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Report on Activities

W.E.T. (Water Extraction Techniques) Lab

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The following is a summary of work to date at Queen's on the Lucas cell counting of radon gas and the extraction of radon gas from water.

1 Depositing ZnS

We have developed a method of coating flat acrylic disks (5 cm diameter) with a unifrom layer of silver activated ZnS powder. ZnS is suspended in alcohol and then allowed to settle onto a submersed acylic disk for a fixed amount of time before it is removed from the alcohol. Subsequently the deposited ZnS is fixed onto the acrylic with methyl chloride. The thicknesses which have been laid down range from 4 to 70 mg/cm^2 as determined by weighing the disk before and after depositing the ZnS.

2 Pulse Height as a Function of ZnS Thickness

We have measured the pulse height spectrum from a PMT detecting light produced by alpha particles striking various thicknesses of ZnS. As the range of a 5.5 MeV alpha in ZnS is about 10 mg/cm^2, two geometries were investigated: "transmission" and "reflection" as described below.

(a) "Transmission" Geometry

The setup is shown in Figure 1. The PMT looks through the ZnS layer. Light from scintillations occurring near the ZnS surface furthest from the PMT face travels through the ZnS layer and is attenuated. The pulse height spectra obtained for various thicknesses of ZnS are shown in Figure 2. The position of the peak changes with thickness and is plotted in Figure 3. Note that the area under each curve is essentially independent of ZnS thicknesses between 3.6 and 70 mg/cm^2.

(b) "Reflection" Geometry

In "reflection" geometry (Figure 4) the PMT can see light directly from scintillations near the surface of the ZnS. Figure 5 shows the pulse height spectra for various thicknesses of ZnS. The peak position changes by less than a factor of two for ZnS thicknesses between 8 to 70 mg/cm^2. In contrast, for "transmission" geometry there is a change of almost a factor of ten. Furthermore, the pulse height spectra in "reflection" geometry have smaller FWHM compared to "transmission" geometry which is advantageous in getting a clean separation between noise and signal.

The above results suggest that much can be gained in rejecting noise by going with "reflection" geometry for a Lucas cell (with at most a very thin layer of ZnS on the face next to the PMT).

3 Scintillations in Clean Acrylic

It was observed that the total count rate went up when a piece of clean acrylic was placed on the PMT face. Tests were carried out to determine the origin of this effect.

A clean ultraviolet transmitting acrylic disk was placed on the PMT face and a ^{241}Am source located several cm away. Various thicknesses of aluminum foil were placed in front of the source. Figure 6 is a plot of the total count rate as a function of the $A\ell$ thickness. The thickness of 20 microns where the count rate levels off also corresponds to the range of 5.5 MeV alphas in aluminum. Because the attenuation length of 25 keV X-rays from the Am source is about 1.5 mm, figure 5 indicates that 5.5 MeV alphas are causing the acrylic to scintillate (at a low level of light output). The geometry was kept fixed and a acrylic disk coated with ZnS was put in place of the clean acrylic disk. A comparison of the resulting count rate with the rate when the clean piece of acrylic was in place shows that **clean acrylic (weakly) scintillates with an efficiency of close to 100% when alphas are incident.**

The net count rate in the clean acrylic disk in the plateau region of Figure 6 was compared with the number of counts observed with a ZnS layer covering the front face of the disk. These two numbers are the same within experimental errors, indicating that **X-rays from the ^{241}Am source cause (weak) scintillations in acrylic with close to 100% efficiency.**

The light produced by scintillation in acrylic is far less than that produced in ZnS. The spectrum observed with bare acrylic looks like a slight tail on the single photoelectron peak, whereas the ZnS produces a clean peak at large pulse height. To estimate the relative light output for the two, one can use the figure of one photon generated for each 9 eV of alpha energy in ZnS (B.L. Cohen, Nucl. Instrum. Meth. **212**, 403 (1983)) and use about 14 photons per 5.5 MeV alpha for bare acrylic (i.e. one pulse per alpha in a phototube with about 14% quantum efficiency and 50% geometric efficiency). Then ZnS produces about 6×10^5 photons per 5.5 MeV alpha, about 5×10^4 times more than the acrylic.

Comparing the light output from acrylic with Čerenkov light in the SNO detector, it is about ten times lower than the light produced by a 7 MeV electron. Therefore, it should not be a problem. However, we must be careful to make sure that our acrylic does not scintillate any more than the sample measured to date or else we may have added background problems.

Acrylic also scintillates from X-rays even though they are below the threshold energy (225 keV) for Čerenkov photon production. This was observed by the change in count rate as the source was removed with thick $A\ell$ foil preventing alphas from reaching the acrylic.

4 Vacuum Extraction of Radon

For the extraction of radon from water, we require a water pump which is strong enough to pull water from a chamber under vacuum and which will not contaminate the water from materials used inside the pump. Positive displacement diaphram pumps are available constructed out of materials which are very clean. We evaluated two such pumps on loan from a manufacturer. A small vacuum chamber was put together into which water could be filled. The most powerful diaphram pump of the two tested required a height difference of a least 135 cm between it and the vaccum chamber in order to be able to pull water out. Also by the nature of its operation, there is a strong pulsing vibration in the pump's discharge hose. We are continuing to look for other types of pumps which may be suitable.

PVC plastic is full of resins, hardeners, releasing agents, etc. which continuously leach out into water and also is not very resistant to biological growth. Polyethylene has been reported to be permeable to radon gas. Discussions with representatives of plastic manufacturers have determined that polypropylene is a coomon choice in ultrapure water systems in terms of cleanliness, resistance to biological growth, permeability to gasses and low rate of water absorption. As well, components (valves, fittings, etc.) are readily available in all sizes and the cost of polypropylene is a factor of ten less than exotic, high tech plastics. We are proceeding with a design of a 100 liter vacuum extraction system fabricated out of polypropylene. The fittings required for a radon extraction board have been delivered and we are proceeding with its assembly.

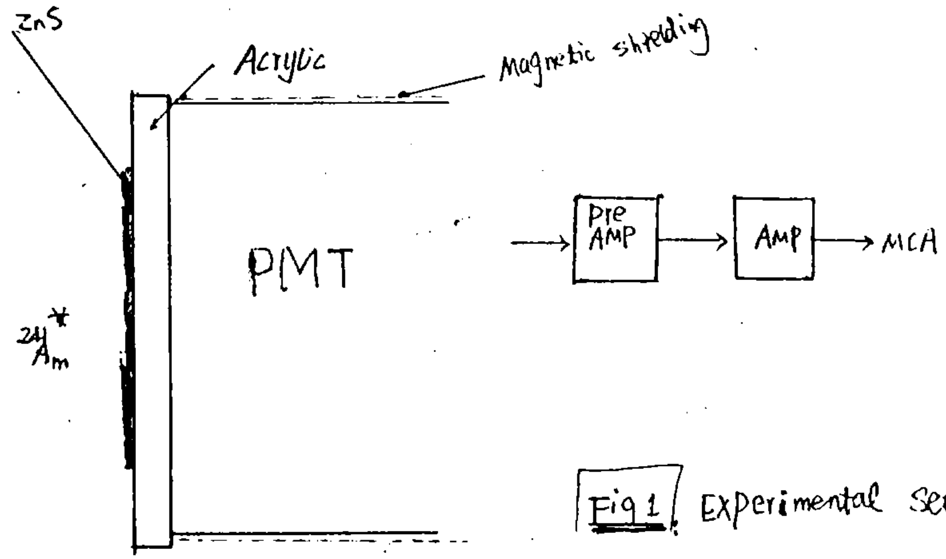

Fig 1 Experimental set up.

^{241}Am, $A = 3.7 \times 10^3 / s$ (α)

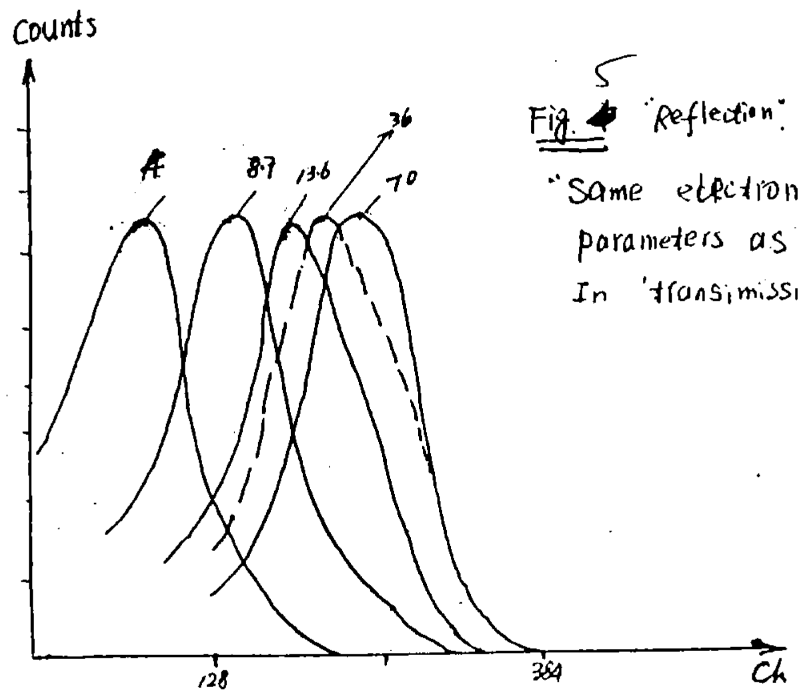

Fig. 5 "Reflection"
"Same electronic parameters as In 'transimission'"

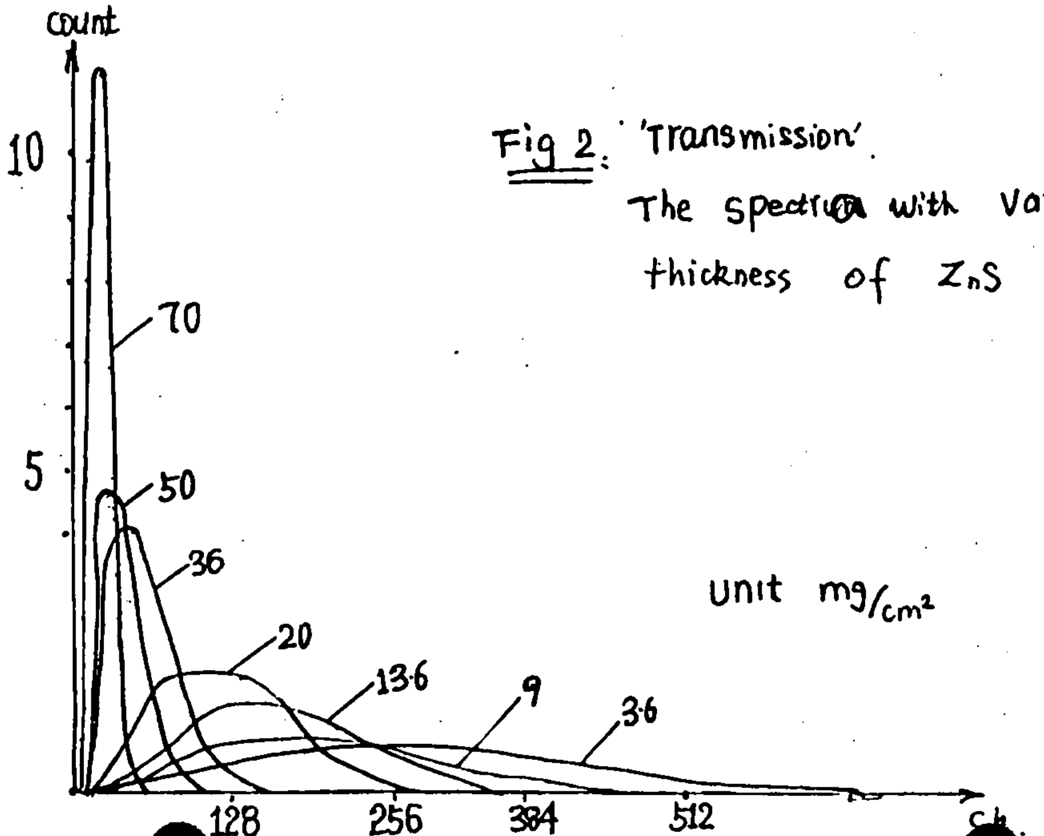

Fig 2: 'Transmission'
The spectrum with various thickness of ZnS

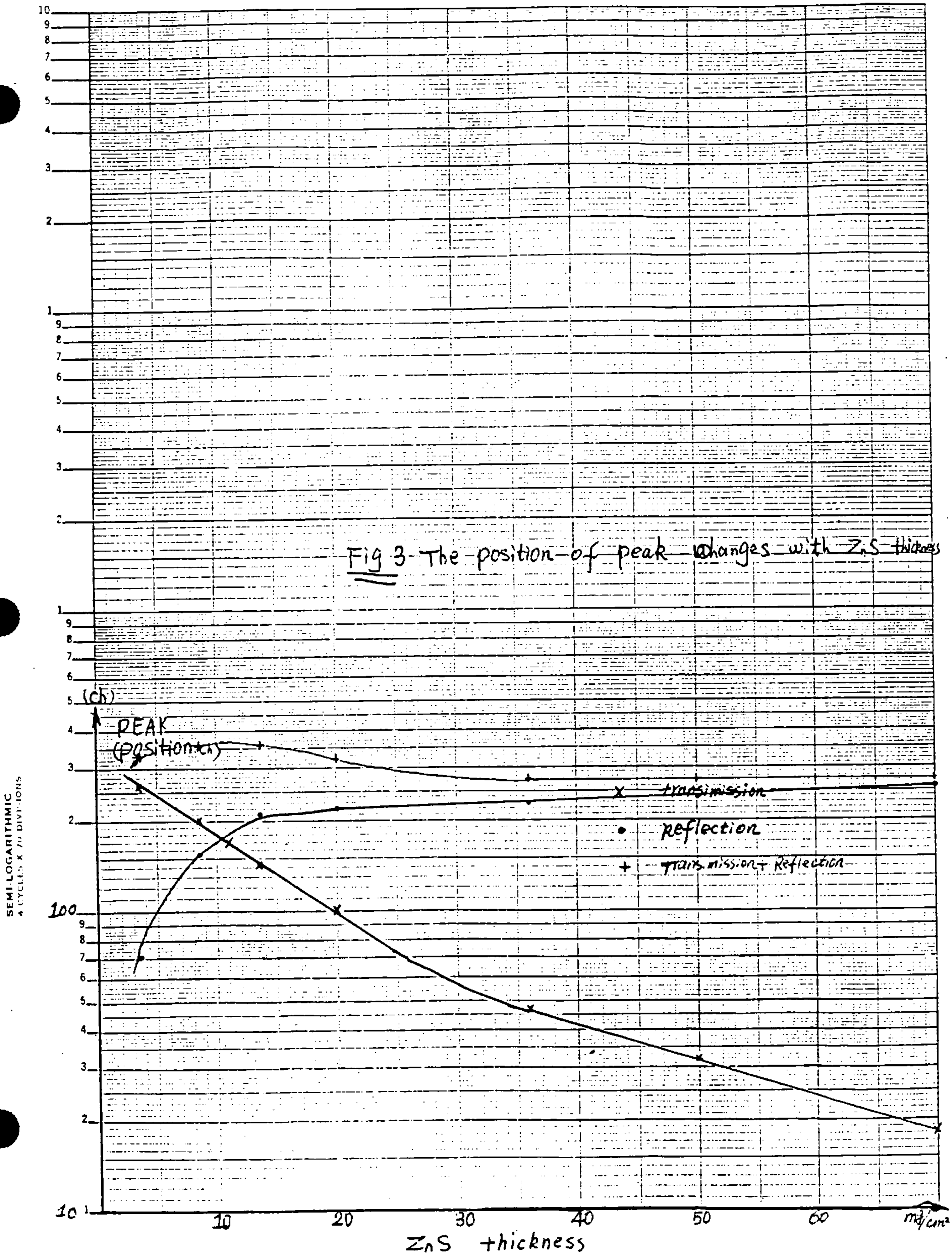

Fig 3 The position of peak changes with ZnS thickness

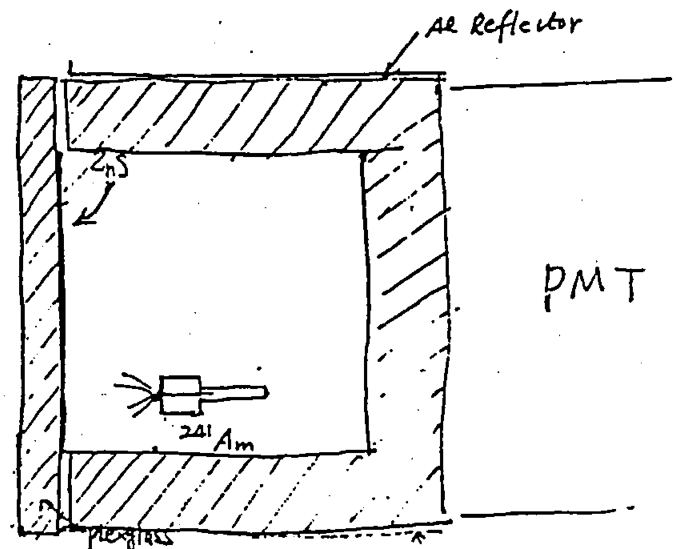

Fig 4. Reflection Geometry

Fig 5 is on page with Figure 1