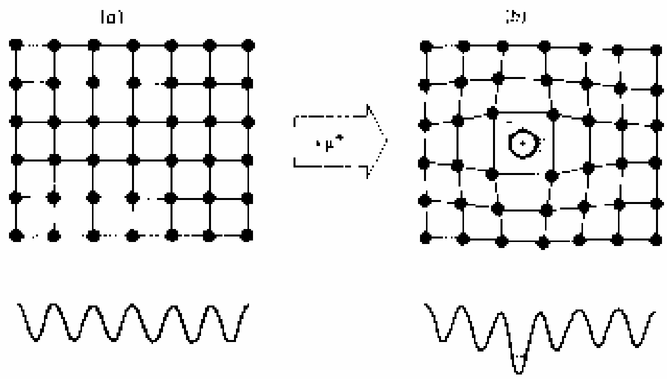

Figure 34. Self-trapping or localisation of muons or protons in metals. In the perfect lattice, the interstitial potential (as measured by a probe that does not perturb its surroundings) is periodic (*a*). The distortion of the lattice on introduction of a charged interstitial impurity, and the consequent lowering of the potential of the occupied site are illustrated in (*b*).

There is a local accumulation of charge density which screens the muon potential, and a small elastic distortion of the lattice. Of interest is how hydrogen diffuses so rapidly from one interstitial site to the next.

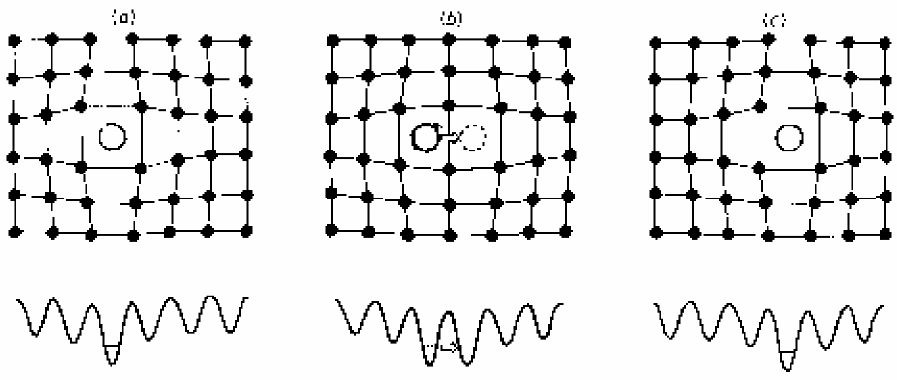

Figure 35. The elemental step in intrinsic diffusion via phonon-assisted tunnelling. Thermal fluctuations provide a favourable intermediate configuration, (*b*), for tunnelling between initial and final states, (*a*), (*c*).

Copper is a good example of a metal where hydrogen itself is too insoluble to allow study by conventional techniques.

Outline of experiment:

- This experiment uses an Oxford Instruments "Optistat" continuous-flow cryostat, with exchange gas around the sample.

- Mount the copper sample in the cryostat, set the exchange gas pressure, and start cooling. Refer to the DEVA manual for details.

- As the sample is much larger than the beam spot, the slit setting can be chosen to give a suitable counting rate. 25-30 Mevents per hour is reasonable.

- Record spectra in a transverse 20 gauss field for a series of temperatures from 280K to 40K, in steps of about 40K, with about 5-10 M events per point. Plot the damping parameter as a function of temperature. Consider and explain the form of this plot.

- Note the change in the line shape from Lorentzian to Gaussian as the temperature is decreased. Above 100K fit the data using the Abragam function to extract the hop rate. Hence determine the activation energy using the Arrhenius model: $\tau_c = \tau_0 \exp(E_a / kT)$.

- At low temperature (40K) and zero field look for the Kubo-Toyabe function – take about 15-20 Mevents to show the recovery to 1/3 at long times.

- Now cool to base temperature (4K) and repeat the zero field measurement. Explain the difference.

- Overnight, attempt a muon level crossing experiment. Work at about 40K, scanning longitudinal field from 0 to 150 gauss in steps of about 10 gauss. You may wish to use smaller steps in the region of the resonance (see figure 13 in reference 1) or two interleaved scans to provide insurance against beam failure. Analyse the level-crossing data using both integral counting and a suitable relaxation function.

References (provided):

1. R. Kadono et al, 'Quantum diffusion of positive muons in copper' Phys Rev B **39** 23-41 (1989)
2. SFJ Cox 'Detection of Quadrupole Interations by Muon Level Crossing Resonance' 1991 RAL report: RAL-91-096. or Z. Naturforsch. **47a** 371-381 (1992)

James Lord
February 2005