COO - AT(11-1)-323-17

JUL 2 6 1968

PROGRESS REPORT AND PROPOSAL

AEC RESEARCH CONTRACT AT(11-1) - 323-17

St. Procopius College
Physical Sciences Laboratory
Lisle, Illinois 60532

June 21, 1968

DISCLAIMER

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

William P. Jesse

Published Papers and Papers in the Process of Publication

1. Isotope Effect in the Ionization of Polyatomic Gases by Alpha Particles
   William P. Jesse, J. of Chem. Phy. 46,4981, (1967).

A preliminary discussion of this paper was given in our 1967 report. A reprint of this paper is included in the present report. A discussion of further work in this field now being pursued is included later in this report.

2. Precision Measurements of W for Polonium Alpha Particles in Various Gases
   William P. Jesse, Radiation Research 33,229 (1968).

A preliminary discussion of this work was given in our 1967 report. A reprint of the published paper is included in this report. This paper has attracted attention both here and abroad, and many requests for reprints have been received.

3. Alpha-Particle Ionization in Argon-Methane Mixtures and the Energy Dependence of W
   William P. Jesse

This work in its preliminary stages was discussed in our 1967 report. The experimental work has now been completed and a paper describing the work has been submitted for publication to the Physical Review. The abstract from this paper follows below. If this work is correct, it would seem that the long standing discrepancy between slow and fast collection is the result of the different gaseous media used in the two cases rather than the mode of collection of ions.

ABSTRACT

Experiments have been performed to investigate a long-standing discrepancy in the measurement of alpha-particle energies by the ionization method. The work of Jesse and his collaborators, carried out in pure argon with a total collection of ions, indicates a linear relation between ionization and alpha-particle energy for energies between 1 and 9 MeV. A different relation between ionization and alpha energy is observed in a large number of experiments with gridded pulse chambers. Here, with collection of only the electronic component of the ionization in argon-methane (or argon-carbon dioxide) mixtures, an appreciable relative decrease of ionization is observed with decreasing alpha energy. Discussions in the literature have often attributed this difference between the two methods to the mode of collection of ions, whether total or electronic collection. The present experiments have investigated the possibility that the discrepancy in the two types of experiment is due to the different media used - whether pure argon or argon-methane mixtures. To this end, a series of measurements was carried out for four alpha particle energies, ranging from 1.58 to 5.3 MeV. For each of these particles the ionization, relative to that in pure argon, was measured by a total collection method for a wide range of argon-methane mixtures. The results indicate a dependence with alpha energy in argon-methane mixtures considerably in excess of any possible dependence which may exist in pure argon. The variation with energy, moreover, in a mixture of argon with 6% methane is in good accord with past results obtained in gridded pulse chambers for this mixture. The present experiments would suggest therefore that the observed difference between the two methods is the result, not of the method of ion collection, but of the different gaseous media used.

RESEARCH IN PROGRESS AND PLANS FOR FUTURE WORK

Isotope Effect as a Function of Alpha-Particle Energy

In the paper dealing with the isotope effect in the ionization by alpha particles (Item 1 above) it was suggested that an experiment be performed to study the magnitude of the isotope effect as a function of the energy of the alpha particle. Such experiments have been carried out and very preliminary results are indicated for methane in Table I below.

In the apparatus the ionization from individual alpha particles was measured by our usual method for a collimated polonium alpha source. By means of a rotating disk, which could be controlled from outside the chamber, mica sheets of varying thickness could be interposed between the polonium source and the collimator. By this device the ionization from alpha particles of four different energies could be measured and the ratio determined between the ionization from the deuterated and undeuterated gas samples for each alpha energy.

In the table below preliminary results are shown for the ionization ratio CD_4/CH_4 for each of the alpha particle energies indicated. These energies have been determined to a very good approximation by comparison of the ionization produced in argon by each alpha particle of reduced energy with that for the unretarded polonium alpha particle.

TABLE 1

Isotope ratio for methane as a function of alpha particle energy

Ratio	5.3 MeV	3.87 MeV	3.04 MeV	1.58 MeV
CD_4/CH_4	1.013	1.021	1.026	1.042

The results in the table show a definite trend for the ionization isotope ratio CD_4/CH_4 to increase with decreasing alpha energy. Thus for an energy of 5.3 MeV, corresponding to the unretarded polonium alpha particle, we have a ratio of 1.013 while for an alpha particle of energy 1.58 MeV the ratio has increased to 1.042. From past experience the estimated standard errors in the two cases are 0.2% for the polonium alpha particle and 0.4 to 0.5 percent for the lowest energy alpha particle. The change in the ratio observed is thus considerably greater than any combination of estimated errors. Moreover the readings were found to be quite consistent and it is believed that a real increase in the isotope ratio occurs here with decreasing alpha energy. Any attempt, however, at any theoretical interpretation of such a change from preliminary readings in this one gas would seem premature. Experiments of this sort are now being continued with other hydrocarbon gases.

Because of the importance of the present results it would seem worthwhile to check eventually the measurements of the isotope ratio for alpha particles of low energy now obtained by passage thru mica sheets, with similar isotope ratios made with a natural alpha emitter of low energy. Such a method would avoid the troublesome range straggling effects which the absorption in mica produces. The ionization jumps on the recorder would therefore

be somewhat more uniform with a natural alpha source.

Probably the most practicable low energy alpha source would be ^{147}Sm with an energy of 2.18 MeV. A compound of this almost pure isotope has been obtained and this could be sprayed on plates of very large area in a specially designed ionization chamber. Experiments with such a source should serve as a valuable check upon the present methods.

The Isotope Effect for Recoil Particles

It has at times seemed to me that it would be of advantage to investigate the isotope effect where the ionizing particles are very massive. We would here have a measure of the effect of massive collisions more closely resembling those which take place in ordinary chemical reactions. Such collisions do not occur for alpha particles until they are almost at the end of their range, and hence might prove quite difficult to measure.

If, on the other hand, one used the recoil particles from an alpha disintegration, the mass of such particles is very large and their velocity very low. They would therefore seem ideally suited to demonstrate the effects of massive collisions.

An original method for measuring the ionization in argon and helium and the corresponding W values produced by the ^{210}Po recoil atoms has already been devised. (Jesse and Sadauskis, Phy. Rev. 102,389 (1956)

It would seem that an application of this method to measure the isotope ratio might be of value. In addition one might obtain from such experiments valuable data as to

the ranges of such particles in gases with different isotopic composition. At present, however, such an experiment is merely a pipedream for work in the future.

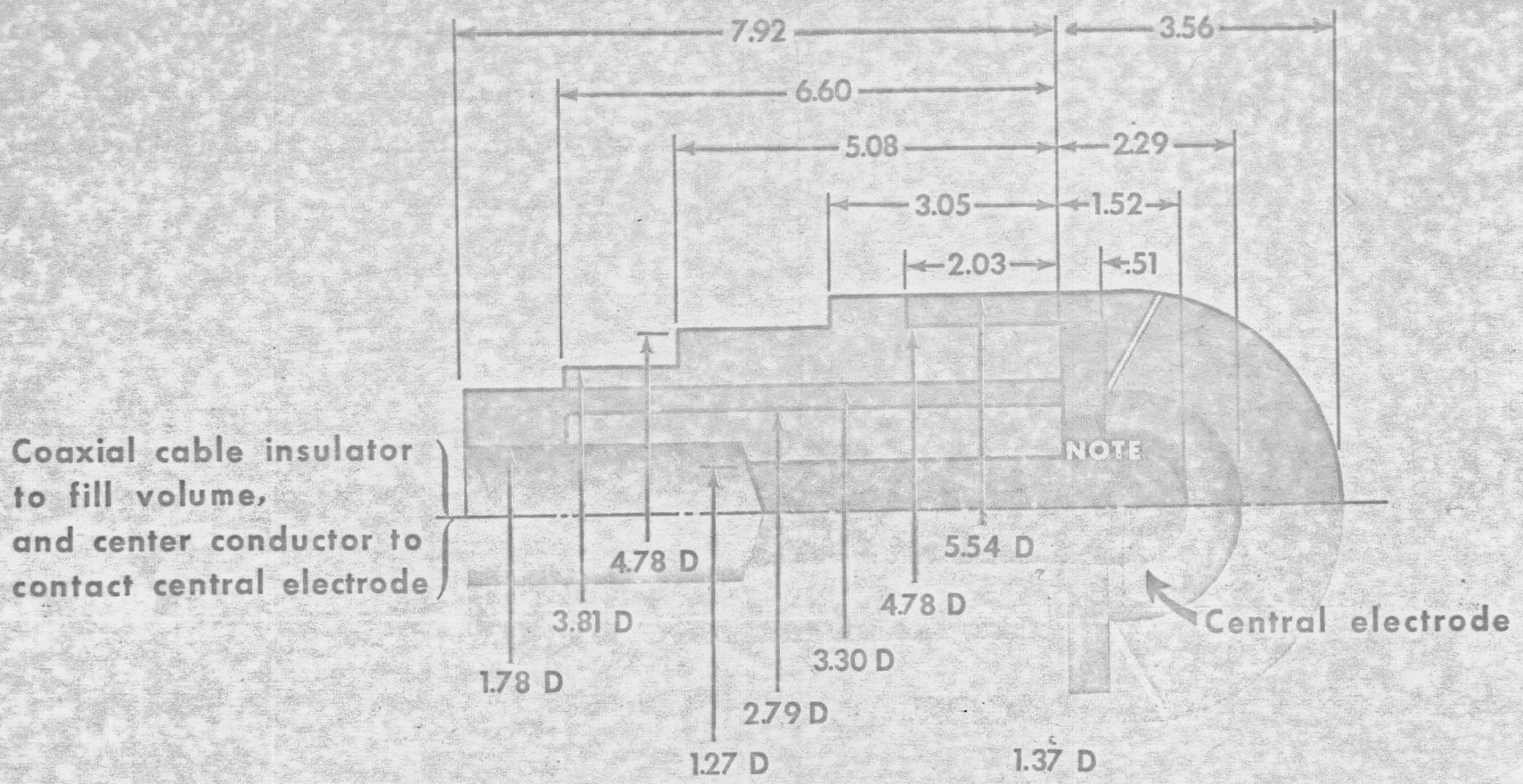
CALCULATED CALIBRATION OF IONIZATION CHAMBERS

Last year's report discussed a very carefully performed set of experiments for calibrating ionization chambers of muscle and air. The purpose of these experiments was to check the calculated output of these chambers. The report also stated that the results of these experiments would be written up for publication in the open literature. RADIATION RESEARCH accepted this paper and a copy (now in its final form) is included with this report. It can be seen from the results given in the paper that the greatest difference between the calculated and experimental values (0.5%) occurs at a distance between the chamber and the calibrating radium source such that the output of the chamber is only twice background. The strength of the certified radium source, the specific gamma ray constant, and the W value of the gas are the greatest sources of error in the experiment.

A THREE TERMINAL CHAMBER OF SMALL SIZE

Through a cooperative effort with AFRI we have constructed three terminal ionization chambers having ionizing volumes of 0.01 ml and 0.05 ml. These can be described as small tips at one end of a small microdot coaxial cable. Their construction was made possible by using ultrasonic welding techniques (to be discussed later) which we developed during this fiscal year. The drawing on page 9 gives the details, including dimensions of the smaller chambers, and shows that the only gas cavity in the entire cable and chamber assembly is the ionizing volume of the chamber itself. Twenty of the 0.01 ml chambers were finished late last fall and a report on them was given at the Chicago AAPM meeting. Rather extensive tests were made with these chambers at AFRI and at ANL. These tests revealed that even though the only gas volume was the ionizing volume itself, there was

MINATURE IONIZATION CHAMBER



Dimensions in mm

TE Plastic, A-150

Polystyrene

NOTE: White arrow denotes holes for gas equillibrium

an extra contribution due to irradiation of the microdot cable. This cable contribution was in the same direction regardless of the polarity of the voltage on the chamber and hence one could make a correction for it. Under the worst conditions this contribution was ten percent of the output, and it was decided to reduce this effect by increasing the ionizing volume of the chamber. Although there are some applications which would call for a smaller chamber it seems that the larger one will be more generally useful. Extensive testing of these chambers is being done at AFFRI and ANL, and at the present time physicists at three other laboratories are using them and are very enthusiastic about their performance. They should prove most useful for measurement of high intensity gamma rays, neutrons, and electron beams from pulsed machines. AFFRI finds that the efficiency of ion collection determined experimentally agrees very well with the calculations using Professor J. Boag's method. They find that at intensities of 10^7 R per second the collection efficiency is nearly 90%, and that one obtains 98% ion collection for neutron pulses from TRIGA when operated at 10^3 rads per pulse. One of the larger chambers with short leads and some of the parts used in its construction are included in this report. These parts will be helpful later in this report for explaining some of the sonic welding techniques.

CONDENSER CHAMBERS

We stated in our last report that we planned to work on the three terminal chambers discussed above and also to work on the development of a condenser chamber. The condenser chamber is important because there are many applications where continuous or immediate readings are not necessary and hence the cable can be dispensed with. Our

last report described condenser chambers of the Sievert cylindrical type, of which we built approximately thirty-five by molding the parts together in cavities such that the assembly was accomplished by injection molding of the parts. Samples of these condenser chambers were sent with last year's report.

This year we redesigned the condenser chambers. The most radical departure was to use a blindended condenser which is charged and read by removing the outer conducting cap of the ionizing volume. Such condenser chambers were built using conducting T. E. plastic muscle material, and polystyrene insulators. The outer conducting electrode was injection molded with a tapered cavity on its axis. A 10 mil thick polystyrene insulator was then injected into this cavity by using the same mold used for molding the outer electrode but having a 10 mil smaller diameter core pin. A tapered conducting central electrode was then pressed into the insulator. Samples of these condenser chambers are also included as an exhibit with this report.

The performance of these chambers is very disappointing. It seems that the chief difficulty is that the insulators are highly polarized due to mechanical stresses. It must be remembered that when polystyrene is injected into conducting muscle plastic (basically polyethylene) that there is no actual bond at the adjoining surfaces and that the temperature coefficients are different for the two materials. In this coming year we plan to retain polystyrene as the insulator and make a composition of carbon with polystyrene for the conducting electrodes of the condenser. We plan to assemble the parts of the condenser by ultrasonic welding. The fact that we would obtain an actual weld at all the interfaces and that the materials have similar physical properties should eliminate most of the difficulties

due to polarization.

NEW CONDUCTING PLASTIC MATERIALS

During this year we had two urgent requests for special conducting plastic materials for other laboratories supported by the AEC. A small batch mixer for plastics was developed and built at this laboratory and was described in our annual report of three years ago. This mixer was badly worn because it had been used to mix hundreds of batches of materials, some of which were quite abrasive. At the present time it is on loan to Dr. John Cameron at the University of Wisconsin. We decided to build a slightly improved model of the batch mixer using extremely hard materials. The new mixer produces a more intensive blend then the previous one ever did and has been in use for several weeks already.

Mr. William Glass of Hanford has been making very precise measurements of radiation with a calorimeter using our tissue equivalent material for the absorber. He has discovered a small discrepancy between the total radiation energy absorbed and the resulting heat energy produced by it. He believes that the small amount of stored energy (approximately 2%) is a result of the carbon mixed in with the other plastics and additives. At his request we are supplying him with nine different compositions using various plastics with varying percentages of carbon.

The other new mixture is in response to a request by Dr. Mudundi R. Raju at Berkeley for producing a material which will be tissue equivalent muscle for pions. At the occasion

of our last meeting with Dr. Raju at Houston he outlined some of the conditions which we were to satisfy. We were to use relatively small atomic number elements which are similar to the elements that occur in muscle, but the most important condition was that there should be even number elements such that the number of "equivalent alpha" particles would be the same as for muscle. The "equivalent alpha" particles were to be counted so that one atom of carbon would be equivalent to three alphas, one oxygen to four alphas, one silicon to seven alphas etc. We have devised a mixture consisting of 24.02% carbon, 54.58% nylon, 16.88% silica and 4.52% calcium fluoride. Symbolically the atomic composition of this muscle "molecule" can be expressed as:

$$C_{4.89788} \quad H_{5.31278} \quad O_{1.04576} \quad N_{0.48298} \quad Si_{0.28139} \quad Ca_{0.05791}$$

This composition does not have the same amount of hydrogen and nitrogen as muscle and consequently it would not be tissue equivalent for neutrons. Likewise the photo-electric absorption is higher than for ICRU muscle and hence it could not be used for very low energy x-rays. However, it is interesting that for the same molecular weight it would have the same summation of the atomic numbers; it would likewise have the same summation of the atomic number squares and also would satisfy the condition that low atomic number elements are to be used and finally that the summation of the "equivalent alphas" would be identical. This material would therefore have the same Compton scattering and absorption by pair production as ICRU muscle. The material has surprisingly good physical properties and a sample of the material has been sent to Dr. Raju. If Dr. Raju believes that this material will in fact simulate muscle for plans we shall have to construct some

small ionization chambers for him. A thin disc of 1" diameter is also included in the exhibit being sent with this report.

ULTRASONIC WELDING OF PLASTIC MATERIALS

The most significant development in plastics technology this year has been in the field of sonic welding. Several years ago we had a demonstrator model of sonic welding equipment from the Branson Company. Although at that time we did not do extensive experimenting with the equipment, we felt that potentially it promised to be extremely useful in our work. This year when we discussed the problem of the small chamber with Branson engineers, they advised us very strongly not to buy their equipment since they were quite sure that it would not do our job. Nevertheless we purchased the largest of their machines having a variable output, which at the time had a sonic output power of 250 watts. We feel that the success we had in constructing the small three terminal chamber represents a very real breakthrough in plastics technology. Parts having the same dimensions as the finished small chamber could of course not be sonically welded together.

The sonic welding techniques and the sequence of operations used in construction of the 0.05 ml chambers can be most easily shown by referring to the exhibit. In order to have sufficient support for the sonic weld we take a 1/2" od X 1" long cylinder of insulating polyethylene (part of which becomes the high voltage insulator) and weld a rod of conducting T.E. muscle to 1/2" depth along its axis. A hole is then drilled into the T.E. muscle rod to a depth of 3/8", and of a diameter such that the wall thickness of the remaining T.E. muscle is 0.01". This conducting plastic is the guard ring in the finished chamber. A solid polyethylene rod used to insulate the collector is

sonically welded into the guard ring.

The solid welds that are obtained are demonstrated by the samples of the subassembly, the cut-away thru its axis, and the turnings from a face cut, all of which are contained in the exhibit. The collector is a conducting taper pin pressed into the inner insulator and the dielectric of the microdot coaxial cable is pushed into a tightly fitting hole, drilled from the end. A large portion of the high voltage insulator is then machined away and the T. E. muscle cap, which is the high voltage electrode, is sonically welded to it. The rest of the welds which include connecting the central conductor of the microdot cable to the collector, the braided shield to the guard ring, and the high voltage lead to the outside electrode, are made using some of our earlier welding techniques.

We believe that the results obtained thus far are only the beginning of many other useful applications of sonic welding and we plan to obtain a machine of higher power rating which is now available. Mr. Stanley Jacka, who is the director and head of engineering for the Branson Company, is quite impressed and has arranged to spend a day with us discussing the various possibilities of sonic welding. He also offers to give us full credit for any Branson equipment we wish to trade in for their larger or more modern equipment.