suggestions and for the development of methods which were useful in the chemical separations.

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A Lower Bound on the Range of Neutron-Proton Interaction

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THE electric quadrupole moment of the deuteron is given by the expression

$$Q=(2^{\frac{1}{2}}/10)\int_0^{\infty} r^2 w(u-w/8^{\frac{1}{2}})dr \Big/ \int_0^{\infty}(u^2+w^2)dr \qquad (1)$$

when the ordinary and tensor forces are assumed to exist. It will be shown here that this formula will not yield a value of Q as large as the experimental value unless the largest range of interaction r_0 is greater than 0.39 e^2/mc^2 regardless of the shapes and relative sizes of u and w for $r<r_0$ provided they are required to be real. In this formula, u and w are, respectively, r times the S and D radial wave functions for the bound state of the deuteron.[1]

Beyond r_0, u and w have the forms

$$\begin{aligned} u&=C\exp(\alpha r_0-\alpha r)\\ w&=D(\alpha r)^{-2}(\alpha^2r^2+3\alpha r+3)\exp(\alpha r_0-\alpha r), \end{aligned} \qquad (2)$$

where $\alpha=|E_0|^{\frac{1}{2}}$, E_0 is the binding energy of the deuteron, and C and D are arbitrary constants. The functions from $r=0$ to r_0 (as yet undetermined) may be represented by step functions of step widths Δr. The integrals employed in Eq. (1) will now be represented by the following symbols:

$$\begin{aligned} A&=\int_{r_0}^{\infty} r^2w(u-w/8^{\frac{1}{2}})dr\\ B&=\int_{r_0}^{\infty}(u^2+w^2)dr\\ a_i&=\int_{r_i-\Delta r}^{r_i} r^2w(u-w/8^{\frac{1}{2}})dr\approx r_i^2w_i(u_i-w_i/8^{\frac{1}{2}})\Delta r\\ b_i&=\int_{r_i-\Delta r}^{r_i}(u^2+w^2)dr\approx(u_i^2+w_i^2)\Delta r. \end{aligned} \qquad (3)$$

It is now desired to find the maximum possible value of the expression,

$$Q=\frac{2^{\frac{1}{2}}}{10}\frac{\sum_{i=1}^{n}a_i+A}{\sum_{i=1}^{n}b_i+B}, \qquad (4)$$

where n is the number of intervals of width Δr from $r=0$ to $r=r_0$. Consider the contribution to Q from any interval, say the jth interval. The contributions of the integrals over this interval will increase or decrease Q depending upon whether or not a_j/b_j is greater than or less than the remainder of Q as given by Eq. (4) with the jth interval omitted from the sums. If the contribution of the jth interval decreases Q, it may be eliminated by setting u_j and w_j equal to zero. Thus an upper bound for Q may be obtained by setting u and w equal to zero in all intervals except the one with the largest value of a_i/b_i or A/B (since the interval from r_0 to ∞ may be included in the argument).

The value of a_i/b_i may be obtained from Eq. (3) and it is seen that a_i/b_i may be maximized by varying u_i/w_i. The maximum occurs when $u_i/w_i=2^{\frac{1}{2}}$ and is $r_i^2/8^{\frac{1}{2}}$. Thus, the largest value of a_i/b_i occurs for $r_i=r_0$ and is $r_0^2/8^{\frac{1}{2}}$. It is also clear from Eq. (2) that A/B is a function of C/D, r_0, and α. Choosing C/D to give a maximum value for A/B makes it possible to obtain an upper bound for $Q=(2^{\frac{1}{2}}/10)(A/B)$ equal to the experimental value[2] of Q, which is 2.73×10^{-27} cm^2 when r_0 is 0.39 e^2/mc^2 and E_0 is 2.17 Mev. For this value of r_0, $(2^{\frac{1}{2}}/10)(r_0^2/8^{\frac{1}{2}})=0.49\times10^{-27}$ cm^2 so that (A/B) is greater than (a/b). For smaller values of r_0 the maximum value of $(2^{\frac{1}{2}}/10)(A/B)$ is less than 2.73×10^{-27} cm^2 so that it is certain that if Eq. (1) is correct for Q and if u and w are real, then the experimental value of Q requires that the neutron-proton interaction be appreciable at a distance of separation of at least 0.39 e^2/mc^2.

It is interesting to note that the minimum value of r_0 obtained by Hu and Massey,[3] using square wells and assuming equal range for the tensor and ordinary forces, was about 0.46 e^2/mc^2; and the minimum value obtained by Schwinger,[4] again assuming equal ranges for the tensor and ordinary forces and, further, that not more than five percent D wave is present, was about 0.93 e^2/mc^2.

Recent changes in the experimental values of E_0 and Q are not large enough to alter these conclusions significantly.

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Theory of Magnetic Properties and Nucleation in Alnico V

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ALNICO V is a permanent magnet alloy containing by weight 8Al, 14Ni, 24Co, 3Cu and 51Fe, with the unique property among conventional magnet alloys that the energy product $(BH)_{\max}$ is increased by heat treatment in a magnetic field from 1.8×10^6 ergs/cc with $H_t=0$ to 5×10^6 ergs/cc after treatment with $H_t\sim1000$ oersteds. After treatment, the remanence, coercivity, magnetostriction, loop shape, and approach to saturation are all characteristic[1,2] of anisotropic materials, and the anisotropy of the electrical resistivity[3] establishes that the treatment affects other than purely magnetic properties. A means whereby magnetic effects may control nucleation and produce the observed anisotropy and other properties is proposed below.

Alnico V is cooled from 1300°C, at which it is stable as a single phase, at about 2 to 5°C/sec. to 600°C with $H_t\sim1000$ oersteds; H_t is effective in the range from 900°C to 800°C. We have found that if the alloy is quenched from 800°C the anisotropic properties are already fully developed, although the coercivity H_c is only 10 oersteds. Further aging at 600°C increases H_c to 600 oersteds. H_t has no effect during the 600°C treatment.

We propose that at 800°–900°C thermal nucleation[4] occurs in the form of plate-like precipitates with a lattice coherent with the matrix, an assumption supported by the small difference 0.10 percent of precipitate and matrix lattice constants.[5] The good coherence means that the surface free energy of the nucleus is unusually small, perhaps equal to the energy of an order-disorder transformation in a layer 2A thick or about 10 ergs/cm^2 (as compared to approximately 1000 ergs/cm^2 for a grain boundary). Estimating equally roughly the energy barrier for a critical nucleus as 5×10^{-12} erg from the slope of log (optimum treatment time at fixed temperatures between 800 and 900°C) *vs.* $1/T$, we obtain a diameter of about 100A for a disk-shaped nucleus leading to a volume of approximately 10^{-19} cm^3 for a 10A thickness.

If the precipitate, whose exact nature is unknown, is magnetically different at 800–900°C from the matrix so that $\Delta I_s=500$ gauss, then a nucleus with H_t perpendicular to its plane will have a demagnetizing energy of $(\Delta I_s)^2NV/2\approx1.5\times10^{-13}$ erg and will be suppressed by a factor of e^{-1} compared to nuclei with H_t in their planes. This rough estimate shows that demagnetization energy could control nucleation so that only those nuclei with planes $\|\Delta I_s\|H_t$ would form, consistent with results on the sample quenched from 800°.

At 600°C elastic energy and concentration gradients will continue the growth of the nuclei on the predetermined planes independent of H_t. Maximum magnetic hardness apparently corresponds to initiation of an optimum number of nuclei between 800° and 900°C and growth of the precipitate in plates at 600°C which divide the matrix into plate and rod-like units whose shortest dimensions may be 100 to 1000A, so that they will behave as single ferromagnetic domains.

The coercive force presumably may be accounted for by the crystalline and magnetostatic anisotropy energy of the matrix units: the plate-like part of the volume will have $H_c=2K/I_s$, requiring a K of only $\sim 5\times 10^5$ ergs/cc, which is not unreasonable; additional coercivity of $\sim 2\pi p\Delta I_s(20°C)$ from the rods may be important for reasonable values of ΔI_s and p, the fractional volume of precipitate.

The above theory does not require internal strains to have an important effect on the coercive force, and is in keeping with the fact that the disregistry strain of the transition lattice[5] is unusually small in Alnico V as compared with other permanent magnet alloys; further, on geometrical grounds it seems likely that the plate-like portion of the volume should be under large loading with symmetry axis normal to the plates. This gives no contribution to the coercive force if the magnetostriction is isotropic; if the magnetostriction is anisotropic, as in Ni, a strain of 0.1 percent (the disregistry strain) will give a small directional anisotropy in the plane of the plate, but in Ni this would only be about 2×10^4 ergs/cc, and it seems unreasonable to suppose a 25 times larger value in Alnico V.

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The Thermal Neutron-Capture Cross Section of A^{36}

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The thermal neutron-capture cross section of A^{36} has been measured as 6.5 ± 1.0 barns. Approximately 500 cc (N.T.P.) of commercial argon were sealed in a boron-free glass flask and irradiated in the thermal column of the N.R.X. pile for one hour. The neutron flux through the gas was measured with manganese foils and found to be 8.6×10^9 neutrons/cm²/sec. These foils had been calibrated[1] by irradiating them in a neutron flux, the value of which was measured by means of a small pulse ion chamber filled with a known amount of BF_3. The neutron flux through the argon was thus based on the neutron-capture cross section of boron, the number of boron atoms in the ion chamber and the counting rate. The experimental error is given as 3.5 percent.

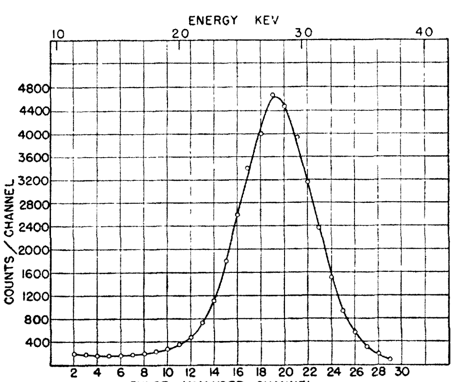

Fig. 1. Activity caused by K-capture in A^{37}.

It was found by comparing foils irradiated inside and outside of a similar glass flask that neutron absorption in this glass was negligible.

After removal of the flask from the reactor, the 110-minute A^{41} activity was allowed to decay through forty half-lives before introducing an accurately measured pressure (10.58 cm) of the irradiated gas into a proportional counter[2] preparatory to counting the A^{37} activity. The pulses from the counter were suitably amplified and fed to a thirty-channel pulse analyzer in parallel with a commercial scaler. (The latter served as a check on the total number of counts.)

The operation of the counter and the location of the 2.8 kev K-capture peak of A^{37} were checked by comparing the amplitude of the argon pulses with those produced by a beam of 17.4 kev x-rays (Mo $K\alpha$ line, selected by a crystal spectrometer). A typical run is shown in Fig. 1. The fraction of K-capture radiation which escapes from the counter must be allowed for, and has been estimated as 4.5 percent. Moreover, there is a low energy tail associated with the K-capture peak due to the reduced field strength at the ends of the counter. This tail must be extrapolated down to zero pulse size and its contribution added to the counting rate. The active volume of the counter (130.2 cc) was taken as the volume enclosed by the cylindrical cathode. It should be noted that the measurements do not extend below 1.2 kev and thus the L-capture radiation was not included. The contribution from L-capture has been measured by Pontecorvo, Kirkwood, and Hanna[2] as between 8 and 9 percent and calculated by Rose and Jackson[3] as 8.2 percent. A correction of 8.5 percent is applied.

The activity thus determined was corrected back to zero decay time using a half-life value of 34.1 days[4] for A^{37}. The calculation of the cross section was based on an isotopic abundance of 0.307 percent for A^{36}. The error shown in the value of the cross section 6.5 ± 1.0 barns is the standard error. We thank Mr. G. C. Hanna for putting his apparatus at our disposal and for valuable help with the experiment.

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Temperature Dependence of Microwave Line Widths*

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In their pioneering work on the pressure broadening of the ammonia inversion spectrum, Bleaney and Penrose[1] assumed that the cross section σ for collisions interrupting the microwave radiation or absorption was independent of the average velocity of impact $\bar{v}$. Although the agreement between their data and theory is actually independent of any possible variation of σ with $\bar{v}$, their assumption has crept into many estimates of microwave intensities, by way of the assumed dependence of the line width parameter $\Delta\nu=(n\bar{v}\sigma)/(2\pi)$ on temperature. Thus the above "hard sphere" theory predicts a line width at constant pressure proportional to $T^{-\frac{1}{2}}(V\simeq T^{\frac{1}{2}};\ n\simeq P/T)$.

Recent theories proposed by Anderson[2] and Margenau,[3] while differing in their basic assumptions, both predict a line width independent of the impact velocity, with σ inversely proportional to $\bar{v}$. These theories, too, are in agreement with Bleaney and Penrose's data, although Anderson's theory alone includes an explanation of observed saturation effect.[4]

We have performed the simple experiment of measuring $\Delta\nu$ for the ammonia 3,3 line as a function of temperature. The results