immense penetrating power and the heavy particles produce intense ionization along their tracks. This is because, being stripped of their electrons, they carry a high charge. In some physical experiments the effect of cosmic rays present an appreciable disturbance, but it is generally possible to correct for this. The chief interest in the heavier particles concerns their damaging effect on living tissues.

A start on the solution of many of the problems of interplanetary space is being made with the present series of satellite launchings. For most of these studies a deep penetration is not required, and many of them only require altitudes up to a few Earth radii.

It seems certain, therefore, that the problems of interplanetary space should soon be yielding to an invasion of that territory, not by men or dogs, but by well-instrumented satellites.

## RECENT DEVELOPMENTS IN ION-EXCHANGE

ONE of the most interesting developments in the field of ion-exchange during the past few years has been the return of interest in inorganic ion-exchangers.

The materials which have been investigated are not the natural or the more recent synthetic zeolites but comparatively simple metal oxides and salts. Precipitates of hydrated oxides such as aluminium hydroxide can behave as either cation or anion exchangers, and the effect has been observed with such metals as zirconium, uranium, thorium and tin.

When zirconyl nitrate, for example, is treated with alkali, the resulting precipitate has an open gel structure cross-linked with -Zr-O-Zr-O- bridges and containing free hydroxyl groups. Such precipitates may be treated with acids such as phosphoric, arsenic or tungstic acids to yield very insoluble products which are stable to high temperatures and contain groups such as the $H_2PO_4$ group in addition to the hydroxyl group. and which therefore have both anion and cation exchange properties. These materials behave differently at different pH values. These new ion-exchange materials are particularly suitable for the analysis and separation of the alkali metals.

The tedious nature of chromatography upon ion-exchange resins with the necessity of developing specific or selective eluting agents has led to an interest in the production of ion-exchange materials containing functional groups which might be hoped to react in a specific manner. The first attempt to prepare a resin with selective chelating properties involved the preparation of a polystyrene containing di-picrylamine groups and this was shown to have a greater affinity for potassium than the conventional resins containing carboxyl or sulphonic acid groups, as would be expected from the insolubility of the potassium salt of di-picrylamine.

A further development of the ion-exchange technique has been the production of ion-exchange papers. Ion-exchange properties may be conferred upon filter-paper by the introduction of active functional groups into the cellulose structure. Such groups have included the sulphonic and carboxylic acid, the quaternary ammonium and the phosphoric acid groups.

Ion-exchange materials in the form of membranes permeable to water have also interesting properties and uses. The anion exchanger is permeable only to anions and the cation exchanger is permeable only to cations, while both have a low electric resistance. With such membranes replacing the conventional semi-permeable membranes, the process of electro-dialysis becomes much more efficient and can be used for the desalting of solutions of amino acids such as are obtained in the hydrolysis of proteins. Another use of these membranes is in the determination of the activities of ions and this facility is valuable for ions for which reversible electrodes are not available. These include fluoride, nitrate and acetate.

Protein mixtures have been successively separated upon columns of ion-exchangers but because of the large molecular size of the proteins, the effect was confined to the surface of the resin. Recently attempts have been made to improve the efficiency of this process by providing exchangers with a more open structure Three types have been described, one in which an inorganic material with a porous structure such as kieselguhr is coated with a sulphonated polystyrene, another in which the resin itself is expanded and made porous and a third which uses chemically modified cellulose which is permeable to the large molecules. (*Chemical Products*, April 1958.)