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RESONANCE STUDIES OF H ATOMS INTERACTING WITH LIQUID HELIUM SUR--ETC(U)
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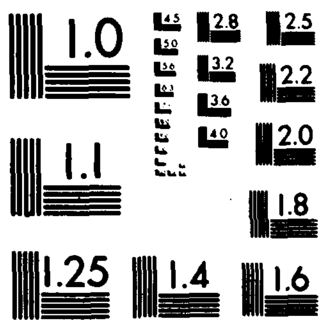

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(6) "Resonance Studies of H Atoms Interacting with Liquid Helium Surfaces"

(11) Oct 80

1. Principal Investigator: (10) Stuart B. Crampton
~~Williams College~~
Williamstown, MA 01267

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2. Contract Description:

Techniques developed by this investigator for studying the hyperfine resonance of gaseous atomic hydrogen in storage bulbs under liquid helium will be extended downwards in temperature to 0.5 K, in order to study the interactions of H atoms with superfluid liquid helium surfaces and with each other while adsorbed on the liquid helium surfaces. A liquid helium temperature state-selected H atom beam will be developed and used to study the feasibility of hydrogen maser oscillation at liquid helium temperatures.

3. Scientific Problem:

The energy of adsorption of hydrogen atoms on liquid helium surfaces, the durations of surface adsorption, and the recombination and spin relaxation interactions between H atoms while adsorbed are important to current attempts to cool sufficient quantities of spin polarized hydrogen atoms in high magnetic fields to low enough temperatures to produce Bose-Einstein condensation in a gas, but these parameters are more precisely observable in low magnetic fields, as in these studies. High densities of H atoms with short durations of adsorption on inert surfaces and long spin relaxation times will be useful for precision spectroscopic measurements and for frequency metrology.

4. Scientific and Technical Approach:

The techniques are extensions to somewhat lower temperatures of the techniques developed by this investigator in collaboration with T. J. Greytak, D. Kleppner, W. D. Phillips and D. A. Smith at MIT for studying H atoms interacting with frozen H_2 surfaces at 4.6 K to 3.2 K. In these studies, which have been continued here at Williams since January 1979, H atoms produced in a 180 MHz RF discharge pass through a 1 cm diameter, 20 cm long glass tube to a 150 cm^3 storage bottle centered in a microwave cavity tuned to the 1.42 GHz H ground state hyperfine transition frequency. Tube and storage bottle are under liquid helium whose temperature is controlled by the vapor pressure over the bath. A short pulse of RF power resonant at the hyperfine transition perturbs the thermal level population difference and produces a coherent superposition of states. The subsequent radiation by the atoms is approximately an exponentially damped cosine, whose amplitude, frequency and radiative decay rate contain information about the durations of surface adsorptions. The change of frequency and radiative decay rate with temperature measure the adsorption energy, and the recovery of amplitudes of response to pulses following level inverting pulses probes the level population recovery rates.

The extension to studying interactions with liquid helium surfaces involves adding helium gas to the system, lowering the temperature to about 0.5 K, and improving thermal isolation of the experimental region from the region in which the atoms are produced and cooled to 4 K. The lower temperature is essential, in order that the vapor pressure of helium gas over a saturated superfluid film be low eneough to allow H atoms to pass between surface collisions undisturbed by collisions with helium atoms. The lower temperatures are also those of interest to spin polarized hydrogen studies.

The state-selected liquid helium temperature H atom beam involves passing H atoms produced in a liquid nitrogen cooled RF discharge through a region cooled by a liquid helium bath before passing through a hexapole magnet. The low thermal speeds at liquid helium temperatures allow a much larger bore magnet and significantly larger beam intensities than possible with room temperature atom sources.

5. Progress:

The original plan for achieving lower temperatures was to use the large He^3-He^4 dilution refrigerator belonging to the MIT spin polarized hydrogen group in alternation with their own investigations of spin polarized hydrogen in high magnetic fields. As the work of this group and that group progressed, it became clear that scheduling posed insuperable problems. Consequently, the construction of a He^3 refrigerator has been started here in collaboration with Assistant Professor James Eisenstein and his undergraduate thesis student. Prof. Eisenstein received his PhD last summer from Berkeley on the basis of investigations of the properties of liquid He^3 in the millikelvin temperature regime. This work is just going to the shop.

The state-selected H atom beam has been designed in collaboration with Assistant Professor Peter Kramer, whose background is in atomic and molecular physics. The magnet design differs from previous designs because the low speed atoms can be focused by relatively low magnetic fields in which the electron magnetic moment of the required state varies with magnetic field strength. Computer studies of atom trajectories have produced a magnet design that promises to focus over 5% of the H atoms leaving the 4 K region in the required spin state while rejecting essentially all other atom states. This magnet can be made by simply enlarging the bore of an existing magnet, and the first two cuts have been made and tested for pole piece field strength. The other hardware for the beam has been built but not tested.

As this design and construction work has gone forward, we have continued the studies of H atoms interacting with H_2 surfaces, in order to pin down the adsorption energy as precisely as possible and to understand the mechanisms for recombination and spin relaxation by collisions between the atoms while adsorbed on the surface. Comparison of theory and experiment strongly favors a model of H surface adsorption on H_2 in which the atoms migrate slowly compared to their free space thermal speeds and in which collisions between atoms while adsorbed favor electron exchange over recombination by a ratio of about ten to one.

6. Publications:

This investigator gave an invited paper at the International Conference on Spin Polarized Quantum Systems held at Aussois, France, in April 1980. The paper was based on work supported by ONR and does acknowledge that support. It will be published with the proceedings of the conference in Journal de Phsyique. A poster based on this work was presented at the International Conference on Atomic Physics held at MIT last summer, and a poster based on this work will be presented at the meeting of the Division of Electron and Atomic Physics of the American Physical Society in Los Angeles next December. A paper presenting our results for the adsorption energy of H on H_2 is in preparation and will be submitted to Physical Review Letters.

7. Extenuating Circumstances:

Other than the realization that we will need a refrigerator here with good cooling power below 1 K instead of relying on use of the MIT dilution refrigerator, the work has been progressing as anticipated without serious setbacks. Although the only experimental results have been extensions of the previous work with H_2 surfaces, the results are highly relevant to work elsewhere on spin polarized hydrogen and to our own investigations here of liquid helium surfaces.

8. Unspent Funds:

We have already spent or committed to be spent by February 28th about 90% of the funds available until then, and we do not anticipate that there will be funds remaining from the first year allocation when the first year is over.

9. Graduate Student Degrees:

There is no graduate program in physics at Williams College. William J. Hurlin, who graduated from Williams last June, received a degree with honors based on his thesis, which initiated the Monte Carlo simulation of the comparison of theory to these experiments. Gus H. Zimmerman, III, received his PhD from Harvard University last January, based in large part on experimental work done here.

10. Other Federal Grant and Contract Support:

Grant # PHY-7910967 A01 from the NSF supports this work through April, 1982, in the amount of $54310. Contract # 955441 from the Jet Propulsion Laboratory supported this work through last April in the amount of $22230. A new contract from the Jet Propulsion Laboratory for a year from this past October 1 in the amount of $22000 is anticipated but not yet finalized.

Stuart B. Crampton
Principal Investigator