strongest evidence for fossil fission pits in calcite was presented by a calcite showing a pronounced yellow color, presumably color centers produced by radiation. This specimen showed 54,000 deep pits per square centimeter. Furthermore, the yellow color could obviously be correlated with the pit density. The end having much less color showed a greatly reduced number of pits. On annealing this specimen essentially all the deep pits failed to develop, leaving a concentration of only a few hundred pits per square centimeter. In the annealing the yellow color also faded.

We concluded that etching the cleavage faces of calcite produces deep pits both from dislocations and from fission damage and that the two can be distinguished by annealing experiments. One further piece of evidence supports this conclusion. A specimen of calcite showing a large number of dislocations was annealed for 18 hours at 400°C and then etched. This specimen should show only dislocation etch pits (Fig. 2) and may be compared with an etched specimen of the yellow calcite (Fig. 3) which should show almost all fission pits. The uniform shape of the presumed dislocation pits indicates a preferred direction of the dislocations. This may be controlled by a preferred growth direction or by the slip systems. In contrast, the fission damage trails will be inclined at all angles to the cleavage face and consequently will not give etch pits of uniform shape. Our interpretation is further strengthened by the fact that the presumed fossil fission pits vary in size (Fig. 3). This is understandable since the damage trails are distributed throughout the volume of the crystal. Those which almost transect the surface will not begin rapid growth until a slight amount of material is removed in the slowly dissolving direction perpendicular to the cleavage surface. Thus, such a pit will effectively be etched for a shorter total time. In contrast, the induced fission pits (Fig. 1) are of uniform size since, in this case, all the fission damage trails originate on the surface.

In addition to the indirect evidence from annealing experiments, an estimate for the durability of the fission damage was obtained from the yellow calcite by direct means. An analysis of this material showed it to contain 42 ± 3 parts of uranium per million (*5*). If we crudely estimate that the etching technique samples a region about 10 μ thick below the surface, we obtain an age of 2.5 × 10^6 years for this specimen. This is not an unreasonable age since the specimen came from the Chihuahua, Mexico, deposits which are thought to be associated with Tertiary or Quaternary volcanic activity (*6*). In any event the fission damage appears to have persisted for at least 10^6 years in this specimen.

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31 January 1964

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Electrokinetic Behavior of Ion-Exchange Resin

Abstract. *If a bed of ion-exchange beads immersed in water is subjected to a vertical electrical field of appropriate strength and polarity, vertical chains of beads are formed at the surface of the bed.*

An ion-exchange bead in water is a very large polyelectrolyte ion with small counterions. A bed of such beads is a good electrical conductor (*1*) with an unusual kind of flexibility which we shall describe.

The experiments which illustrate this behavior were carried out with 100- to 200-mesh (about 0.1 mm diameter) beads of polystyrene-divinyl benzene anion-exchange resin (Dowex 1-X8) in the chloride form, or cation-exchange resin (Dowex 50W-X8) in the hydrogen form. The resins were prepared by washing with dilute base and acid, and then by thorough washing with conductivity water. The resin beds were formed in a glass U-tube, or in a straight, vertical, glass tube, with platinum electrodes and with electrical fields of 0 to 25 v/cm in the water above the resin.

At a threshold of approximately 10 v/cm, the beads at one surface of a bed in the U-tube align into chains which rise vertically. A photograph of such chains is shown in Fig. 1. The chain height is roughly proportional to the applied electric field up to a limiting height of a few centimeters at 20 v/cm. At higher voltages the chains become unstable and lose small fragments which drift through the water and ultimately settle until they reach the surface of the bed or another chain. Cation-exchange resin chains form on the side of the anode, and anion-exchange resin chains on the side of the cathode. In a vertical tube chains are formed only if the appropriate electrode is above the bed. Mixed cation-exchange and anion-exchange beads do not form chains.

Each resin bead is a good electrical conductor because of its mobile ions, and the resin bed is also a good conductor because the beads are in contact. In an electrical field the bed is polarized. With a cation-exchanger the mobile counterions migrate toward the cathode, leaving the anode side negatively charged owing to the fixed charges. The electrophoresis of the beads toward the anode is opposed by gravity. A bead in a chain is supported by those below it and is more highly charged owing to polarization. If the field is strong enough to pull a fragment, perhaps a single bead, from the

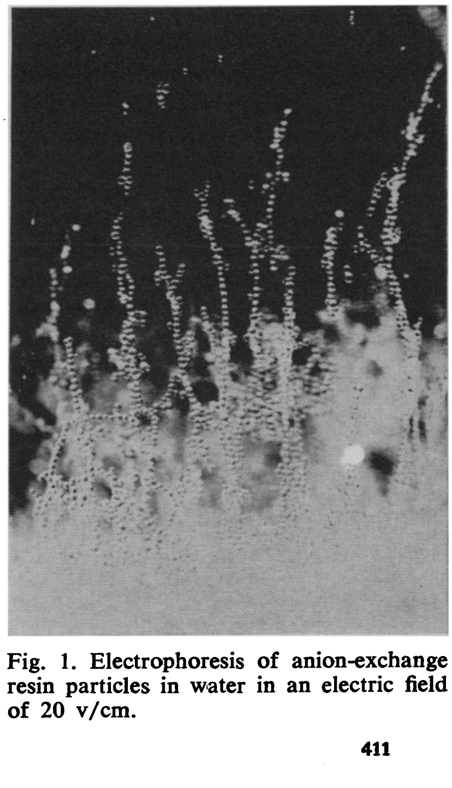

Fig. 1. Electrophoresis of anion-exchange resin particles in water in an electric field of 20 v/cm.

top of the chain, the isolated fragment soon loses part of its charge by hydrolysis and is pulled back by gravity to the surface of the bed or to another chain. With an anion-exchange resin the only difference is that the chains are attracted to the cathode.

The corresponding electro-osmotic flow of the water in the opposite direction was studied, but was not reproducible.

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Selective Rat Toxicant

Abstract. *The maleimide adduct of an unusual fulvene is highly toxic to rats when administered orally or parenterally. It does not induce significant toxic or other biological changes in common house pets and commercially useful mammals and birds when given at dose levels 200 times greater than the dose which is lethal to 50 percent of the rats it is administered to.*

One member of a series of norbornenedicarboximides has been found to be selectively toxic to rats. This compound, 5-(α-hydroxy-α-2-pyridylbenzyl)-7-(α-2-pyridylbenzylidene)-5-norbornene-2,3-dicarboximide, which we have called McN-1025, does not affect mice or other species thus far tested even at high doses.

The material was administered orally to female rats (*1*), and the median lethal dose (LD_{50}) was determined, by the method of Litchfield and Wilcoxon (*2*), to be 5.3 (4.4 to 6.5) mg/kg (*3*). This compound is almost nontoxic in the mouse, for the LD_{50} is 2250 (1760 to 2800) mg/kg. It was also administered to a variety of other species (Table 1) and had no effect on the common varieties of mammals and birds. The animals were observed closely after initial administration and periodically for at least 5 days. Except in guinea pigs and rabbits, high doses (1000 mg/kg, orally) did not induce any significant behavioral changes.

The dicarboximide was given orally to two groups of dogs (eight animals each). One group received a daily amount equal to 0.1 percent of the daily food intake for 60 days without exhibiting deleterious effects. The second group received 10 times this amount. This treatment was terminated in two animals after 15 days and in two more after 30 days, but was continued in the other four animals for 60 days. All the animals in this group survived the designated treatment period, but they became somewhat ill and did not consume their normal amount of food.

The compound was also administered orally to a group of 50 wild Norway rats (*Rattus norvegicus*) captured at a local waste disposal plant. These animals were maintained in captivity for periods ranging from 2 to 30 days. The LD_{50} in this group of wild males and females was similar to that found in albino rats (Table 1). Likewise, a group of wild Roof rats (*Rattus rattus*) were obtained and given the dicarboximide by stomach tube. The data (Table 1) indicate that the LD_{50} in this species is approximately 30 to 40 mg/kg of body weight.

Table 1. Relative toxicity of a dicarboximide (McN-1025) to mammals and birds. In each instance the compound was administered orally by stomach tube as a solution in dilute acid or in dry powder tablet or capsule form.

Common name and species	Sex	No. of animals	Dose (mg/kg)	Remarks
Rat, albino (*Rattus norvegicus*)	F	30	5.3 (4.4–6.5)	LD_{50}
Rat, wild Norway (*R. norvegicus*)	M, F	50	12 (10–13)	LD_{50}
Rat, roof (*R. rattus*)	M, F	7	60	7/7 dead
		8	55	8/8 dead
		8	50	5/8 dead
		8	45	5/8 dead
Cattle (*Bos taurus*)	M, F	2	100	No effect
Cat (*Felis catus*)	M, F	6	100–1000	No effect
Dog (*Canis familiaris*)	M, F	11	100–1000	No effect
Guinea pig (*Cavia porcellus*)	M, F	12	30–1000	Deaths at 300 & 1000
Horse (*Equus caballus*)	M	1	100	No effect
Monkey, Rhesus (*Macaca mulatta*)	F	2	1000	No effect
Rabbit (*Oryctolagus cuniculus*)	M, F	31	10–1000	1/9 deaths at 1000
Sheep (*Ovis aries*)	M, F	2	1000	No effect
Chicken (*Gallus domesticus*)	M, F	20	10–1000	No effect
Turkey (*Meleagris gallopavo*)	M, F	4	1000	No effect

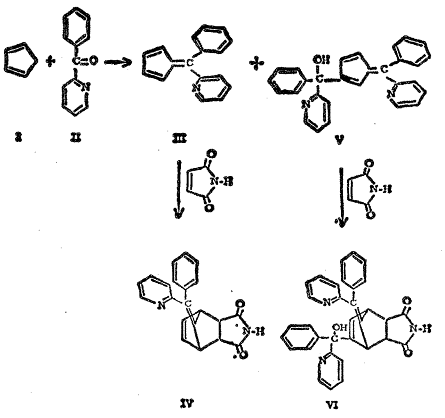

Fig. 1. Synthesis of the toxic carboximide.

After oral administration of an overdose of this material to rats, death occurred rapidly, that is, within 15 minutes to 4 hours. In the primary stages of illness, the animals initially assumed a huddled position and later there was locomotor impairment due to a weakening but not paralysis of the hind extremities. Struggling, labored breathing, and, in some instances, a mild convulsion preceded death. The peripheral extremities were blanched but not cyanotic. Gross and histopathological examination of selected vital organs and tissues revealed no characteristic abnormalities. These findings suggest that this carboximide induces some type of circulatory impairment which may, in turn, cause death.

The synthesis of this toxic carboximide (VI) is shown in Fig. 1. The base-catalyzed reaction of cyclopentadiene (I) and 2-benzoylpyridine (II) leads to a mixture of several products. The maleimide adduct IV of the expected 6-phenyl-6-(2-pyridyl) fulvene (III) has already been described (*4*).

In addition to this fulvene, the condensation of cyclopentadiene and 2-benzoylpyridine produces 2-(α-hydroxy-α-2-pyridylbenzyl)-6-phenyl-6-(2-pyridyl) fulvene (V), which can be obtained in high yield by varying the reaction conditions. Except for the multiple condensation of acetone with cyclopentadiene to give a complex mixture of products (*5*), there is no precedent in the literature for the formation of a trisubstituted fulvene such as this one.

A solution of 5.02 g of sodium in 1420 ml of absolute ethanol was pre-