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LABORATORY RESEARCH

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Where does laboratory research enter into a workshop on observing techniques? It can suggest observations that would test theories or that would provide new information. In order to properly interpret the rapidly growing body of observational data, many types of laboratory measurements are needed. Brief surveys of cometary laboratory research may be found in the last five triennial reports of Commission 15 in the respective IAU Transactions.

Molecular spectroscopy in the visible, has been recognized for some time and is being carried out in several laboratories, gradually but systematically and is described in IAU Commission 14 reports. Similar systematic measurements in the ultraviolet, infrared and microwave region of the spectra are required. Photochemistry is another well established research area for cometary studies.[1]

A new and rapidly developing phase is laser fluorescent spectroscopy of photofragments. This provides data on identity and internal energy distribution of radicals. A potentially powerful application of this work is the suggestion that newly created CN_2 fragments could be detected by their expected high rotational excitation.[2] Jackson's report will describe the present state of research in this field.

The large cross section for ionic reactions has led to several theoretical analyses of chemical processes in the coma and the possible considerable effects on coma composition. The development of refined and highly sensitive spectroscopic techniques is expected to permit observational investigations of this phenomena. These developments, in addition to already available observations of coma radicals, means laboratory cross-section or reaction rate measurements are needed to interpret the data. Flow tube techniques[2], fluorescent spectroscopy detection[3] for neutrals and a variety of ion-molecule reaction techniques[5,6] have provided some data and will continually add to our knowledge.

Another category of experiments simulate solar-wind interactions with comets. References to these experiments also appear in Commission 15 Reports.

The properties and behavior of ice mixtures are clearly important for icy comet models. Some work has been carried out in the Soviet Union and reported in several Colloquia.[7,8,9]

Experiments on the sublimation rate of ice, and the phase transition from amorphous to crystalline ice have been carried out at Dudley Observatory. A tapered Element Oscillating Microbalance whose oscillating frequency is a function of the mass deposited on a low mass substrate (Figure 1) is used.[10] The results for a phase transition in pure H_2O ice is given in Figure 2. This shows the temperature and sublimation rate increase at the phase transition during the initial warm-up and the absence of any increase during subsequent warm-ups. A summary for the entire range of H_2O/CO_2 ratios is given in Figure 3. For mixtures, the transition occurs at higher temperatures and is not as sharp as for pure H_2O ice.

The final category of experiments deals with irradiation of ice. The ultlraviolet ice irradiation experiments at Leiden will be described by Dr. Greenberg.

Electron impact dissociation and excitation of molecules of cometary interest are reported in the Commission 15 reports. Much of the work that has been done is described in untranslated Soviet journals and therefore generally unfamiliar to western astronomers.

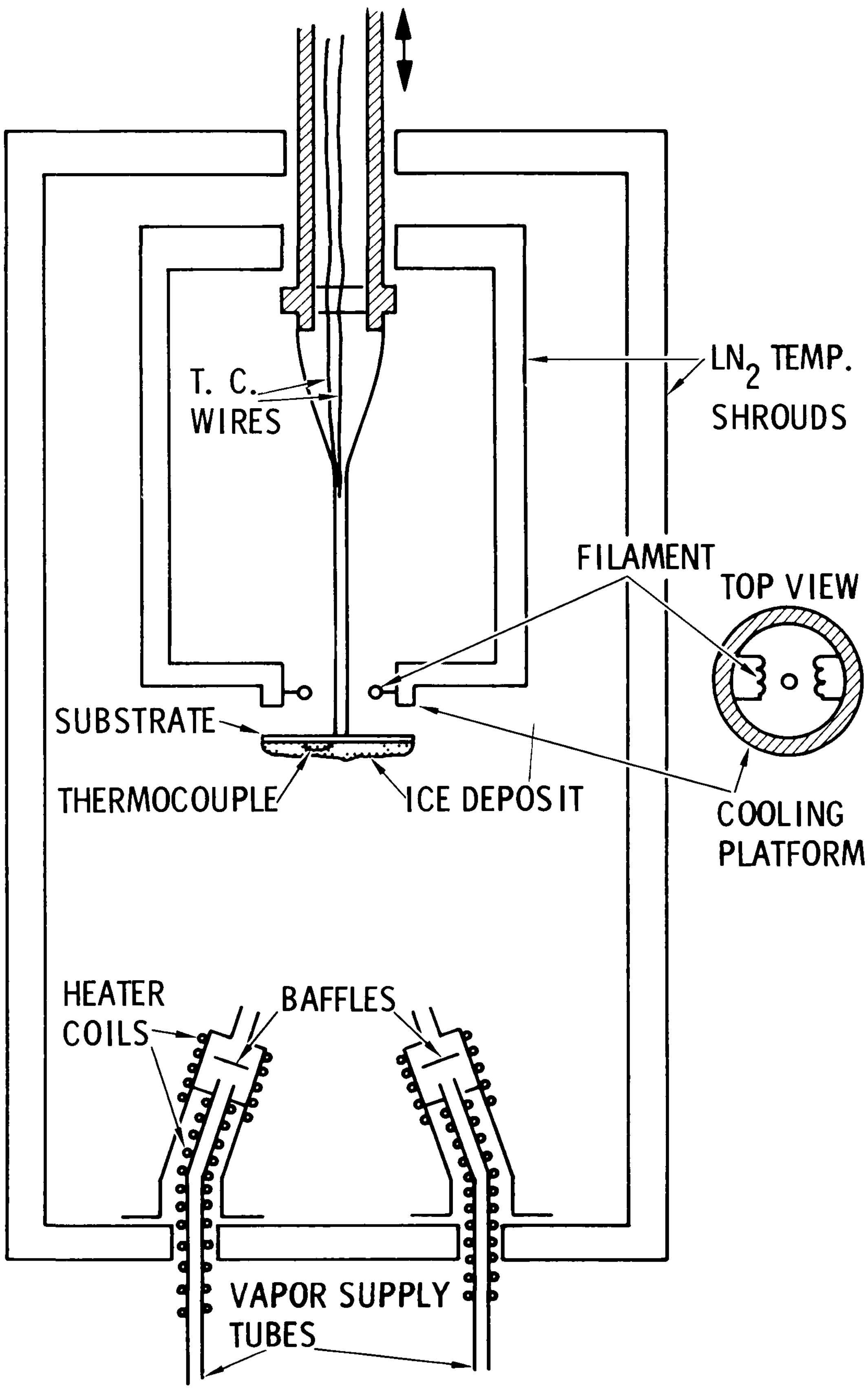

Figure 1. Tapered Element Oscillating Microbalance. The light source and photodetector for measuring frequency are not shown.

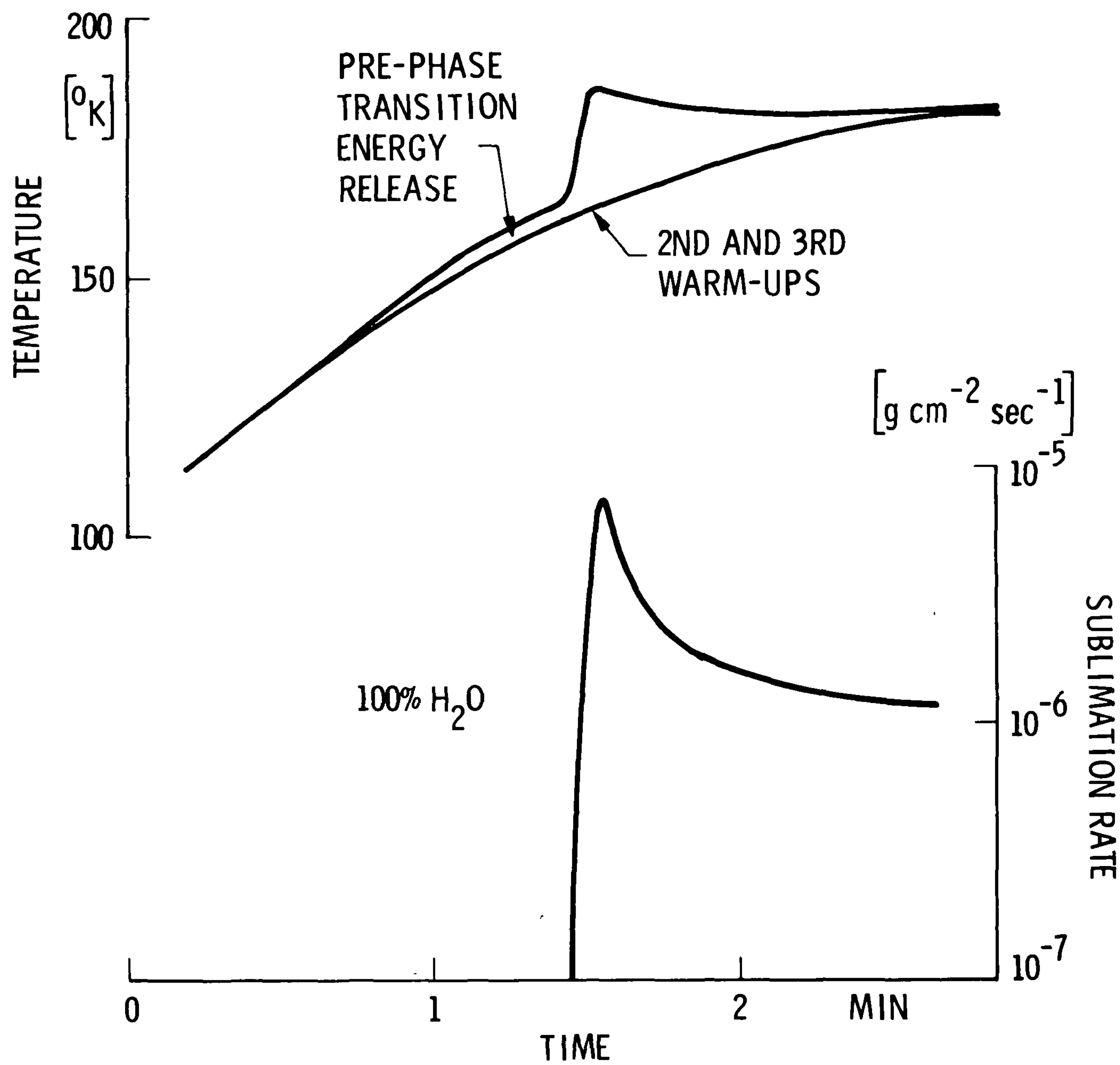

Figure 2. Energy release and sublimation rate of water ice.

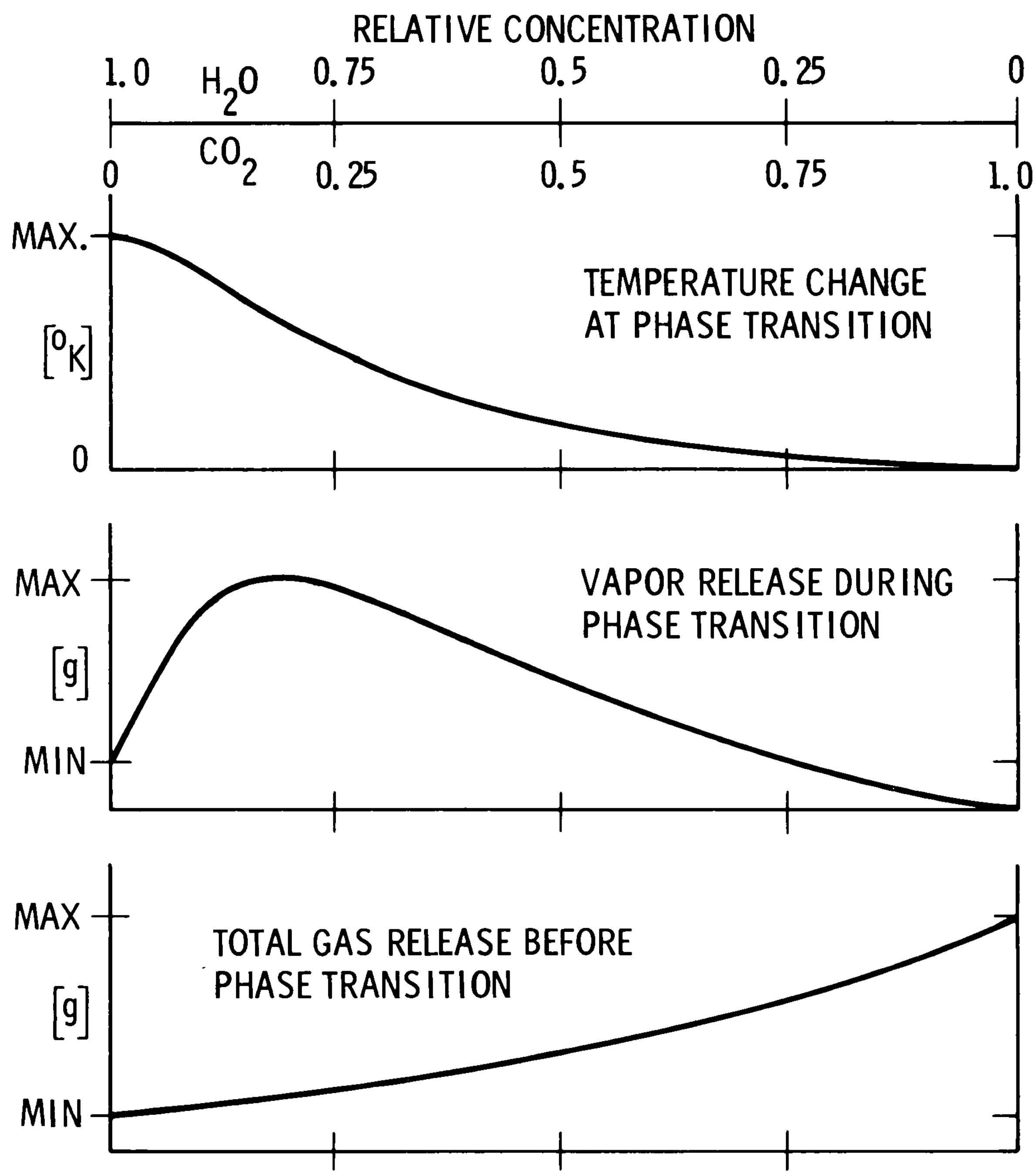

Figure 3. Summary of energy and vapor releases for H_2O-CO_2 ice mixtures.

I will now describe an experiment nearly completed at Goddard on the proton irradiation of ice mixtures. The object is to determine the effect of galactic cosmic rays on comets stored in the Oort cloud for 4 x 10^9 years. This study will form the Ph.D. thesis of Marla Moore who is in the University of Maryland Astronomy Program. The ices were various combinations of H_2O, NH_3, CH_4, CO, CO_2, N_2, condensed at 12 K. Infrared spectra were obtained at intervals during an irradiation that lasted up to eight hours. Figure 4 displays the experimental arrangement showing the 1 MV proton beam from the van de Graaff accelerator, the closed cycle cryostat and sample film, and the window for the light beam from the infrared spectrophotometer. A quick summary of results shows:

1. New, small molecules are formed:

   i. $H_2O + NH_3 + CH_4 \rightarrow CO_2$, N_2O, NO

   ii. $H_2O + CH_4 + NH_3 \rightarrow CO_2$, C_2H_6, C_3H_8

   iii. presence of CO_2 produced CO

   iv. pressure bursts occur when sample is warmed above 15-20 K. This suggests release of H_2,

   v. of particular interest for the study of "new" comets is the formation of non-volatile residue that remains after the sample is warmed to room temperature. Further studies to determine the fraction of the film that is convected to the residue and its composition are underway.

I thank H. Patoshnik for providing the results of his experiments on ice mixtures.

References

1. H. Okabi. 1978, The Photochemistry of Small Molecules, Wiley: Interscience, NY.

2. B. Donn and R. J. Cody. 1978, Icarus 34, 436.

3. C. J. Howard. 1979, J. Phys. Chem. 83, 3.

4. J. V. Michael and J. H. Lee. 1979, J. Phys. Chem. 83, 10.

5. S. S. Prasad and W. T. Huntress, Jr. 1980, Ap. J. Suppl. 43, 1.

6. E. W. McDaniel, V. Cermak, A. Dalgarno, E. E. Ferguson and L. Friedman. 1970, Ion-Molecule Reactions, Wiley: Interscience, NY.

7. E. A. Kajmakov and V. I. Sharkov. 1972, The Motion, Evolution of Orbits and Origin of Comets. Ed. by C. A. Chebatarev, E. I. Kazimirchak-Polonskaya and B. G. Marsden. D. Reidel: Dordrecht, Holland, p. 308.

8. E. A. Kajmakov and V. I. Sharkov, ibid, p. 316.

9. O. V. Dobrovolski and E. A. Kajmakov. Comets, Asteroids, Meteorites, ed. by A. H. Delsemme, University of Toledo, Toledo, OH, p. 37.

10. H. Patashnik and C. L. Hemenwey. 1969, Rev. Sci. Inst. 40, 1008.

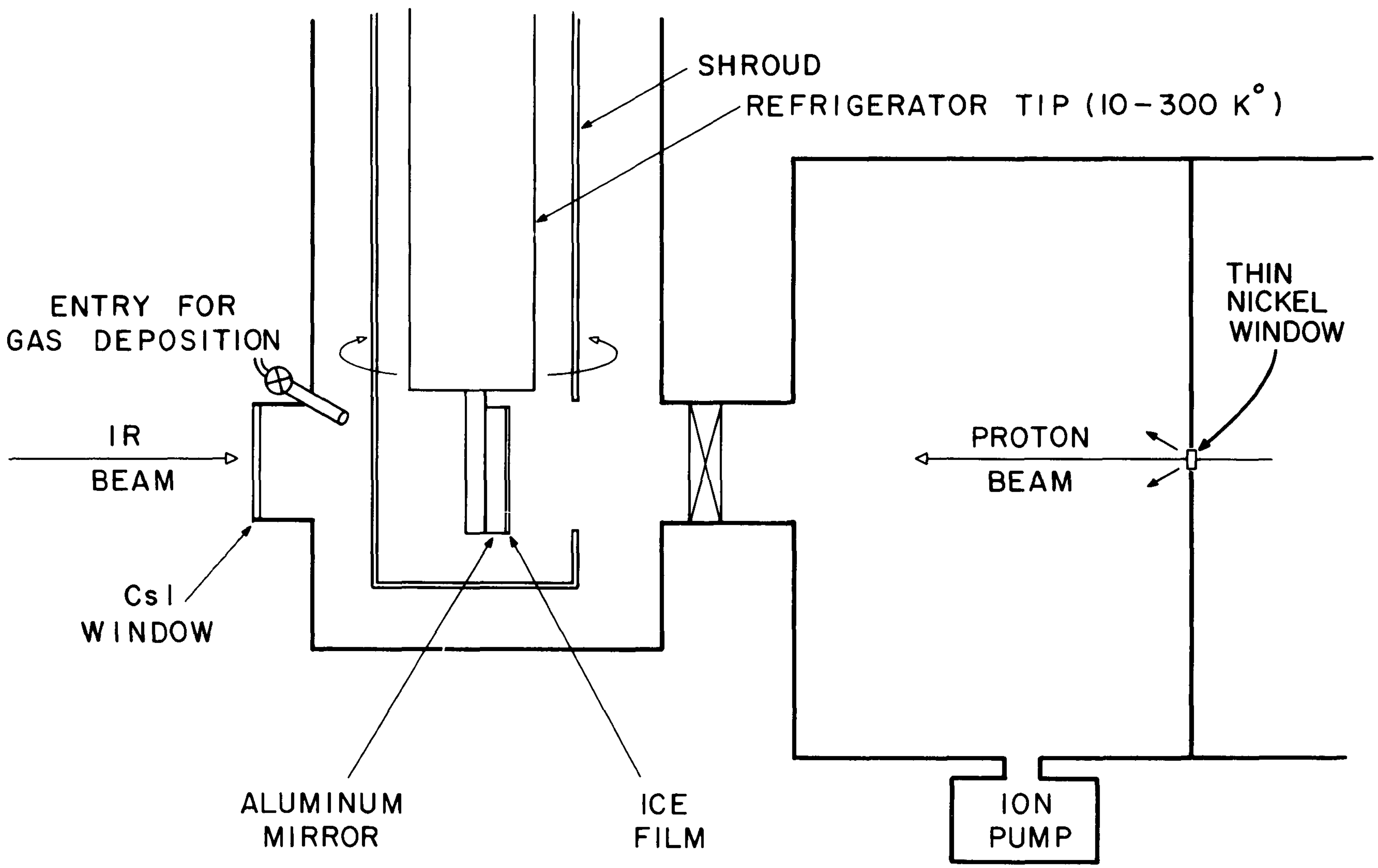

Figure 4. Apparatus for proton irradiation of ice mixtures.