Total Reflection of Neutrons on Cobalt

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ATTENTION has recently been called to the possibility of producing polarized neutron beams by reflection from magnetized iron mirrors.[1] The indices of refraction differ for the two neutron spin states, since their magnetic scattering amplitudes are opposite in sign. The resultant difference in critical angle of total reflection can be used to separate the spin components.

For Fe, the coherent nuclear amplitude exceeds the magnetic amplitude, so that the index of refraction is less than one for both spin states, and both are capable of total reflection. Since the critical angle is proportional to neutron wavelength, two wave-lengths (one for each spin state) will overlap. This circumstance prevents attainment of complete polarization, since intensity requirements dictate the use of a fairly broad band of neutron energies.

It is interesting to note that by reflecting neutrons from a cobalt mirror magnetized along the beam direction one can obtain an exact analog of the Nicol prism. The coherent scattering cross section of Co is $\sim$1.8 barns[2] compared to 10.3 barns for Fe. At the same time, the magnetic amplitude for Co is $\sim 4.6\times10^{-13}$ cm, which is only slightly below the value 6.0×10^{-13} for Fe, so that for Co the magnetic amplitude *exceeds* the nuclear amplitude. Consequently, the refractive indices for the two spin states lie on opposite sides of unity for *all* wave-lengths, and only one of the spin components is capable of undergoing total reflection. With an arbitrarily broad spectrum of incident neutrons, the mirror will reflect a completely polarized beam.

D. J. Hughes and his associates are now conducting reflection experiments with Fe and Co.

[1] O. Halpern, Phys. Rev. **75**, 343 (1949).
[2] C. G. Shull and E. O. Wollan, unpublished.

On the "Magic Numbers" in Nuclear Structure

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A SIMPLE explanation of the "magic numbers" 14, 28, 50, 82, 126 follows at once from the oscillator model of the nucleus,[1] if one assumes that the spin-orbit coupling in the Yukawa field theory of nuclear forces leads to a strong splitting of a term with angular momentum l into two distinct terms $j=l\pm\frac{1}{2}$.

If, as a first approximation, one describes the field potential of the nucleons already present, acting on the last one added, as that due to an isotropic oscillator, then the energy levels are characterized by a single quantum number $r=r_1+r_2+r_3$, where r_1, r_2, r_3 are the quantum numbers of the oscillator in 3 orthogonal directions. Table I, column 2 shows the multiplicity of a term with a given value of r, column 3 the sum of all multiplicities up to and including r. Isotropic anharmonicity of the potential field leads to a splitting of each r-term according to the orbital angular momenta l (l even when r is odd, and vice versa), as in Table I, column 4. Finally, spin-orbit coupling leads to the l-term splitting into $j=l\pm\frac{1}{2}$, columns 5 and 6, whose multiplicities are listed in column 7.

The "magic numbers" (column 8) follow at once on the assumption of a particularly marked splitting of the term with the highest angular momentum, resulting in a "closed shell structure" for each completed r-group, together with the highest j-term of the next succeeding r-group. This classification of states is in good agreement with the spins and magnetic moments of the nuclei with odd mass number, so far as they are known at present. The anharmonic oscillator model seems to us preferable to the potential well model,[2] since the range of the nuclear forces is not notably smaller than the nuclear radius.

A more detailed account will appear in three communications to Naturwissenschaften.[3]

TABLE I. Classification of nuclear states.

1 Oscillator-quantum number r	2 Multiplicity	3 Sum of all multiplicities	4 Orbital momentum l	5 Total angular momentum j	6 l_j-symbol	7 Multiplicities	8 Magic numbers
1	2	2	0	1/2	$s_{1/2}$	2	
2			1	3/2	$p_{3/2}$	4	
	6	8		1/2	$p_{1/2}$	2	
3			2	5/2	$d_{5/2}$	6	14
				3/2	$d_{3/2}$	4	
	12	20	0	1/2	$s_{1/2}$	2	
4			3	7/2	$f_{7/2}$	8	28
				5/2	$f_{5/2}$	6	
			1	3/2	$p_{3/2}$	4	
	20	40		1/2	$p_{1/2}$	2	
5			4	9/2	$g_{9/2}$	10	50
				7/2	$g_{7/2}$	8	
			2	5/2	$d_{5/2}$	6	
				3/2	$d_{3/2}$	4	
	30	70	0	1/2	$s_{1/2}$	2	
6			5	11/2	$h_{11/2}$	12	82
				9/2	$h_{9/2}$	10	
			3	7/2	$f_{7/2}$	8	
				5/2	$f_{5/2}$	6	
			1	3/2	$p_{3/2}$	4	
	42	112		1/2	$p_{1/2}$	2	
7			6	13/2	$i_{13/2}$	14	126
				11/2	$i_{11/2}$	12	
			4	9/2	$g_{9/2}$	10	

[1] See, e.g., H. A. Bethe and R. Bacher, Rev. Mod. Phys. **8**, 82 (1937), pars. 32–34.
[2] Which anyhow does not lead to a very different term-sequence compared with that of an anharmonic oscillator, see reference 1.
[3] (a) Haxel, Jensen, and Suess, Naturwiss. (in press). (b) Suess, Haxel, and Jensen, Naturwiss. (in press). (c) Jensen, Suess, and Haxel, Naturwiss. (in press).

Concerning the Abundance of Atmospheric Carbon Monoxide

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IN October of 1941 the 4.7-micron region of the solar spectrum was examined by the author at the Lowell Observatory, Flagstaff, for evidence of the carbon monoxide fundamental. The observation was made with a 2400-lines/inch grating in an $f/5$-Pfund type spectrometer of focal length 30 inches. Galvanometer deflections were recorded photographically. The solar spectrum was compared with laboratory observations,[1] but no conclusive evidence could be deduced for the existence of spectroscopically detectable quantities of carbon monoxide in the atmosphere above the observatory. The adequacy of the solar spectrum can be judged from the fact that carbon dioxide fine structure (some of it since traced to ν_3 of $C^{13}O_2^{16}$), which is twice as difficult to resolve as carbon monoxide fine structure, was abundantly present and clearly resolved.

One notes with interest, therefore, Migeotte's recent observation of the carbon monoxide fundamental as a prominent feature in the solar spectrum at Columbus, Ohio.[2]

The purely local nature of atmospheric abundance of carbon monoxide is emphasized by its absence over Flagstaff,