TDC Part III
Paper VI
Inorganic Chemistry

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TOPIC: - INORGANIC POLYMERS, DIFFERENT STRUCTURES OF SILICATES

Different structures of silicates

Silicate Structures				
Structure	Figure	Corners shared at each tetrahedron	Repeat unit	Example
Tetrahedra	1	0	SiO_4^{4-}	*Olivines,* $(Mg/Fe)_2SiO_4$
Pairs of tetrahedra	2	1	$Si_2O_7^{6-}$	*Thortveitite,* $Sc_2(Si_2O_7)$
Closed rings	3	2	SiO_3^{2-}	*Beryl,* $Be_3Al_2(Si_6O_{18})$
Single chains	4	2	SiO_3^{2-}/$Si_2O_6^{4-}$	*Pyroxenes,* $CaMg(Si_2O_6)$
Double chains	5	2.5	$Si_4O_{11}^{6-}$	*Amphibole,* $Ca_2Mg_5(Si_4O_{11})_2(OH)_2$
Sheets	6	3	$Si_2O_5^{2-}$	*Talc*, $Mg_3(Si_4O_{10})(OH)_2$
Three-dimensional network	7	4	SiO_2	*Quartz,* $(SiO_2)_n$

Table 1

Notes: Photographs of silicates can be found at http://www.mindat.org.

Tetrahedra / pairs of tetrahedra

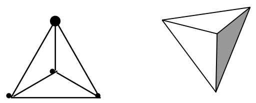


Fig. 1

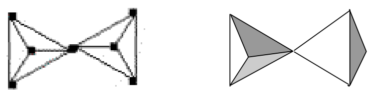


Fig. 2

The cations are arranged around the tetrahedral units on a regular crystalline lattice.

(a) Closed rings

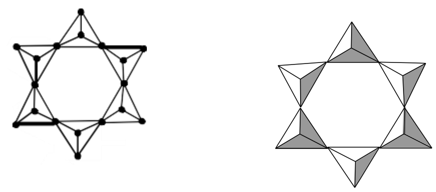


Fig. 3: Beryl, ($Si_6O_{18}^{12-}$)

(b) Single chains

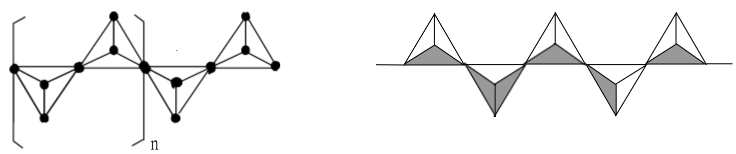


Fig. 4: Pyroxenes, ($Si_2O_6^{4-}$)

(c) Double chains

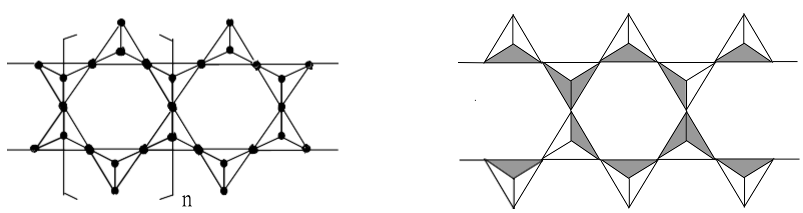


Fig. 5: Amphibole, $(Si_4O_{11}^{6-})_n$

Asbestos

Asbestos is a generic term for a group of naturally occurring hydrated silicates that can be processed mechanically into long fibres. It refers to two kinds of minerals: serpentines and amphiboles. Serpentines, the most common of which is chrysotile, $Mg_3Si_2O_5(OH)_4$, account for almost 90% of worldwide asbestos production. Chrysotile has a sheet structure of Fig. 6 while Tremolite (amphibole), $Ca_2Mg_5(Si_4O_{11})_2(OH)_2$, possesses the double chain structure of Fig. 5. Both chain and sheet structures are held together by the electrostatic attraction between the cations and the negative silicate structures. Crystal cleavage is expected to occur along the chain direction because the non-directional ionic links are comparatively weaker than the strong Si-O covalent bonds. Hence asbestos minerals are fibrous.

(d) Sheets

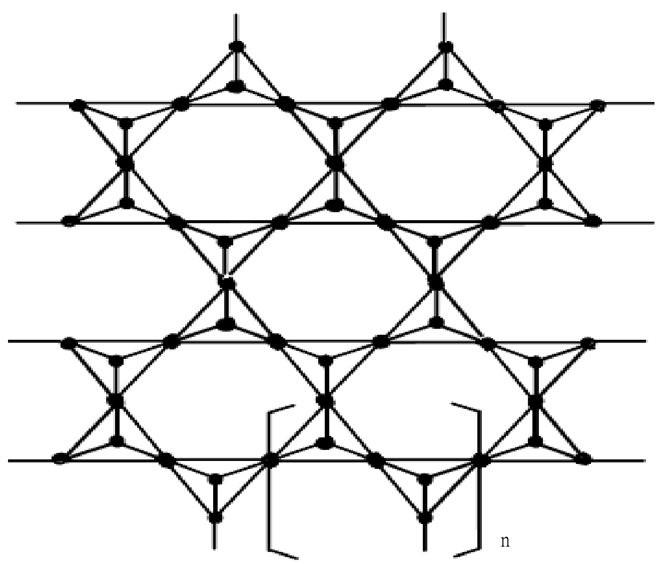


Fig. 6: Talc, $(Si_2O_5{}^{2-})_n$

Talc

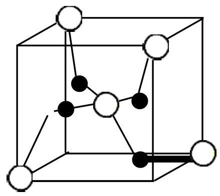
Talc, $Mg_3(Si_4O_{10})(OH)_2$**,** has a structure consisting of layers and parallel sheets. All of the strong bonding interactions among the atoms occur within the layers. Two parallel sheets have the unshared oxygen atoms of the tetrahedra pointing toward each other. In the middle of this sandwich are the magnesium and hydroxide ions, which serve to bind the two silicate sheets together. Only weak van der Waals forces hold the sandwiches (layers) together. Thus layers can slip easily across one another and accounts for the ease for it to be pulverized to make talcum powder, a soft and fine powder to make one's skin feel smooth and dry.

A VRML (Virtual Reality Modelling Language) image of talc is available at http://www.ill.fr/dif/3D-crystals. The double layers of silica tetrahedra sandwiching a single layer of MgO octahedra (contributed by Mg^{2+} and OH^- ions) is apparent. H atoms play no role in the sandwiched layers.

The website provides three-dimensional diagrams of numerous crystal structures, including the silicates. A special viewing technique, called the VRML is employed in which viewers can manipulate the diagrams as if he is handling a real object and can look at it at various angles by performing operations such as rotation, roll,zoom and panning. VRML viewer can be downloaded from the following website:

http://www.parallelgraphics.com/products/cortona/download/iexplore.

(e) Three-dimensional network



- O atom

- Si atom

Fig. 7: Quartz, $(SiO_2)_n$

Quartz

The mineral ***Quartz*** is one form of silica. In quartz, all the four vertices of each tetrahedron are linked to other tetrahedra. The quartz network carries no charge and there are no cations in its structure. The three-dimensional network silicates such as quartz are much harder than their linear or layer counterparts. As the silica structure consists of a giant network of strong covalent bonds. Melting points of quartz and silica (sand) are very high.

Exercises:

By referring to Table 1, predict the structure of each of the following silicate minerals (double chains, sheets, networks, and so forth).

1. $Ca_3Fe_2(SiO_4)_3$
2. $Na_2ZrSi_4O_{10}$
3. $Ca_2ZnSi_2O_7$
4. $Mg_3Si_2O_5(OH)_4$

*Answers:*1. Tetrahedra 2. Sheets 3. Pairs of tetrahedra 4. Sheets