

ZEOLITES

A zeolite is a naturally occurring ion exchanger. In the case of a zeolite, the negatively charged frame is the aluminosilicate (aluminum/silicon) skeleton. The aluminosilicate skeleton is built up of neutral silicate tetrahedra wherein a silicon atom is surrounded by four oxygen atoms. The resulting arrangement of atoms looks like a pyramid with a triangular base. The oxygen atoms are located at each apex of each triangular face. The negative charge on the framework arises when an aluminum atom substitutes for a silicon atom. This is possible because the aluminum and silicon atoms are very similar in size. However, the valence (i.e., the maximum charge) of aluminum is +3, whereas the valence of silicon is +4. The result of aluminum substitution for silicon is a deficiency of positive charges or, in other words, an excess of negative charges on the aluminosilicate skeleton.

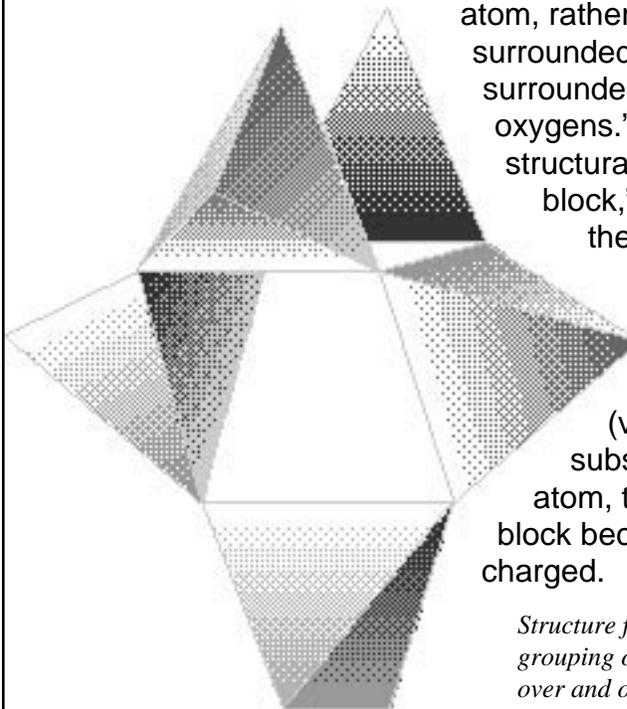
Balancing positive charges are supplied by positively charged ions (cations) attracted from the solution surrounding the zeolite, which attach by electrical attraction to the zeolite skeleton. In most naturally occurring zeolites, the charge-balancing cations are sodium (Na^+), potassium (K^+), and calcium (Ca^{2+}).

The charge-balancing cations are called "exchangeable cations"

because, depending upon the composition of the water bathing the zeolite, they may exchange places with cations in solution. The exchangeable cations are not all held with equal strength by the zeolite. Multivalent (e.g., divalent Ca^{2+}) cations are usually held more tightly than univalent (e.g., Na^+) cations.

Zeolite Structure

The building blocks for the aluminosilicate framework of zeolites are silica tetrahedra—a central silicon atom surrounded by four oxygen atoms. The valence (maximum charge) of silicon is +4, whereas the valence of each oxygen atom is -2. The tetrahedron, SiO_4 then should have a charge of -4 [$+4 + 4(-2)$] and would be classified as a complex anion. A complex anion, such as SiO_4 , is composed of two or more elements which act as an inseparable charged unit. A simple anion, such as Cl^- , is a single, charged atom. However, in the zeolite structure, each oxygen is shared with a neighboring tetrahedron. The effect is that each silicon



atom, rather than being surrounded by four oxygens, is surrounded by 4 "half-oxygens." The basic structural unit, the "building block," of the zeolite is then SiO_2 , which is electrically neutral. (You do the calculation.) If an aluminum atom (valence +3) substitutes for a silicon atom, that basic building block becomes negatively charged.

Structure for part of a zeolite. This grouping of tetrahedra is repeated over and over to form a zeolite.