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MASTER

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INTRODUCTION

During the past six months every effort has been made to overcome a major set-back, the sudden death of Dr. Francis R. Shonka on October 11, 1970.

A degree of success has been achieved in surmounting this difficulty. Immediately upon learning of Dr. Shonka's death, the project was placed in the hands of Dr. John J. Spokas for evaluation and determination of the course to be followed.

The decision was reached very early that the research activity of Dr. Shonka in the area of dosimetry and conducting equivalent plastics was far too important to allow to lapse. Many researchers in laboratories across the country have relied on the raw equivalent plastics and the variety of dependable ionization chambers produced in our shops. In fact the tissue-equivalent plastics developed here have become international standards.

Fortunately a logical choice of substitute principal investigator, Dr. John J. Spokas, was available to assume immediate supervision of the project. His name was presented to the Atomic Energy Commission and was quickly ratified. The new projector director had been carrying a full teaching load in the Department of Physics. However, a new man was hired by the department and on November 16, 1970, took over that entire teaching load. Thus, relatively little time was lost and the continuity of the research program was maintained.

The secretary of the Physical Sciences Laboratory since February 1967, resigned effective April 30, 1971. Ample notice having been given, a replacement was

secured who assumed her position in advance of the former secretary's termination.

The transition was therefore smooth and we are now strengthened in this department.

We have been running without a fulltime scientific and technical assistant for which we have authorization. It was not possible to give this matter proper attention until only recently. Therefore, we have been operating somewhat short-handed in this area. Some relief was obtained by means of part-time student help.

Several candidates have been interviewed for the position of scientific assistant in our laboratory. An excellent prospect has been found and an offer has been extended to him. An affirmative has just been received and the new man will start June 7, 1971.

Dr. Jesse will retire from full-time research at the end of the 1971 - 1972 contract period. Therefore, a suitable replacement for Dr. Jesse will be sought throughout the year. It is desired to find a person who would conduct fundamental experiments which relate to a degree to the other projects underway in our laboratory. Such would give a degree of completeness to our total program.

This report and proposal is divided into two principal parts. The first covers the phase titled "Ionization of Gases". The second pertains to the phase titled "Special Problems in Nuclear Instrumentation". The report concludes with a review of the current budget and a proposal budget for the ensuing year.

Budget information removed.

REPORT OF RESEARCH ON THE IONIZATION OF GASES AND THE AVERAGE ENERGY TO MAKE AN ION PAIR

William P. Jesse

In our last report it was pointed out how desirable it would be to be able to make ionization measurements in gases and vapors at temperatures up to 300°C , and how many interesting research problems would be made possible were such techniques available. Valuable results would also be expected from measurements made at low temperatures—of the order of -200°C .

DESIGN OF HIGH TEMPERATURE IONIZATION CHAMBER

To this end a great deal of effort has been expended in designing and constructing a satisfactory high temperature ionization chamber. As was expected, the mechanical difficulties have proved formidable. Some of these difficulties have been discussed in our last report. Perhaps the most serious of these is to find a material for the insulator which maintains adequate properties, both mechanical and electrical, at a temperature of 300°C . A second major difficulty is to construct a system of gaskets which will make the junction between insulator and metal chamber continuously vacuumtight as the chamber is heated and cooled.

Our attempt to use disks of highly polished quartz as insulators and the difficulties encountered there has been discussed at length in the report of last year. We discovered, what we later found already in the literature, that fused quartz is not a reliable insulator at temperatures above 250°C .

Experiments have also been carried out with teflon insulators. Here thin disks of teflon, squeezed between metal surfaces in the chamber, serve both as insulator and vacuumtight gaskets. This results in a very simple construction, since the combined chamber insulator assembly consists simply of a stack of thin teflon washers. The necessary guard rings in this case are provided by sheets of 10 mil aluminum foil inserted between the teflon washers with suitable external electrical connections.

This construction has proved reasonably successful. The two main difficulties were;

(1) Teflon under compression undergoes plastic flow, especially at high temperatures.

Because of its lack of elasticity after a succession of heatings, air leaks develop in such teflon gaskets. An ingenious remedy, suggested by the late Dr. Francis Shonka, is to have the stack of teflon gaskets compressed by a system of spring loading bolts which draw them down. Thus, even though the teflon gaskets squeeze out and vary slightly in thickness, because ^{of} the action of the helical springs the same pressure is maintained between the teflon gasket and the opposing metal surfaces. Thus with spring loading a much more satisfactory vacuum can be maintained after repeated oven heatings. At the temperatures attained by the oven, the stiff compression springs on the tie bolts tend to lose their temper. This is counteracted by making the tie bolts very long and locating the compression springs in a relatively cool area, well above the oven itself.

(2) It was feared that a second difficulty with teflon might be that it would disintegrate with heating and give off gases, which would effect the ionization measurements involved. In our experiments so far, no large evolution of gas from the teflon insulators has been observed under vacuum as the temperature is raised to 300° C, although small traces of evolved gas may, of course, be undetected.

Experiments have been carried out in argon gas with such Teflon insulated chambers and a constant ionization with an internal ^{63}Ni beta source has been observed for a range of temperatures from 25 °C to 280 °C. Thus no adverse effect of a possible evolution of a gas from Teflon has been observed here.

IONIZATION MEASUREMENTS IN MERCURY VAPOR AT ELEVATED TEMPERATURES

The first series of experiments carried out with the Teflon insulated high temperature chamber consisted of the determination of the W-value for pure mercury irradiated with the beta particles from ^{63}Ni . These experiments have been successfully completed and a paper reporting them has been submitted for publication to the Journal of Chemical Physics. Since a copy of this paper has been included in this report, any detailed discussion of the results would seem redundant here.

IONIZATION STUDIES IN MIXTURES OF ARGON AND MERCURY VAPOR

A series of experiments is now in progress to investigate the ionization in mixtures of argon and mercury vapor as the concentration of mercury molecules in argon is varied. The general procedure followed is that of well known previous experiments [Jesse and Sadauskis, Phys. Rev. 100, 1755(1955); Melton, Hurst and Bortner, Phys. Rev. 96, 643(1954)]. In this case the desired concentration of mercury molecules in argon is obtained by heating the ionization chamber containing a mercury pool enclosed in an atmosphere of argon. The concentration of mercury may be calculated from the

known vapor pressure at any chamber temperature.

It should be pointed out that in such measurements in argon the monatomic mercury molecule would seem to have a distinct advantage. The energy levels of the metastable states (and the two lower radiative states) in argon cluster about a value of 11.5 eV. The transfer of energy from such states with the formation of an ion pair is possible with the mercury molecule (ionization Potential 11.4 eV.) . Previously to find a contaminant gas with a low enough ionization potential to discharge such states, one had to resort to polyatomic gases, generally hydrocarbons, with the added complexity that some of the energy transferred may go into rearrangement within the molecule itself. [Platzman Vortex, 23, No8 (1962)]. The monatomic mercury molecule, where such rearrangement is impossible, would thus, as a contaminant in argon, seem to simplify our thinking concerning an explanation of the processes involved.

The experiments carried out in mercury-argon mixtures must at the moment be considered very preliminary, and any results obtained must be checked and rechecked before they can be accepted. Certain trends in the measurements, however, should perhaps be mentioned, since they may be suggestive.

(1) In the mercury argon mixtures, as in previous experiments [Phy. Rev. 100, 1755 (1955)] , as the concentration of mercury atoms increases the ionization increases over that found in pure argon. This increase is at first rapid and then slower until finally a relatively constant maximum ionization current value is attained. The maximum ionization value is about 30 percent higher than that for pure argon. This increase is somewhat less than 43 percent predicted by Platzman's approximate empirical formula.

It is interesting to note that the 30 per cent increase is almost exactly the same as that obtained by Hurst and his co-workers and by ourselves for acetylene in argon. This was the highest increase for any hydrocarbon contaminant in argon so far found by the Hurst group.

(2) A search has been made for a possible pressure effect in mercury-argon mixtures. Preliminary measurements over a range of mixture pressures from 90 to 30 cm of Hg would indicate that, in the curve relating ionization current to mercury concentration, the ionization rises more abruptly at the origin the greater the pressure of the mixture. In the notation adopted previously, [Phys. Rev. 100, page 1758, (1955)] the ratio K_i / K_d is larger for higher mixture pressures. Here K_i is proportional to the cross section for ionization, and K_d is proportional to the cross section for the alternative radiative process.

(3) The ratio K_i / K_d , calculated from our preliminary curves, is found to be relatively small in mercury-argon mixtures. This ratio is several times smaller than that previously found for methane-argon mixtures for alpha particle ionization (See reference above). Thus the mercury molecule does not show here the very high value of the ratio K_i / K_d found in mercury-helium mixtures.

SUGGESTED FUTURE EXPERIMENTS FOR VARIATION

IN IONIZATION WITH TEMPERATURE

As was mentioned in our last report, there are many interesting experiments which involve the possible variation of ionization with temperature. The successful development

of a high temperature ionization chamber should now make such experiments possible.

Some of the more important of these to be carried out are:

(1) Continuation of work on mercury-argon mixtures.

Even our preliminary experiments on the ionization in mercury-argon mixtures have turned up many interesting points. The marked difference in the behavior of mercury-argon mixtures and the mercury-helium mixtures is striking. One wonders whether the processes at work in mercury-argon mixtures may not be markedly different from those involved in mercury-helium mixtures.

To carry out the experimental work in mercury-argon mixtures with the necessary accuracy to be really valuable will probably prove a difficult task. The explanation of the experimental results may prove an even more difficult task. This work, however, would seem to be very much worthwhile.

In this connection it is heartening to learn from a communication from Dr. Mitio Inokuti of the Argonne Laboratory, that he is contemplating a theoretical study of ionization processes in the mercury molecule. A combined approach to such a phenomena, both from the experimental and theoretical sides, might prove to be of great value.

(2) Of interest to the biologist would be a good determination of the W value of H_2O vapor - in this case superheated steam - where, leaky insulators from vapor condensation would probably cease to be a problem. Determinations of this constant have been made in the past [Alder and Bothe, Z. Naturforsch, 20a, 1700 (1965)] but it would seem possible to obtain a more precise value.

An additional valuable experiment in this field would be the isotope effect for water vapor, determined by a comparison of the ionization from H_2O and D_2O in vapor form.

(3) The work of Bristeau [Comp. Rend. February (1964)] indicates that a large change in measured ionization in noble gas mixtures occurs as the temperature of the mixture is changed. In this case the greatest effect is obtained by cooling the chamber to temperatures of the order of $-200^{\circ} C$. This work is suggestive and should be repeated and extended. Similar work has been reported by Jones and Robertson [J. Chem. Phy. 49, 4240 (1968)] , but the accuracy of their measurements leaves something to be desired. It would seem that extended measurements of this sort should be pursued.