A PROPOSED PRODUCTION METHOD FOR SPIN-ALIGNED HYDROGEN

William Stwalley

► To cite this version:

William Stwalley. A PROPOSED PRODUCTION METHOD FOR SPIN-ALIGNED HYDROGEN. Journal de Physique Colloques, 1978, 39 (C6), pp.C6-108-C6-109. 10.1051/jphyscol:1978649 . jpa-00217972

HAL Id: jpa-00217972

<https://hal.science/jpa-00217972>

Submitted on 1 Jan 1978

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

A PROPOSED PRODUCTION METHOD FOR SPIN-ALIGNED HYDROGEN

William C. Stwalley,

Univ. of Iowa, Iowa City, IA 52242, U.S.A.

Résumé.- Une méthode expérimentale pour la production de la substance unique (mais encore hypothétique), "spin-aligned" hydrogène, est décrite.

Abstract.- An experimental method for production of the unique (but thusfar hypothetical) substance, spin-aligned hydrogen, is described.

INTRODUCTION.- Spin-aligned atoms are atoms with their electronic spin magnetic moments aligned with an external magnetic field. The classic demonstration of spin in fact involved production of two oppositely aligned beams of silver atoms from an initially unaligned beam /1/. Ordinarily, thermal energy is far greater than electronic spin Zeeman energy and thus spin alignment is rapidly destroyed. At low temperatures, however, it is conceivable that macroscopic samples having (electronic) spin alignment can be maintained.

The spin-aligned atoms of dominant current interest are the isotopes of spin-aligned hydrogen /2,3/. Only spin-aligned hydrogen (symbolized $H\uparrow$) will be discussed here. The arrow symbolizes a magnetic moment aligned with the external field and corresponds to the low energy electronic spin state ($m_s = -1/2$) (with either nuclear spin). $H\downarrow$ represents the oppositely aligned $m_s = +1/2$ state.

Even in the strongest attainable magnetic fields low temperature equilibrium corresponds entirely to H_2 . However if the rate of processes converting $H\uparrow$ to H_2 can be suppressed, a new metastable form of matter could be created. The energy release for conversion of $H\uparrow$ to H_2 is enormous, especially per gram (~ 100 times gunpower) and indeed this was the initial justification ("rocket fuel") for $H\uparrow$ studies.

Also significant is the extremely quantum mechanical behavior of $H\uparrow$, which exceeds considerably even helium /2,4/. In particular, $H\uparrow$ should remain a gas even to absolute zero, because of its large "zero point motion"! Moreover, $H\uparrow$ should be nearly ideal Bose gas, showing Bose-Einstein Condensation, superfluidity, and other quantal properties. At ~ 50 atmospheres, it should form a dilute quantum solid ($\sim 10^{22} H\uparrow/cm^3$).

Recently the stability conditions for low density ($\lesssim 10^{18} H\uparrow/cm^3$) $H\uparrow$ have been discussed /3,5,6/. In the gas, one expects $H\uparrow$ will be metastable at high field to temperature ratios: $\mathcal{H}/T \gtrsim 1 \times 10^6 G/K$. At high densities and in the solid, spin-wave processes provide alternative destruction mechanisms. Impurities (e.g. $D\uparrow$) can also provide a troublesome but avoidable destruction mechanism.

Surface problems can presumably be avoided by 4He coatings on all surfaces (3He , H_2 or Ne might also be satisfactory) /7/. $H\uparrow$ atoms should not diffuse into the 4He /7/. Since $H\uparrow$ is bound at most very weakly ($\lesssim 2$ K) to 4He surfaces /7,8/ and is highly mobile on such surfaces, it is thought that no surface recombination processes will occur when the corresponding gas phase processes do not. Indeed "two-dimensional" $H\uparrow$ is interesting in itself. At high surface coverages (say $\gg 10^{12} H\uparrow/cm^2$), however, a two-dimensional spin-wave mechanism may be of concern. The precise binding energy of $H\uparrow$ to 4He is of great interest in estimating the relative gaseous and surface concentrations under various conditions.

Finally note that though there are yet no experimental results on $H\uparrow$ in bulk, there are intriguing results for H in H_2 , /9,10/.

PROPOSED PRODUCTION METHOD.- Experimental plans for producing $H\uparrow$ at Iowa are shown in figure 1. A liquid He cooled (unaligned) H atom beam will be directed into a small opening in a dilution refrigerator operating at say 0.08 K. Quite significantly, the MIT group has obtained a beam of $9 \times 10^{12} H$ atoms/second at 4 K /11/.

As the H atoms pass through the shields, the magnetic energy will become significant compared to the atomic kinetic energy (Figure 2).

Fig. 1 : Schematic diagram of $H^\dagger$ production apparatus.

Fig. 2 : Field and energy profiles in $H^\dagger$ production apparatus.

The $H^\dagger$ atoms will be accelerated by the field while the $H^\dagger$ atoms will be decelerated. The $H^\dagger$ atoms will (usually) slow down, stop, and then move backward to lower field. The $H^\dagger$ atoms will continue on and strike the cooling wall. The cooling wall will be located in a high magnetic field region with somewhat less than the maximum field. When the $H^\dagger$ atoms (with ~ 12 K kinetic energy) strike the cooling wall, they should transfer most of their energy (as in ^3He collisions with ^4He surfaces/12/), and in some cases perhaps stick to the surface. In either case, however, they will be strongly attracted to the regions of higher field, i.e. down the capillary and into the sample cell. Additional wall collisions will cool the $H^\dagger$ atoms to ~ 0.08 K. Initial experiments will involve highly sensitive bolometer detection of $H^\dagger$ atoms ($\sim 10^5$ H atoms recombining/second) and will directly establish magnetic field/temperature conditions needed for stability.

Of course, a very few $H^\dagger$ atoms can also reach the cooling wall, i.e. the high kinetic energy tail of the Bose velocity distribution. However, for a variety of reasons, it seems likely that significant destruction of the $H^\dagger$ will nevertheless not occur at the cooling wall.

Support received from the Donors of the Petroleum Research Fund, administered by the American Chemical Society, is gratefully acknowledged.

References

- /1/ Stern, O.S. and Gerlach, W., Z. Phys. 9 (1922) 349.
- /2/ Miller, M.D. and Nosanow, L.H. Phys. Rev. B 15 (1977) 4376 and references therein.
- /3/ Stwalley, W.C., Phys. Rev. Lett. 37 (1976) 1628 and references therein.
- /4/ Hecht, C.E., Physica 25 (1959) 1159.
- /5/ Berlinsky, A.J. et. al., Phys. Rev. Lett. 39 (1977) 356.
- /6/ Berlinsky, A.J., Phys. Rev. Lett. 39 (1977) 359.
- /7/ Stwalley, W.C., in S.B. Trickey, A.D. Adams and J.W. Dufty, editors, "Quantum Fluids and Solids" (Plenum, N.Y.) 1977, p. 293 and references therein.
- /8/ Miller, M.D., Bull. Am. Phys. Soc. 23 (1978) 85.
- /9/ Hess, R. Adv. Cryog. Eng. 18 (1973) 427.
- /10/ Webeler, R.W.H., J. Chem. Phys. 64 (1976) 2253.
- /11/ Kleppner, D., et. al., Bull. Am. Phys. Soc. 23 (1978) 86.
- /12/ Edwards, D.O., et. al., in S.B. Trickey, Kirk, W.P. and Dufty, J.W., editors, "Quantum Statistics and the Many-Body Problem" (Plenum, N.Y.) 1975, p. 195.