Table 4.4.2.3. *Characteristics of some typical elements and isotopes used as neutron filters*

Element or isotope	Resonance (eV)	σ_s (resonance) (barns)	λ (Å)	$\sigma_s(\lambda)$ (barns)	$\frac{\sigma_s(\lambda/2)}{\sigma_s(\lambda)}$
In	1.45	30000	0.48	94	319
Rh	1.27	4500	0.51	76	59.2
Hf	1.10	5000	0.55	58	86.2
^{240}Pu	1.06	115000	9.55	145	793
Ir	0.66	4950	0.70	183	27.0
^{229}Th	0.61	6200	0.73	<100	>62.0
Er	0.58	1500	0.75	127	11.8
Er	0.46	2300	0.84	125	18.4
Eu	0.46	10100	0.84	1050	9.6
^{231}Pa	0.39	4900	0.92	116	42.2
^{239}Pu	0.29	5200	1.06	700	7.4

1 barn $= 10^{-28}$ m^2.

where $F_N(\boldsymbol{\kappa})$ is the nuclear structure factor and $F_M(\boldsymbol{\kappa}) = [(\gamma/2)r_0]\sum_\nu M_\nu f(hkl)\exp[2\pi(hx+ky+lz)]$ is the magnetic structure factor, with $f(hkl)$ the magnetic form factor of the magnetic atom at the position (x, y, z) in the unit cell. The vector $\mathbf{P}$ describes the polarization of the incoming neutron with respect to $\mathbf{B}$; $\mathbf{P} = 1$ for $+$ spins and $\mathbf{P} = -1$ for $-$ spins and $\boldsymbol{\mu}$ is a unit vector in the direction of the atomic magnetic moments. Hence, for neutrons polarized parallel to $\mathbf{B}$ $(\mathbf{P}\cdot\boldsymbol{\mu} = 1)$, the diffracted intensity is proportional to $[F_N(\boldsymbol{\kappa}) + F_M(\boldsymbol{\kappa})]^2$, while, for neutrons polarized antiparallel to $\mathbf{B}$ $(\mathbf{P}\cdot\boldsymbol{\mu} = -1)$, the diffracted intensity is proportional to $[F_N(\boldsymbol{\kappa}) - F_M(\boldsymbol{\kappa})]^2$. The polarizing efficiency of the diffracted beam is then

$$P = \pm 2F_N(\boldsymbol{\kappa})F_M(\boldsymbol{\kappa})/[F_N(\boldsymbol{\kappa})^2 + F_M(\boldsymbol{\kappa})^2], \qquad (4.4.2.10)$$

which can be either positive or negative and has a maximum value for $|F_N(\boldsymbol{\kappa})| = |F_M(\boldsymbol{\kappa})|$. Thus, a good single-crystal polarizer, in addition to possessing a crystallographic structure in which F_N and F_M are matched, must be ferromagnetic at room temperature and should contain atoms with large magnetic moments. Furthermore, large single crystals with 'controllable' mosaic should be available. Finally, the structure factor for the required reflection should be high, while those for higher-order reflections should be low.

None of the three naturally occurring ferromagnetic elements (iron, cobalt, nickel) makes efficient single-crystal polarizers. Cobalt is strongly absorbing and the nuclear scattering lengths of iron and nickel are too large to be balanced by their weak magnetic moments. An exception is ^{57}Fe, which has a rather low nuclear scattering length, and structure-factor matching can be achieved by mixing ^{57}Fe with Fe and 3% Si (Reed, Bolling & Harmon, 1973).

In general, in order to facilitate structure-factor matching, alloys rather than elements are used. The characteristics of some alloys used as polarizing monochromators are presented in Table 4.4.2.4. At short wavelengths, the 200 reflection of $Co_{0.92}Fe_{0.08}$ is used to give a positively polarized beam [$F_N(\boldsymbol{\kappa})$ and $F_M(\boldsymbol{\kappa})$ both positive], but the absorption due to cobalt is high. At longer wavelengths, the 111 reflection of the Heusler alloy Cu_2MnAl (Delapalme, Schweizer, Couderchon & Perrier de la Bathie, 1971; Freund, Pynn, Stirling & Zeyen, 1983) is commonly used, since it has a higher reflectivity and a larger d spacing than $Co_{0.92}Fe_{0.08}$. Since for the 111 reflection $F_N \approx -F_M$, the diffracted beam is negatively polarized. Unfortunately, the structure factor of the 222 reflection is higher than that of the 111 reflection, leading to significant higher-order contamination of the beam.

Other alloys that have been proposed as neutron polarizers are $Fe_{3-x}Mn_xSi$, $^7Li_{0.5}Fe_{2.5}O_4$ (Bednarski, Dobrzynski & Steinsvoll, 1980), Fe_3Si (Hines *et al.*, 1976), Fe_3Al (Pickart & Nathans, 1961), and $HoFe_2$ (Freund & Forsyth, 1979).

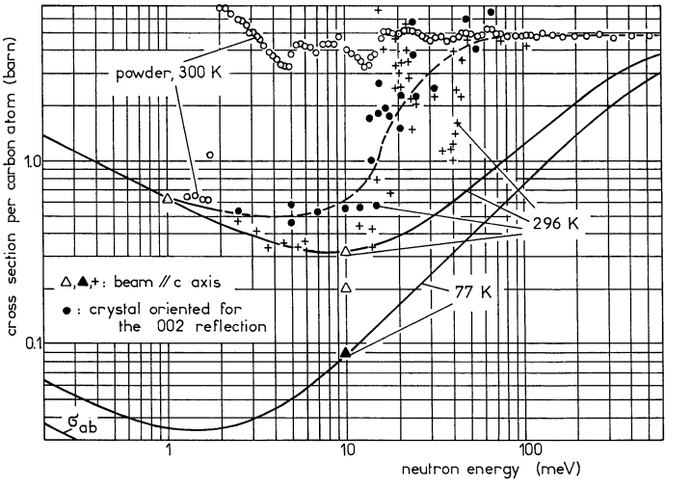

Fig. 4.4.2.8. Energy-dependent cross section for a neutron beam incident along the c axis of a pyrolytic graphite filter. The attenuation peaks due to the 00ξ reflections can be seen.

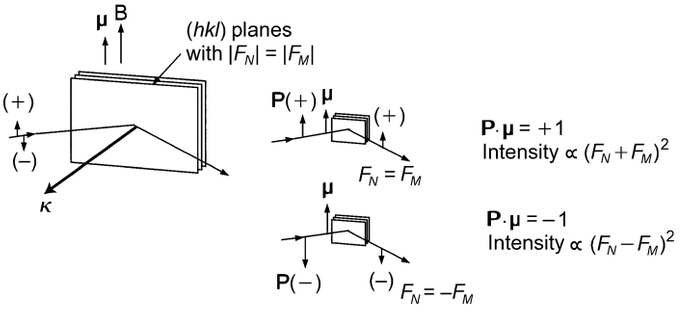

Fig. 4.4.2.9. Geometry of a polarizing monochromator showing the lattice planes (hkl) with $|F_N| = |F_M|$, the direction of $\mathbf{P}$ and $\boldsymbol{\mu}$, the expected spin direction and intensity.

references