which case the metals near ^{56}Fe could be most abundant.

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*Fellow, Academia Sinica, Republic of China.

†Permanent address: Cornell University, Ithaca, New York.

[1]H. Gursky, R. Giacconi, F. R. Paolini, and B. Rossi, Phys. Rev. Letters 11, 30 (1963).

[2]S. Bowyer, E. T. Byron, T. A. Chubb, and H. Friedman (to be published).

[3]Two Arab astronomers, Haly and Albumazar, observed a very bright star, located near this x-ray source, for four months around A.D. 827. They report a brightness "comparable with the quarter moon," which is brighter (and therefore probably closer) than the original Crab explosion. However, no Chinese or Japanese records have been found yet to corroborate this event.

[4]H. Y. Chiu, Ann. Phys. 26, 364 (1964).

[5]Such estimates were first made by R. Stabler (Ph.D. thesis, Cornell University, 1960, unpublished), but he used too large a value for the effective opacity.

[6]S. Chandrasekhar, An Introduction to Stellar Structure (Dover Publications, New York, 1951), Chap. 10.

[7]This estimate is essentially the result of a dimensional analysis and could be in error by several orders of magnitude.

[8]B. Adams, M. Ruderman, and C.-H. Woo, Phys. Rev. 129, 1383 (1963). Other neutrino processes give a rate a few orders of magnitude below those discussed in this paper.

[9]For fixed T_c, our L_{ph} could be in error by factors of 4 or 5 and T_e by factors of about 1.5. L_ν (and hence the cooling time τ) is uncertain by larger factors. D. Morton (unpublished) has made independent estimates of T_e (but not of τ) which agree well with ours.

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ENERGY TRANSFER PHENOMENA IN LIQUID HELIUM

Joshua Jortner, Lothar Meyer, Stuart A. Rice, and E. G. Wilson
Department of Chemistry and Institute for the Study of Metals, The University of Chicago, Chicago, Illinois
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The occurrence of scintillation from liquid helium arising from ionizing radiation is now well established.[1,2] Recent studies have demonstrated that the intensity of light emitted per alpha particle seems to decrease by about 10% when the temperature is lowered below the lambda point.[3,4] During an investigation of this interesting effect, we have observed impurity emission from liquid helium in the visible optical region. These observations are of considerable interest and will be reported in the present note.

We have carried out a spectroscopic study of the light emitted from liquid helium bombarded by alpha particles. Scintillation light was produced by a 50-mCi ^{210}Po α source immersed in liquid helium. The total light emission was monitored by a detector above the liquid helium Dewar. Part of the light passed through a LiF window above the helium into the entrance slit of a vertically mounted $\frac{1}{2}$-meter McPherson Seya-Namioka vacuum spectrometer. The light detectors were EMI 9514B photomultiplier tubes coated with sodium salicylate. The spectrometer was sensitive in the region 1200 Å (the LiF cutoff) to 6000 Å, while the monitor detector was sensitive to much shorter wavelengths.

The following observations were recorded:

(1) Emission was observed from pure liquid helium (liquefied and transferred to the cryostat under standard purity precautions), but could not be detected by the spectrometer. This is consistent with the emitted light having wavelengths shorter than 1200 Å.[1] However, if the emission were in the region 1200 to 6000 Å and spread over a range of wavelengths, the spectrum would have been too weak to detect.

(2) The total light emission increased by about two orders of magnitude when the liquid helium was exposed to the atmosphere or when small amounts of oxygen and nitrogen were externally introduced into the helium.[5] Analysis of the emission spectrum established the presence of emission lines due to O_2 and N_2. This observation supports an energy transfer mechanism, in which the liquid helium absorbs most of the energy from the α particles and transfers some of it to the nitrogen and oxygen. Since their solubility in liquid helium is expected to be negligible, the possibility of energy transfer to colloidally dispersed nitrogen and oxygen cannot be excluded.

(3) Neither commercially pure liquid nitrogen nor liquid nitrogen containing dissolved oxygen

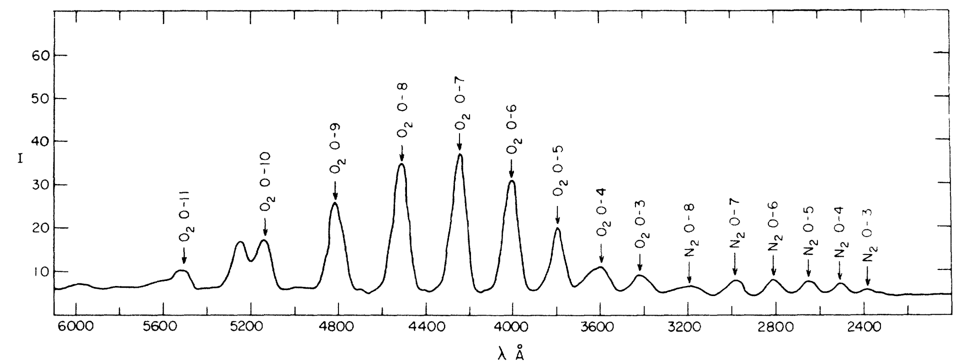

FIG. 1. The emission spectrum of liquid helium containing nitrogen and oxygen at 4.2°K. Slit width 2 mm. Line width is instrumental. The intensity I is presented in arbitrary units. Zero line is located at $I = 4.5$. The labels $O_2\ v' \rightarrow v''$ refer to the oxygen $C\,^3\Sigma_u^+ \rightarrow X\,^3\Sigma_g^-$ and the nitrogen $A\,^3\Sigma_u^+ \rightarrow X\,^1\Sigma_g^+$ transitions, respectively.

yielded any detectable light emission under the same conditions. This observation supports the energy transfer mechanism.

(4) The intensity of the emission, both in the pure and in the (N_2+O_2)-doped liquid helium, was independent of the height of the helium above the source. Thus, no self-absorption was observed.

(5) A preliminary study of the temperature dependence of the emission was made. When relatively pure helium was used, exhibiting a weak emission, the intensity recorded by the monitor decreased by about 5% when the temperature was lowered from 4.2°K to 1.8°K. The intensity of the emission from (N_2+O_2)-doped liquid helium was found to decrease by about 10% to 20% on cooling from 4.2°K to 1.8°K. The process was reversible upon warming from 1.8°K to 4.2°K.[6] Thus, this decrease in the impurity emission may be relevant to an interpretation of the decreased emission observed below the lambda point in liquid helium.[3,4]

(6) Rough estimates of the efficiency of the scintillation process in (N_2+O_2)-doped liquid helium show that the scintillation yield (light energy output/α energy) is of the order of ~0.1%.

We plan to repeat these experiments in a high vacuum system using very highly purified He.

The spectral distribution of the emission from liquid helium containing N_2+O_2 is presented in Fig. 1. The lines observed in the region 2000 to 6000 Å can be assigned to the O_2 Herzberg bands[7,8] $(C\,^3\Sigma_u^+ \rightarrow X\,^3\Sigma_g^-)$ and to the Vegard Kaplan N_2 bands[8,9] $(A\,^3\Sigma_u^+ \rightarrow X\,^1\Sigma_g^+)$. This observation of symmetry- and spin-forbidden transitions due to energy transfer in liquid helium shows promise as a useful and versatile method for identification of forbidden electronic transitions. We are planning to apply this method to small molecules (i.e., H_2O or NH_3) where the locations of the triplet states are not known, and to larger aromatic molecules, where we hope to obtain information regarding the location of some spin- and symmetry-forbidden transitions.

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[5] Of the order of 10 cm^3 (NTP)/liter He (liq) were needed to observe this effect.

[6] A possible explanation of this observation is that colloidally dispersed solid N_2 and O_2 settles down to the bottom of the Dewar below the lambda point, thus decreasing the impurity emission. The colloid can be dispersed upon warming by bubbling of the liquid helium above the lambda point.

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