Diffusion of ^{18,19}Ne out of mylar tape

V. E. Iacob and J. C. Hardy

Several years ago we successfully measured the half life of ^{34}Ar ($t_{1/2}$ = 0.84 s) [1]. Although argon is a noble gas with the potential to diffuse out of the detection region during the measurement, we demonstrated with ^{35}Ar ($t_{1/2}$ = 1.775 s) that measurable diffusion did not occur over a 35-second period. With that result in mind we sought to measure the half life of another noble gas: ^{18}Ne ($t_{1/2}$=1.7s). To check for possible diffusion of implanted neon ions out of the Mylar tape of our fast tape-transport system we began by measuring the decay of ^{19}Ne. We hoped to be able to put an upper limit on the loss of neon by measuring its half-life and comparing our result to the well-known half-life, $t_{1/2}$ = 17.219(17) s [2]. We produced ^{19}Ne using the ^{1}H(^{19}F, 2*n*) reaction and collected it via MARS, the tape-transport system and our 4π proportional gas counter as described in Ref. [1]. We collected each sample on tape for 1.5 s and observed its decay for 150 s. Figure 1 presents the experimental spectrum (red) actually obtained along with the expected ^{19}Ne exponential. The difference between the two curves clearly identifies the presence of significant diffusion of the radioactive gas during the 150-s detection time.

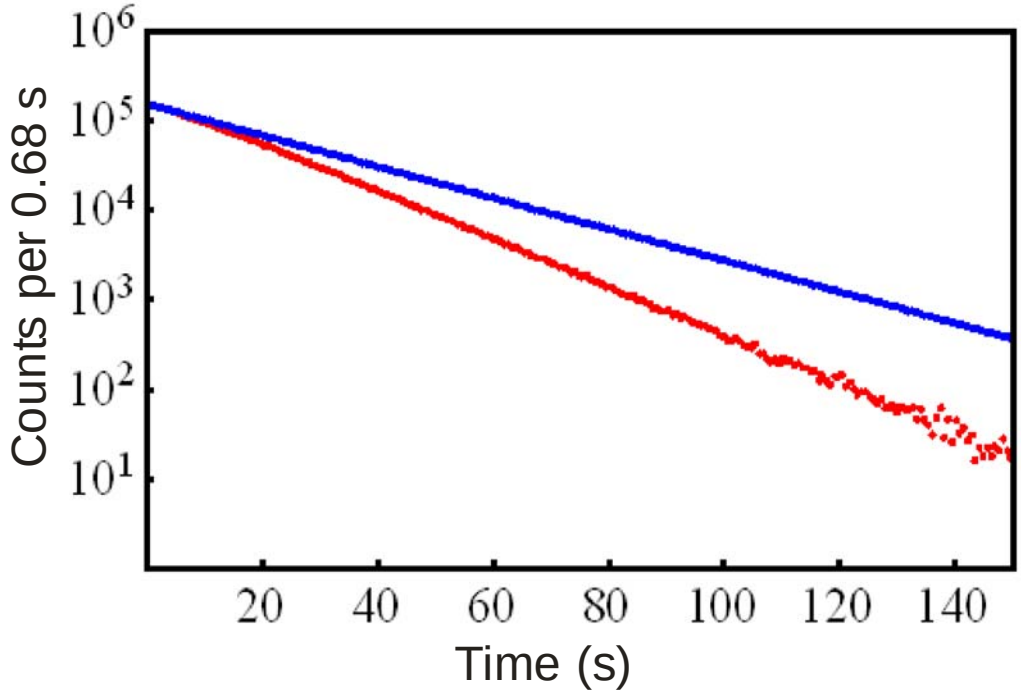

FIG. 1. Observed (red) versus expected (blue) ^{19}Ne ($t_{1/2}$ = 17 s) decay. The contribution of the diffusion losses significantly "speeds up" the observed decay.

If we are to have any hope of extracting a half-life from such a measurement on neon, we need to consistently account for the diffusion process. In our experiments, we prepare the sources by implanting radioactive ions in a 76-μm-thick Mylar tape; then the radioactivity is moved to the center of a 4π proportional counter where we observe the decay and ultimately multiscale it. The source consists of an

almost uniform distribution with the shape of a 1.5-cm-diameter disk, 20 μm thick and located in the middle of the tape. The 4π proportional gas counter is split in two halves that enclose the tape, having an air gap of about 1 mm between the halves.

To try to understand neon diffusion out of our detection system, we calculated the diffusion of (non-radioactive) neon atoms in the Mylar tape and detector air-gap. For the source geometry, the in-tape-diffusion is essentially a 1-dimensional process in the direction perpendicular to the tape. A source with a original rectangular distribution in the direction perpendicular to the tape (as in our implanted source) evolves toward a bell shape that broadens and reaches the tape edges. Figure 2 shows the expected modification of the concentration of Ne atoms after 3.5 s, assuming them to be uniformly implanted in the middle of the tape over a depth range of 20 μm; the diffusion coefficient of neon in Mylar (2.16×10^{-10} m^2/s) was taken from [4].

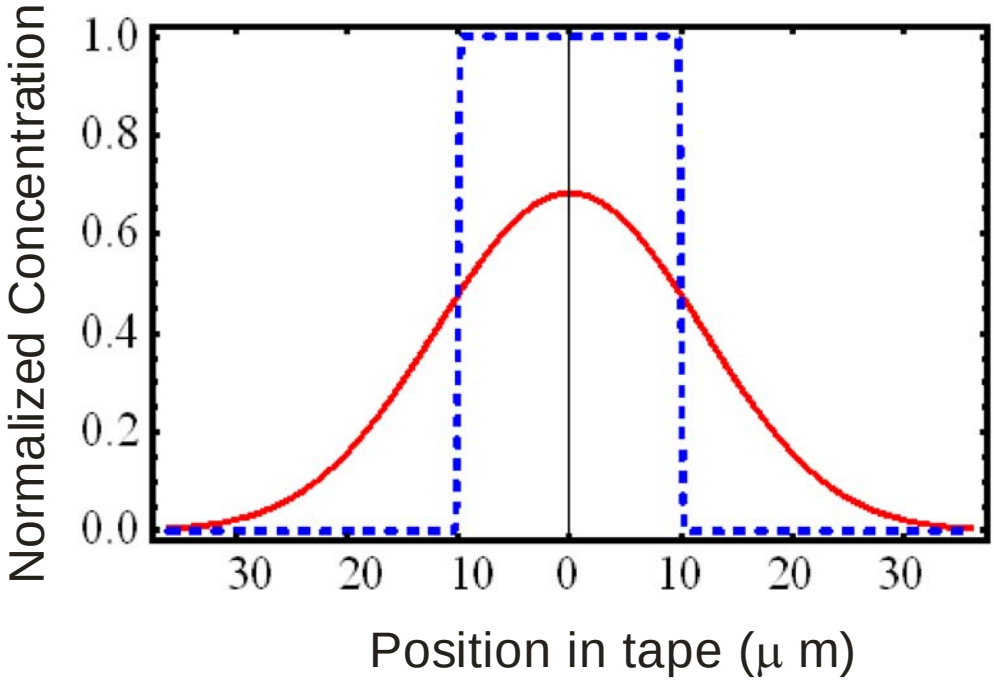

FIG. 2. Diffusion-induced redistribution of uniformly implanted Ne ions in the direction perpendicular to the tape. The abscissa extends over the whole thickness of the Mylar tape (76 μm). The blue dashed curve corresponds to the initial distribution; the red curve is the calculated distribution after a 3.5 s diffusion time.

Once the neon atoms reach the Mylar-air interface, the neon diffusion in air proceeds extremely fast: the diffusion coefficient of neon in air ($1.89\times10^{-5}m^2/s$) [5] is 5 orders of magnitude higher than it is in Mylar. Thus the only real cause for a neon presence in the air gap of our proportional counter is the diffusion current of neon atoms emerging from the tape. A calculation of the diffusion current of non-radioactive neon atoms at the Mylar-air interface gives a reasonable idea of the losses of activity related to diffusion only. Figure 3 presents the time evolution of the out-of-tape diffusion current. A constant implantation current over a 1.5 s period was assumed to distribute the Ne atoms uniformly in the center of the tape over a depth range of 20 μm. Although the implantation is limited to the first 1.5 s, the diffusion current is seen to reach its maximum at about 0.5 s after the implantation stopped. From the perspective

of a ^{18}Ne half-life measurement ($t_{1/2}$=1.7 s), this peaking time makes the bookkeeping of the diffusion losses extremely difficult, as the diffusion losses will superimpose on the radioactive decay. Moreover, the fast drop in the diffusion current during the normal detect-time implies a fast loss of neon atoms: once out in the air, the neon atoms will rapidly pass out of the active detection volume.

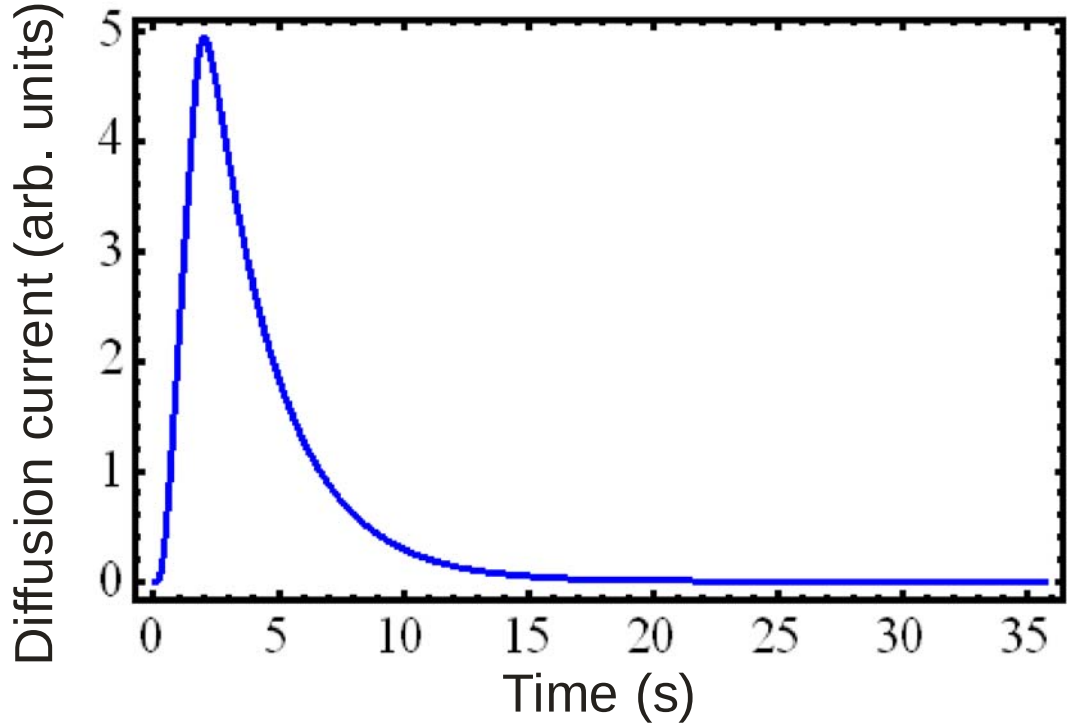

FIG. 3. Calculated time evolution of the diffusion current at the Mylar-air interface. The neon atoms are assumed to be uniformly implanted in the central 20 μm of the Mylar tape for a time interval of 1.5 s.

The final step in our model-analysis of the diffusion process was to determine the time evolution of the non-radioactive neon atoms present in the active volume of the detector. In real measurements, after the implantation of the radioactive ions in the tape, the beam is turned off, and then the activity is moved in about 0.18 s to the center of our 4π proportional counter where the decays are counted and multiscaled. The equivalent for the transport of the non-radioactive neon atoms requires the continuous removal of the neon atoms that exit the tape during the 0.18-s transport time. Thus we are faced with the full loss of all neon atoms that escaped out of the tape during both the collect and move time intervals. With all these effects considered, we calculate that about 85% of the implanted neon atoms are still present in tape at the beginning of the detection time. The diffusion of these atoms out of the active volume of the detector is presented in Fig.4. The diffusion losses show a decay-like evolution with an equivalent diffusion half life of 1.9 s.

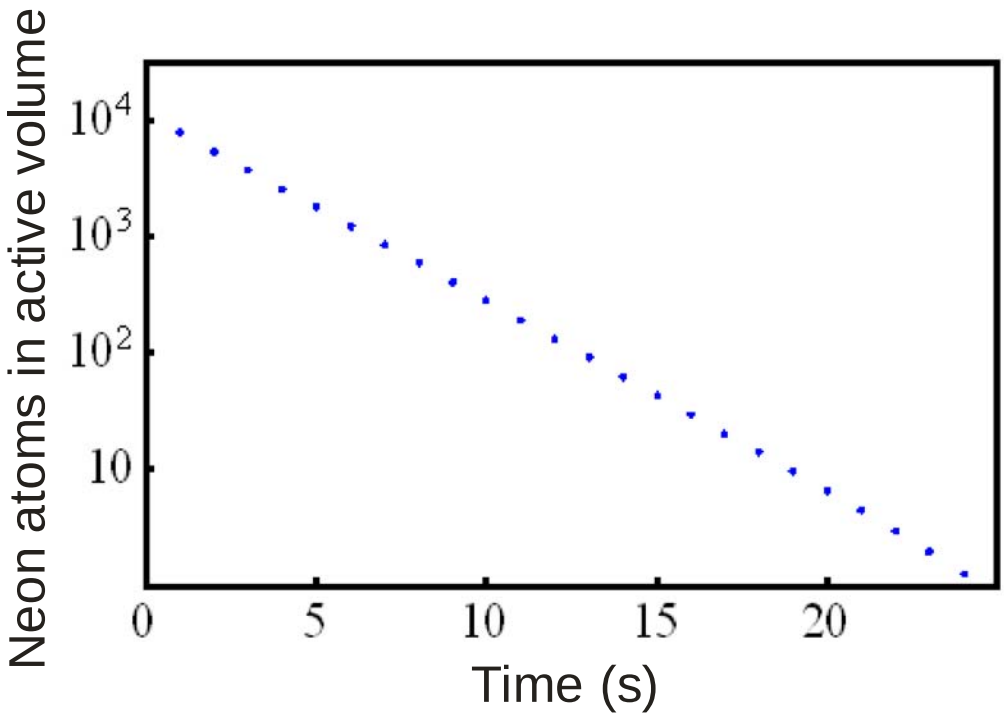

FIG. 4. Calculated time evolution of the total number of (stable) neon atoms in the active volume of the detector during the "detection" time. A total of 10^4 neon atoms were uniformly implanted in the Mylar tape for 1.5 s, and then the tape surface was wiped for 0.18 s (equivalent to the losses occurring during the transport of the activity). The diffusion induced migration of the neon atoms shows an exponential loss in the total retained neon atoms with an equivalent half life of 1.9 s.

While the trend predicted by these results is consistent with the experimental observations, caution must be exercised in taking the numbers too seriously since the value of the diffusion coefficient for neon in Mylar came from a rather old measurement [3]. In the case of another noble gas, argon, a more recent value for its diffusion coefficient in Mylar [5] differs significantly from the corresponding value in [3]. Moreover, as our Mylar tape is coated with a thin Al layer, it is likely that it will introduce some delay in the neon release. In view of these uncertainties, we conclude that it would be virtually impossible to extract a precise half-life for ^{18}Ne from a system such as ours that uses Mylar tape to hold the implanted samples.

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