Novel ion-exchange materials are helping to remove toxic waste from the environment

New ions for old

>> JOHN PARISE

PhotoDisc

Toxic metals in the environment are dangerous for public health, and ways must be found to concentrate and remove them. This is a job for 'ion exchangers', which many people already use in their homes as water purifiers, or 'softeners'. The materials used are minerals or synthetic resins; they trap the unwanted ions – mostly positively charged metal ions – and replace them with harmless ions.

New types of mineral structures must be invented to trap or exchange specific ions. We use neutron and X-ray diffraction to understand the structure of these materials, and to guide the development of new and more efficient ion exchangers. For example, researchers at Sandia National Laboratories in the US have developed novel molecular sieves for removing ions such as the isotope strontium-90 found in radioactive waste.

Designer minerals

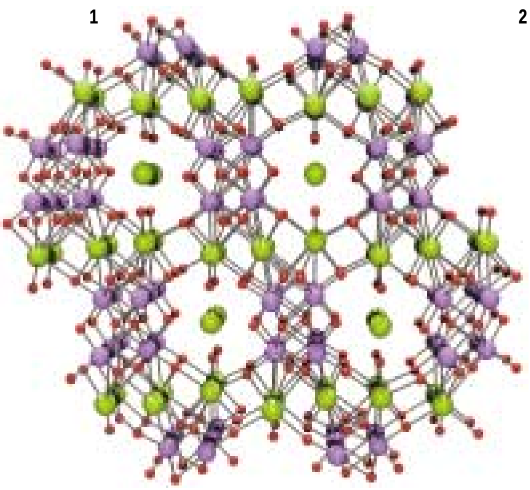
Sandia Octahedral Molecular Sieves (SOMS) consist of a hydrated niobium-titanium-sodium oxide arranged in an octahedral framework (see Figure 1). Some of the sodium ions reside in channels where they are relatively mobile. One of these materials, SOMS-3, can give up these harmless sodium ions in exchange for radioactive strontium-90 ions, which are then trapped because they are larger. This material was designed to have channels large enough to release sodium, but small enough to trap strontium-90.

Alumino-silicate minerals, or zeolites, are also used extensively as ion exchangers (see p.6). Their aluminium (Al) silicon (Si) oxide framework structures contain similar channels. Conventionally, the ion-exchange capacity is proportional to the relative amounts of aluminium and silicon, since replacing silicon ions, Si^{4+}, with Al^{3+}, which has one less positive charge, allows other positively charged ions to be accommodated – while still retaining the correct balance of positive and negative charges (from the oxide ions) in the crystal. However, the maximum Al/Si ratio that can be obtained is 1. We have found that the ion-exchange capacity can be further increased by exchanging singly-charged lithium ions (Li^+) for Si^{4+}; the lithium oxide components are more flexible and can more easily accommodate other positively charged ions.

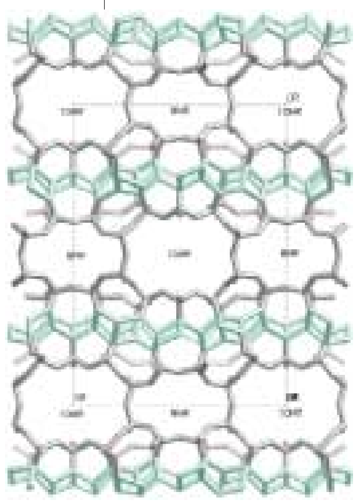
Of course, lithium is a very light element, and is much more easily located with neutrons than with X-rays, so a combination of the two techniques must be used to understand these new ion-exchange materials. We synthesised several new porous litho-silicates, including the complex framework structure called RUB29 shown in Figure 2. Here the Si-Si (blue) and Li-Li (grey) frameworks only are shown. Notice the large channels surrounded by the flexible lithium oxide structure; these channels can accommodate large metal ions such as caesium, removing them from the environment. This type of material is again of potential interest for cleaning up radioactive waste, with the removal of radioactive caesium isotopes.

These two examples illustrate how neutron diffraction can be used to understand such structures, and in particular the mechanism whereby ions enter and leave the pore spaces shown in the figures. This information will help to develop new materials for cleaning up the environment. ■

1



2



1 SOMS-1, a new ion exchanger for removing unwanted ions from the environment

2 RUB29, a new lithium-containing zeolite for cleaning up radioactive caesium

Research team: **J. B. Parise, S-H. Park, A. Tripathi *(State University of New York, USA)*; T. Nenoff and M. Nyman *(Sandia National Laboratory, USA)***