offhand, it would appear not to be a reason for failing to support the cooperative research organization.

The difficulties are well shown in the promotion in Parliament of the Rubber Industry Bill, which had for its object the imposition of a statutory levy on all imported (and retained) rubber for the purpose of financing cooperative research. That was opposed by some of the manufacturers, although it was warmly advocated by the majority of the trade. The bill, however, could not be presented for third reading last session owing to lack of time, and it, therefore, failed.

An interesting sidelight on the attitude in some quarters towards cooperative research is given in the report of the department. It is stated that a prominent firm which had been a strong supporter of its research association had a large overdraft at the bank, and the bank, as one condition of arranging the overdraft, insisted that the subscription to the industrial research association should be withdrawn on the ground that it was an unnecessary expenditure.—*Correspondent of the London Times.*

SCIENTIFIC APPARATUS AND LABORATORY METHODS

THE USE OF "DRY ICE" OR SOLID CARBON DIOXIDE AS A LABORATORY REFRIGERANT

"DRY ICE" is a trade name for solid carbon dioxide. Carbon dioxide is a gas at ordinary temperature, but solidifies at a temperature of $-73°$ C. or $-100°$ F. Solid carbon dioxide has been known for a long time, mainly as a laboratory curiosity, being easily prepared from liquid carbon dioxide by tying a piece of cloth over the outlet of a steel tank of the latter and allowing some of the contents to escape. As the liquid evaporates it takes up a large amount of heat and so part of it is cooled down to the solidification point. This forms the CO_2 "snow" as it is called, since it resembles real snow very much.

During the last few years solid CO_2, or Dry Ice, has assumed commercial importance as a refrigerant, particularly for perishable goods in transit, being used in place of ice from water. It is manufactured for this purpose on a large scale, recourse being had to not only cooling but high pressure in making it. Its advantages over "regular" or ordinary ice are easily perceived. It is much colder and thus a given weight will be more effective, it lasts longer, and on melting disappears as a gas into the air, leaving no water, as is the case with ordinary ice.

It is prepared in ten-inch cubes weighing forty pounds each. In lots of forty to two hundred pounds it costs ten cents per pound. In lots of two hundred pounds or more it costs five cents per pound.

During the past year in connection with hardiness studies the writer has had occasion to attempt some freezing tests on apple twigs as a check on other methods of determining hardiness. That is, it was desired to freeze different samples of twigs from different varieties of apples during the dormant period, holding them at varying temperatures from $-5°$ C. down to $-40°$ C., perhaps, and thus to determine their killing point. Liquid CO_2 in steel tanks was first tried. In this case the CO_2 was allowed to expand in a copper expansion coil surrounded by an ether bath. The excised twigs were placed in sealed glass bottles in the ether. This seemed to require too much CO_2 and was therefore abandoned in favor of solid CO_2. This proved very satisfactory, as it was cheaper, the work could be done faster and the method is simple.

Pint-size thermos bottles were used as containers, mainly because they were available. Quart size would perhaps be better, as larger sizes of twigs could then be used. They were about two thirds filled with ether and stoppered loosely with one-hole rubber stoppers, through each of which was thrust a thermometer so that its lower end dipped into the ether. The twigs were cut in about six-inch lengths and placed in sealed test-tubes, and these placed in the thermos bottles, two test-tubes in each. The temperature was lowered gradually by dropping into the ether small pieces of Dry Ice, a little at a time. The fragments sink to the bottom and volatilize rapidly, thus causing a violent bubbling which aids in maintaining the temperature of the bath the same in all parts of the container. After the desired point was reached it could be held by dropping in another small fragment whenever the temperature started to rise slightly. In cases where a large number of samples of twigs were to be frozen, a gallon-size thermos jug, such as used by campers, was used as a container. Thus the results for several varieties would be exactly comparable, all being held at the same temperature for any given series.

Care must be taken in handling the Dry Ice as it burns the hands when held even for an instant. Blocks of a pound or more were cut off with an ordinary wood saw. These in turn could be broken into smaller fragments with a knife or cold chisel. A supply of small pieces for cooling down the ether was kept in a thermos bottle.

After the twigs had been kept at the desired temperature for a given length of time, one hour in these experiments, they were taken out and placed in small, wide-mouthed bottles with their lower ends in water. They were then allowed to bud out at room temperature, those failing to do so being regarded as killed.

Over a range of several different temperatures marked differences in varieties could be noted.

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THE USE OF SOLID CARBON DIOXIDE IN MAKING FREEZING-POINT DETERMINATIONS WITH PLANT JUICES

Dunn[1] has recently employed "Dry Ice" as a refrigerant in subjecting tissues of apple stems to freezing temperatures.

The ease with which this material can be handled and the ease with which low temperatures can be obtained and maintained caused the writer to test out its use as a refrigerant in determining the freezing-point depression of plant juices.

Although others may possibly have employed Dry Ice for this purpose, it seems to the writer that knowledge of this method should receive more publicity. Because of the ease of manipulation and the cleanliness and rapidity of the method, it seems as though its use would be of value to workers in the plant sciences.

In this method an ether bath surrounds the air jacket of the usual Beckman freezing-point apparatus. The temperature of the bath is regulated by adding to it pieces of Dry Ice (solid CO_2) until the desired temperature is reached. When the pieces of Dry Ice drop into the ether they sink, causing at the same time violent bubbling of the liquid, while the temperature of the bath becomes lower. The bubbling causes the temperature of the bath to become uniform throughout, dispensing thus with stirring.

The air-jacket may be filled with ether or alcohol if desired. The ether bath should be in a cylindrical container, tall enough to accommodate the air-jacket and its contents and the auxiliary thermometer. The container may be of metal, enamelware or glass, and should have a capacity preferably of two to two and one half liters, and tall enough to accommodate the freezing tube.

The desired temperature of the bath may be maintained during an experiment by adding small pieces of solid CO_2 whenever there is a tendency for the temperature of the bath to rise. The apparatus should be placed in sawdust or some other insulating material.

The advantages of using ether for a bath lie in the following points: (1) Ordinary ether is cheap. (2) The freezing-point of ether is very low. (3) Ether is volatile, leaving the apparatus clean after its use. (4) In other liquids that are volatile and do not adhere to the parts of the apparatus in contact with them, difficulty is obtained in lowering the temperature of the bath if water is present. For this reason alcohol has been discarded as a bath. In alcohol the pieces of CO_2 become coated with ice which retards or stops the volatilization of the CO_2.

It is apparent that this method excels as cooling is produced by drawing air through the ether bath causing rapid evaporation therein because of the more rapid lowering of the temperature.

The advantages of this method over methods where a salt-ice mixture is used are the following: (1) The temperature of the cooling mixture is more easily controlled. (2) The material is cleaner and easier to handle. (3) The ether in the bath may be used over and over again. (4) The temperature of the ether bath can be lowered more rapidly and accurately.

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[1] Stuart Dunn, "The Use of 'Dry-Ice' or Solid Carbon Dioxide as a Laboratory Refrigerant," Science, March 29, 1929.

SPECIAL ARTICLES

SERIES IN THE ARC SPECTRUM OF BROMINE[1]

Recently we have photographed the spectrum of bromine as emitted by a Geissler tube, from the ultra-violet to beyond 9300A in the near infra-red. The type of spectrum obtained depends both on the pressure of the gas within the tube and the character of the exciting discharge. When the gas at low pressure is activated by an uncondensed discharge from a high-voltage transformer the spectrum observed is predominantly that of the neutral atom, the arc spectrum.

With the new wave-length data and the wave-lengths observed by Turner[2] in the Schumann region, we have succeeded in working out the structure of the arc spectrum, Br I. The theoretical structure of the spectrum is similar to that of Cl I which we described in our note to Science for October 12, 1928. Turner's lines represent the combination of the lowest term $s^2p^4 \cdot 4p\ {}^2P$ with the higher ${}^2P$ and ${}^4P$ terms coming from the electron configuration $s^2p^4 \cdot 5s$. These terms, in turn, combine with still higher terms coming from $s^2p^4 \cdot 5p$ and $s^2p^4 \cdot 6p$ to give the prominent arc lines observed in the infra-red and in the green and blue.

For the lines observed by Turner, we give the following classification.

The lines from the $5p$ and $6p$ electrons are in Rydberg sequence. We therefore use them in calculating

[1] Publication approved by the director of the Bureau of Standards, of the U. S. Department of Commerce.

[2] *Physical Review*, 27: 400. 1926.