In the southern hemisphere Rocco and Broecker[7] reported 3·7 d.p.m. strontium-90/100 l. at 800 m, 14·6 at 1,000 m and 2·2 at 1,300 m, in March 1961 at 49° 19′ to 25′ S., 78° 44′ to 45′ W. Although a small number of samples are represented, both variability and concentration levels correspond reasonably well with those of the 1,000 m samples of Table 2. These observations are consistent with northward flow of Antarctic Intermediate Water at rates near the minima estimated by Defant. The resumption of testing in October 1961 produced a much smaller change in southern hemisphere fall-out rates[10] than on those in the northern hemisphere. It is not possible, therefore, to be equally sure of the injection date of higher strontium-90 concentrations in Antarctic water masses, nor to discount the possibility that the strontium-90 data reflect in fact northward flows at higher rates than Defant's minimum estimates.

It does, nevertheless, seem clear that the increase in mid-depth strontium-90 concentrations shown by comparison of Tables 1 and 2 is quite consistent with the water circulation patterns and rates which have been developed from the study of physical oceanography. This internal consistency has been widely reported[3–6,8,11,12]. Only the measurements of Broecker[7,13] have shown patterns of distribution of strontium-90 and caesium-137 which appear clearly inconsistent with our understanding of the directions and rates of movement of intermediate depth currents in the Atlantic Oceans; in fact, as seen in Table 1, and as we have discussed elsewhere[6], their earlier set of analyses[7] showed, where comparison was profitable, satisfactory correspondence with ours. We have no explanation for the fact that their more recent measurements are completely irreconcilable with the measurements of other workers in this field.

More detailed reports of the data presented here are being prepared for publication elsewhere. Various aspects of the programme have been supported by the U.S. Atomic Energy Commission, the U.S. Office of Naval Research, and the U.S. National Science Foundation.

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Sizes of Atmospheric Ice Nuclei

ATTEMPTS to identify and count atmospheric ice nuclei, as the first steps towards establishing the chemical and physical nature of such nuclei and their mode of action, have occupied cloud physicists for many years. It is generally accepted that ice nuclei are solid particles; the diameters of these particles have been reported[1–6] to be mostly between 0·1μ and 1μ.

The temperature at which a particle causes nucleation is determined largely (apart from a slight time dependence) by the presence of an effective site on the surface of the particle. It is therefore plausible that the larger the particle, the greater the probability that such a site will be found on it.

Droplet-freezing experiments[7] with the melts of hailstones from the Western Canadian province of Alberta have shown that the hail contains very effective nuclei. Fig. 1 shows a typical nucleus spectrum for Alberta hail compared with one for hail from the Montreal (Eastern Canada) region. In order to obtain some information about the sizes of the nuclei in these hailstones, the melt was filtered through membrane filters of various pore sizes. The pore size of such a filter puts an upper limit on the size of the particles that remain in the transfluent. The filters themselves do not add particles to the filtrate, as has been shown by the processing of a sample of water which was of greater purity than the hail, and which retained that purity after filtration. An example is shown in Fig. 2 of how filtering changes the distributions of freezing events for 0·01 cm³ drops of Alberta hail cooled at a rate of 2°/min.

The nucleus spectra—the concentrations of nuclei are obtained as the fraction of unfrozen drops freezing within one degree of the specified temperature times the number of drops per ml.—derived from the histograms of Fig. 2 are shown in Fig. 3. Apart from minor details, these results show that the removal of particles larger than 0·01μ reduces the concentration of nuclei through most of the temperature range by a factor of only 2 to 4. Thus it seems that a large fraction of the Alberta hail nuclei

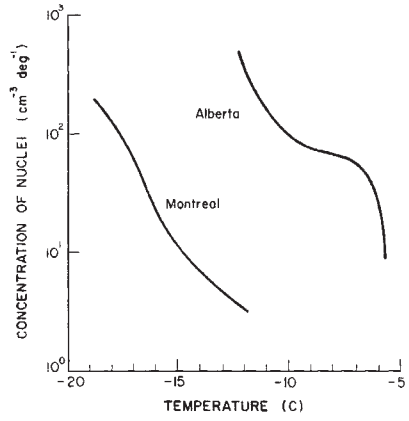

Fig. 1. Concentrations of ice nuclei, characteristic of hail from Alberta and from the Montreal region, as measured in the melt.

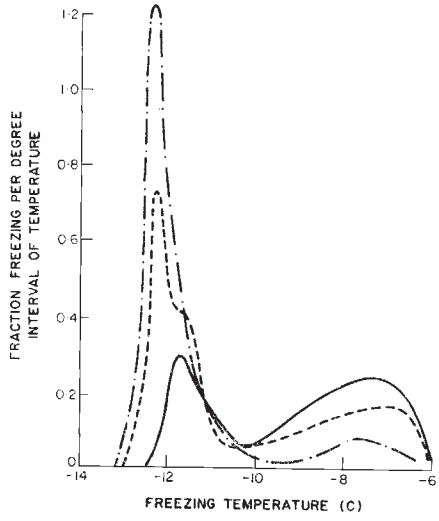

Fig. 2. Distributions of freezing events for a sample of Alberta hail. ———, Unfiltered; - - - -, 1·2μ filter; —·—·—, 0·01μ filter.

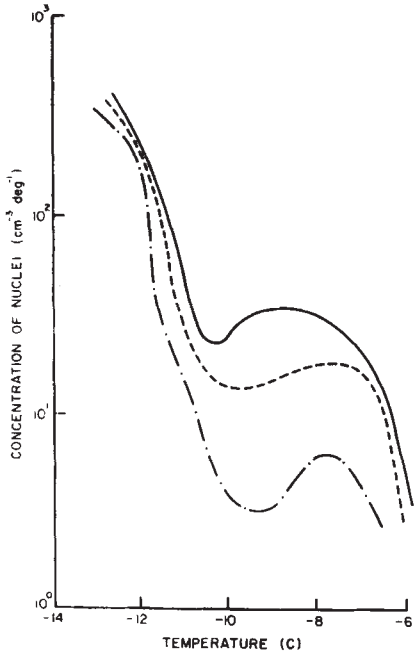

Fig. 3. Nucleus spectra for a sample of Alberta hail. ———, Unfiltered; – – – –, 1·2μ filter; —·—·—, 0·01μ filter.

are smaller than 0·01μ, an order of magnitude smaller than generally assumed, and that they fall within the size range of the Aitken nuclei. The assumption that the concentration of nuclei effective at specified temperatures is proportional to size (either radius, surface or volume) does not seem to be substantiated by Fig. 3.

Ono[8] reported recently that the nucleation activity in a unsaturated phloroglucinol solution was not diminished by filtration through a 0·01μ pore-size filter. Furthermore, ice nuclei less than 100 Å in size can be active at just a few degrees below 0° C. The contribution of these nuclei to natural cloud-physical processes can therefore not be neglected.

The mechanism by which particles of such sizes may enter into the developing precipitation is capture by the cloud droplets. Brownian motion and motion due to microturbulence are very efficient mechanisms at these size-ranges for causing the coalescence of cloud droplets and the solid particles. Results obtained by Greenfield[9] show that the half-life of 0·01μ diameter particles against capture by droplets in a cumulus cloud of average characteristics is only 0·4 h, and decreases further with decreasing particle diameter. Thus, nearly all of the particles less than 0·01μ in diameter will be captured within the life-cycle of a thunderstorm. The measured concentration of ice-nuclei active at temperatures above −12° C is 10^3 per ml. of hail. Each ml. of hail is derived from about 10^7 cloud droplets, which means that one cloud droplet out of 10^4 contained an ice nucleus. The corresponding concentration of the nuclei in the air before capture is 10^4 particles per m^3. This estimate is within the range of concentrations measured in cloud-chambers[3,5].

Models of heterogenous nucleation normally picture the development of an ice-embryo on a plane substrate surface or in steps or cracks on the substrate. If the particles are comparable in size with the critical embryo size, the applicability of such ideas becomes questionable. The mechanism that nucleates ice on such small organic or non-crystalline particles is unknown. We may need to re-examine the techniques and experiments used to determine the concentrations and size-distributions of ice-nuclei, if particles as small as these can serve as ice-nuclei.

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Distribution of Normal Paraffins in Libyan and Nigerian Crude Oils

IN the course of work on the hydrocarbon type analyses of wax distillate fractions obtained during assays of crude oils, a method[1] was devised for the separation of normal paraffins. It relies on the specific retention of normal paraffins on a type 5 Å molecular sieve, and their quantitative recovery therefrom after destroying the sieve with hydrofluoric acid. The separated normal paraffins are examined by temperature programmed chromatography and the data obtained, taken in conjunction with chromatographic analyses of the light distillates, make it possible to determine the normal paraffin carbon number distribution of a crude oil.

Using this procedure, the normal paraffin distribution in crude oils from the Sarir field in Libya and the Bomu field in Nigeria, containing respectively 23·9 and 13·9 weight per cent of normal paraffins, has been obtained (Fig. 1, Table 1).

Both crudes have irregular normal paraffin distributions. The Sarir crude from what is probably a Cretaceous formation and the Bomu crude from an upper Miocene formation have carbon preference indices (CPI)[2] of 1·09 and 1·12 respectively in the C_{25}–C_{35} range. Each CPI value in this range is the mean of the two ratios obtained when the sum of the concentrations of odd numbered normal paraffins in the C_{25}–C_{35} range is divided by the sum of the concentrations of even numbered normal paraffins in the (*a*) C_{24}–C_{34} and (*b*) C_{26}–C_{36} ranges.

Odd numbered predominances have been claimed as support for the hypothesis that straight-chain fatty acids from animal fats, and the fatty acids, alcohols and free hydrocarbons from plant waxes, are the probable precursors of normal paraffins in petroleum[2–4]. The fatty acids contain an even number of carbon atoms[5] which, if simple decarboxylation occurred, would yield normal

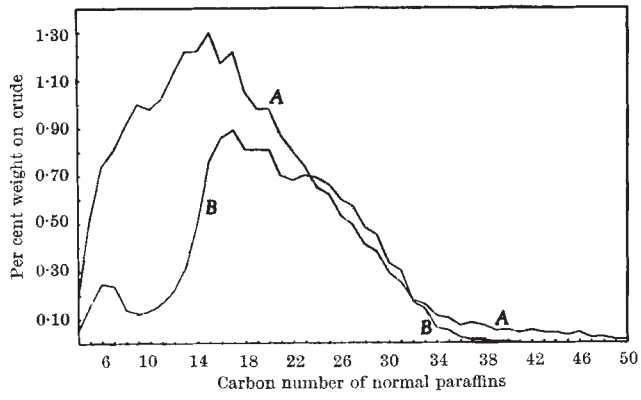

Fig. 1. Normal paraffin carbon number distribution of Libyan (*A*) and Nigerian (*B*) crude oils (per cent by weight).