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the wavelength resolution is determined by the monochromator, whereas the timing and moderator characteristics determine the wavelength resolution on a time-of-flight instrument. Although the second term in equation (2.9.5.1) is standard in scattering, it has a unique characteristic, in that the angular divergence of the reflected beam determines the resolution. This is the case because the sample is a δ-function scatterer, so that the angle of the incident beam can be determined precisely by knowing the reflected angle (Hamilton, Hayter & Smith, 1994). For a more complete description of both types of neutron reflectometry instrumentation, see Russell (1990).

2.9.6. Resolution in real space

From Fig. 2.9.2.3, the period δQ of the reflectivity oscillation (in the region where the Born approximation becomes valid, sufficiently far away from the critical angle) is inversely proportional to the thickness t of the film. That is, $2\pi/(\delta Q) = t$. Consequently, in order to be able to resolve reflectivity oscillations for a film of thickness t, the instrumental Q resolution ΔQ [from equation (2.9.5.1)] must be approximately $2\pi/t$ or smaller. With sufficiently good instrumental resolution, even the thickness of a film with non-abrupt interfaces can be accurately determined, as demonstrated by the hypothetical case depicted in Fig. 2.9.6.1 (where the instrumental resolution is taken to be perfect): an overall film-thickness difference of 2 Å (between 42 and 40 Å films) is clearly resolved at a Q of about 0.2 Å^{-1}. In practice, differences even less than this can be distinguished. Note, however, that to 'see' more detailed features in the scattering-density profile (such as the oscillation on top of the plateau shown for the long-dash profile in the inset of Fig. 2.9.6.1), other than the overall film thickness, it can be necessary to make reflectivity measurements at values of Q corresponding to 2π/(characteristic dimension of the feature).

2.9.7. Applications of neutron reflectometry

2.9.7.1. *Self-diffusion*

One of the simplest, yet powerful, examples of the use of neutron reflectivity is in the study of self-diffusion. Most techniques to measure diffusion coefficients rely on chemical and mechanical methods to measure density profiles after a sample

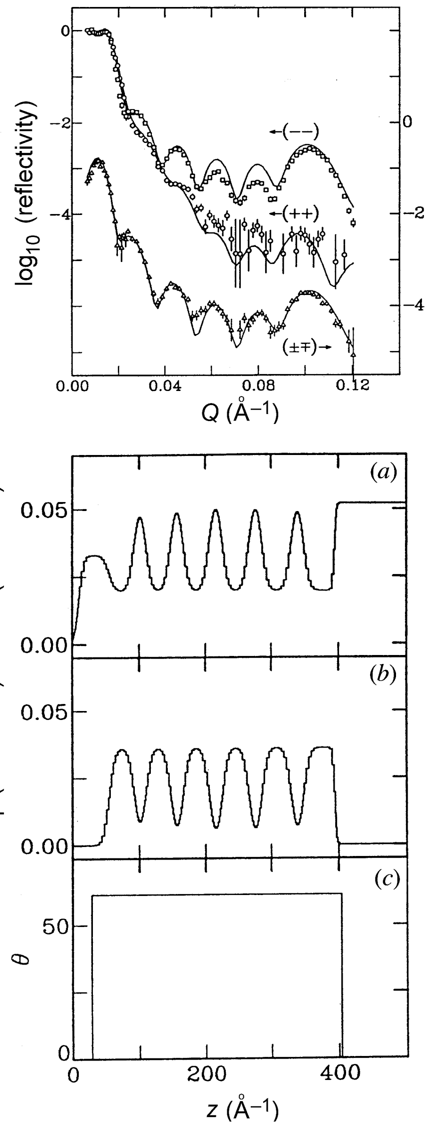
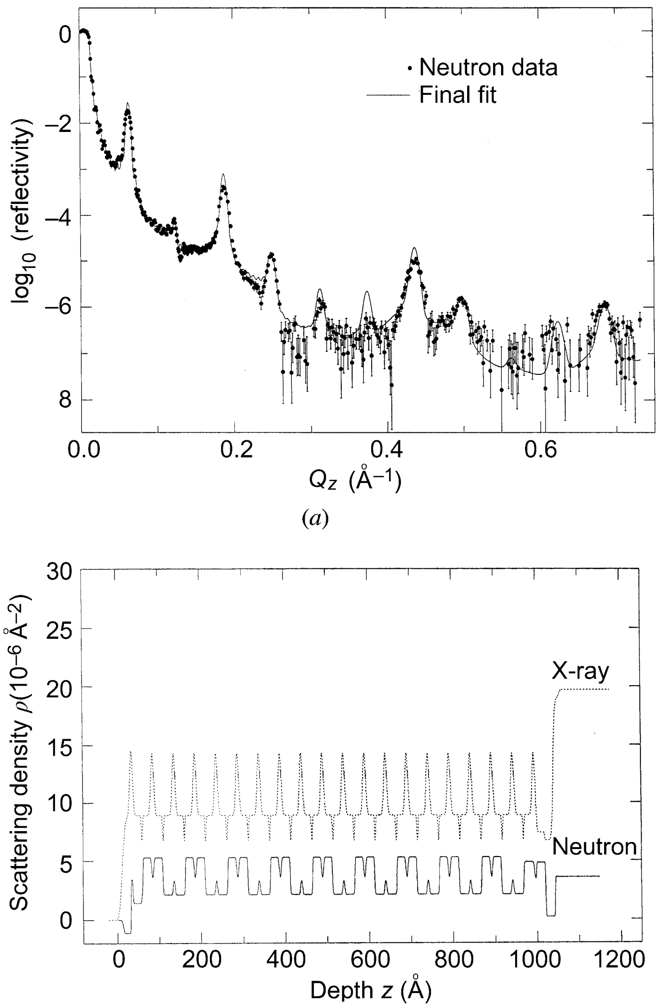


Fig. 2.9.7.3. Co/Cu(111) spin-dependent reflectivities (top). Nuclear (Nb) and magnetic (Np) scattering densities (bottom). Also shown is the (constant) moment direction [after Schreyer *et al.* (1993)].



(*a*)

(*b*)

Fig. 2.9.7.4. (*a*) Measured neutron reflectivity for the Langmuir–Blodgett multilayer described in the text along with the fit. (*b*) Both corresponding neutron and X-ray scattering density profiles. The X-ray reflectivity is more sensitive to the high-Z barium in the head groups whereas the neutron reflectivity can distinguish mixing between adjacent hydrogenated and deuterated hydrocarbon tails [after Wiesler *et al.* (1995)].