

Oxygen Salts.

2. SILICATES.

The Silicates are in part strictly anhydrous, in part hydrous, as the zeolites and the amorphous clays, etc. Furthermore, a large number of the silicates yield more or less water upon ignition, and in many cases it is known that they are, therefore, to be regarded as basic (or acid) silicates. The line, however, between the strictly anhydrous and hydrous silicates cannot be sharply drawn, since with many species which yield water upon ignition the part played by the elements forming the water is as yet uncertain. Furthermore, in the cases of several groups the strict arrangement must be deviated from, since the relation of the species is best exhibited by introducing the related hydrous species immediately after the others.

This chapter closes with a section including the Titanates, Silico-titanates, Titano-niobates, etc., which connect the Silicates with the Niobates and Tantalates. Some Titanates have already been included among the Oxides.

Section A. Chiefly Anhydrous Silicates.

I. Disilicates, Polysilicates.

II. Metasilicates.

III. Orthosilicates.

IV. Subsiliates.

The DISILICATES, RSi_2O_6 , are salts of disilicic acid, $H_2Si_2O_6$, and have an oxygen ratio of silicon to bases of 4 : 1, as seen when the formula is written after the dualistic method, $RO.2SiO_2$.

The POLYSILICATES, $R_nSi_nO_{3n}$, are salts of polysilicic acid, $H_nSi_nO_{3n}$, and have an oxygen ratio of 3 : 1, as seen in $2RO.3SiO_2$.

The METASILICATES, $RSiO_3$, are salts of metasilicic acid, H_2SiO_3 , and have an oxygen ratio of 2 : 1. They have hence been called *bisilicates*.

The ORTHOSILICATES, R_2SiO_4 , are salts of orthosilicic acid, H_4SiO_4 , and have an oxygen ratio of 1 : 1. They have hence been called *unisilicates*. The majority of the silicates fall into one of the last two groups.

Furthermore, there are a number of species characterized by an oxygen ratio of less than 1 : 1, e.g., 3 : 4, 2 : 3, etc. These basic species are grouped as SUBSILICATES. Their true position is often in doubt; in most cases they are probably to be regarded as basic salts belonging to one of the other groups.

The above classification cannot, however, be carried through strictly, since there are many species which do not exactly conform to any one of the groups named, and often the true interpretation of the composition is doubtful. Furthermore, within the limits of a single group of species, connected closely in all essential characters, there may be a wide variation in the proportion of the acidic element. Thus the triclinic feldspars, placed among the polysilicates, range from the true polysilicate, $NaAlSi_3O_8$, to the orthosilicate, $CaAl_2Si_2O_8$, with many intermediate compounds, regarded as isomorphous compounds of these extremes. Similarly of the scapolite group, which, however, is included among the orthosilicates, since the majority of the compounds observed approximate to that type. The micas form another example.

I. Disilicates, RSi_2O_6 . Polysilicates, $R_nSi_nO_{3n}$.

PETALITE.

Monoclinic. Crystals rare (castorite). Usually massive, foliated cleavable (petalite).

Cleavage: *c* perfect; *o* (201) easy, *z* (905) difficult and imperfect. Fracture imperfectly conchoidal. Brittle. *H.* = 6-6.5. *G.* = 2.39-2.46. Luster vitreous, on *c* pearly. Colorless, white, gray, occasionally reddish or greenish white. Streak uncolored. Transparent to translucent.

Comp— $LiAl(Si_2O_6)_2$ or $Li_2O.Al_2O_3.8SiO_2$ = Silica 78.4, alumina 16.7, lithia, 4.9 = 100.

Pyr., etc.—Gently heated emits a blue phosphorescent light. B.B. on charcoal becomes glassy, subtransparent, and white, and melts only on the edges; gives the reaction for lithia. With borax it forms a clear, colorless glass. Not acted on by acids.

Obs.—Petalite occurs at the iron mine of Utö, Sweden, with lepidolite, tourmaline, spodumene, and quartz; on Elba (*castorite*). In the U. S., at Bolton, Mass., with scapolite; at Peru, Maine, with spodumene in albite. The name *petalite* is from *πέταλον*, a leaf, alluding to the cleavage.

Milarite. $HKCa_2Al_2(Si_2O_6)_2$. In hexagonal prisms. *H.* = 5.5-6. *G.* = 2.55-2.59. Colorless to pale green, glassy. From Val Giuf, Grisons, Switzerland.

Eudidymite. $HNaBeSi_2O_6$. In white, glassy, twinned crystals, tabular in habit. *H.* = 6. *G.* = 2.553. Occurs very sparingly in elaeolite-syenite on the island Ovre-Arö, in the Langesundfjord, Norway.

Epididymite. Same composition as eudidymite. Orthorhombic. Southern Greenland.

Feldspar Group.

α. Monoclinic Section.

		$\tilde{a} : \tilde{b} : \tilde{c}$	β'
Orthoclase	$KAlSi_3O_8$	0.6585 : 1 : 0.5554	116° 3'
Soda-Orthoclase	$(K,Na)AlSi_3O_8$		
Hyalophane	$(Na,K)AlSi_3O_8$	0.6584 : 1 : 0.5512	115° 35'

β. Triclinic Section.

Microcline	$KAlSi_3O_8$
Soda-microcline	$(K,Na)AlSi_3O_8$
Anorthoclase	$(Na,K)AlSi_3O_8$

Albite-anorthite Series. Plagioclase Feldspars.

		$\tilde{a} : \tilde{b} : \tilde{c}$	α	β	γ
Albite	$NaAlSi_3O_8$	0.6335 : 1 : 0.5577	94° 3'	116° 29'	88° 9'
Oligoclase		0.6321 : 1 : 0.5524	93° 4'	116° 23'	90° 5'
Andesine	$(nNaAlSi_3O_8, mCaAl_2Si_2O_8)$	0.6357 : 1 : 0.5521	93° 23'	116° 29'	89° 59'
Labradorite		0.6377 : 1 : 0.5547	93° 31'	116° 3'	89° 54½'
Anorthite	$CaAl_2Si_2O_8$	0.6347 : 1 : 0.5501	93° 13'	115° 55'	91° 12'
Celsian	$BaAl_2Si_2O_8$		90½°		

The general characters of the species belonging in the FELDSPAR GROUP are as follows:

1, *Crystallization* in the monoclinic or triclinic systems, the crystals of the different species resembling each other closely in angle, in general habit, and in methods of twinning. The prismatic angle in all cases differs but a few degrees from 60° and 120°.

2, *Cleavage* in two similar directions parallel to the base *c* (001) and clinopinacoid (or brachypinacoid) *b* (010), inclined at an angle of 90° or nearly 90°. 3, *Hardness* between 6 and 6.5. 4, *Specific Gravity* varying between 2.5 and 2.9, and mostly between 2.55 and 2.75. 5, *Color* white or pale shades of yellow, red or green, less commonly dark. 6, In composition silicates of aluminium with either potassium, sodium, or calcium, and rarely barium, while magnesium and iron are always absent. Furthermore, besides the several distinct species there are many intermediate compounds having a certain independence of character and yet connected with each other by insensible gradations; all the members of the series showing a close relationship not only in composition but also in crystalline form and optical characters.

The species of the Feldspar Group are classified, first as regards form, and second with reference to composition. The *monoclinic* species include (see above): ORTHOCLASE, potassium feldspar, and SODA-ORTHOCLASE, potassium-sodium feldspar; also HYALOPHANE, barium feldspar.

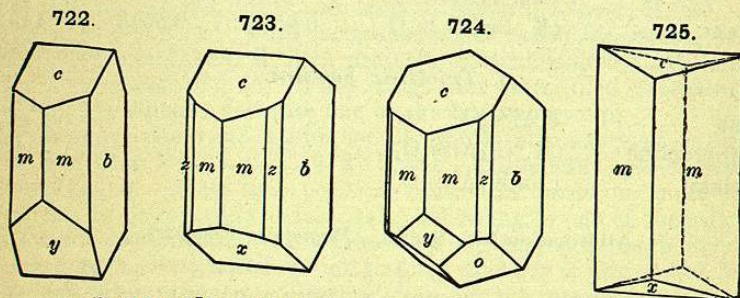
The *triclinic* species include: MICROCLINE and ANORTHOCLASE, potassium-sodium feldspars; ALBITE, sodium feldspar; ANORTHITE, calcium feldspar; CELSIAN, barium feldspar.

Also intermediate between albite and anorthite the isomorphous sub-species, sodium-calcium or calcium-sodium feldspars: OLIGOCLASE, ANDESINE, LABRADORITE.

α. *Monoclinic Section.*

ORTHOCLASE.

Monoclinic. Axes $a : b : c = 0.6585 : 1 : 0.5554$; $\beta = 63^\circ 57'$.



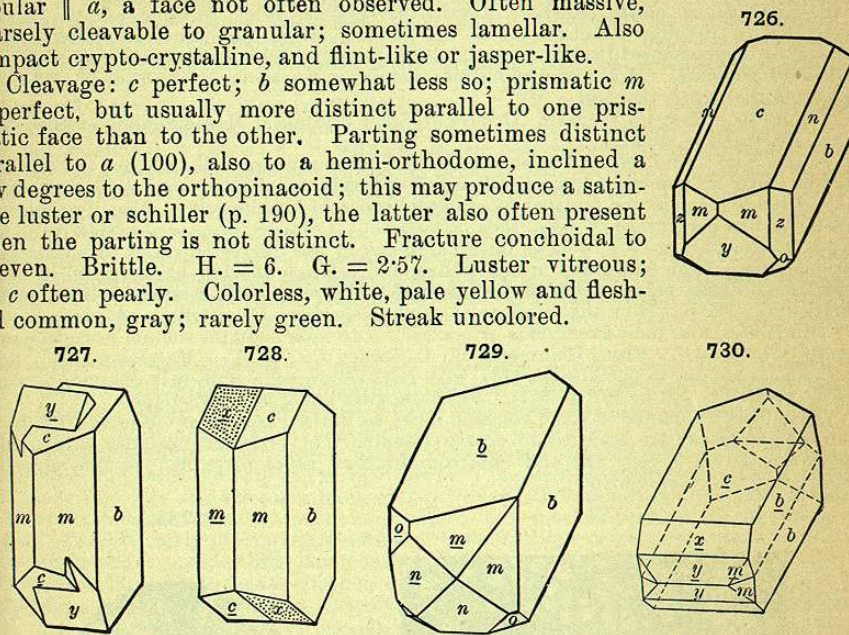
mm'' , $110 \wedge \bar{1}10 = 61^\circ 13'$.	cn , $001 \wedge 021 = 44^\circ 56\frac{1}{2}'$.
zz' , $130 \wedge \bar{1}30 = 58^\circ 48'$.	nn' , $021 \wedge 0\bar{2}1 = 89^\circ 53'$.
cx , $001 \wedge \bar{1}01 = 50^\circ 16\frac{1}{2}'$.	cm , $001 \wedge 110 = 67^\circ 47'$.
cy , $001 \wedge \bar{2}01 = 80^\circ 18'$.	co , $001 \wedge \bar{1}11 = 55^\circ 14\frac{1}{2}'$.

Twins: tw. pl. (1) *a* (100), or tw. axis *b*, the common *Carlsbad* twins, either of irregular penetration (Fig. 727) or contact type; the latter usually with *b* as composition-face, often then (Fig. 728) with *c* and *x* nearly in a

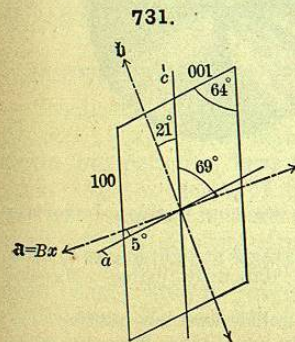
plane, but to be distinguished by luster, cleavage, etc. (2) *n* (021), the *Baveno* twins forming nearly square prisms (Fig. 729), since $cn = 44^\circ 56\frac{1}{2}'$, and hence $cc = 89^\circ 53'$; often repeated as fourlings (Fig. 417, p. 129), also in square prisms, elongated $\parallel a$. (3) *c* (001), the *Manebach* twins (Fig. 730), usually contact-twins with *c* as comp.-face. Also other rarer laws.

Crystals often prismatic $\parallel b$; sometimes orthorhombic in aspect (Figs. 723, 725) since *c* and *x* are inclined at nearly equal angles to *b*; also elongated $\parallel a$ (Fig. 726) with *b* and *c* nearly equally developed; also thin tabular $\parallel b$; rarely tabular $\parallel a$, a face not often observed. Often massive, coarsely cleavable to granular; sometimes lamellar. Also compact crypto-crystalline, and flint-like or jasper-like.

Cleavage: *c* perfect; *b* somewhat less so; prismatic *m* imperfect, but usually more distinct parallel to one prismatic face than to the other. Parting sometimes distinct parallel to *a* (100), also to a hemi-orthodome, inclined a few degrees to the orthopinacoid; this may produce a satin-like luster or schiller (p. 190), the latter also often present when the parting is not distinct. Fracture conchoidal to uneven. Brittle. H. = 6. G. = 2.57. Luster vitreous; on *c* often pearly. Colorless, white, pale yellow and flesh-red common, gray; rarely green. Streak uncolored.



Optically negative ($Bx_a = a$) in all cases (Fig. 731). Ax. pl. usually $\perp b$, sometimes $\parallel b$, also changing from the former to the latter on increase of temperature (see p. 225). For *adularia* (Dx) $Bx_{a,r} \wedge b = -69^\circ 11'$, $Bx_{a,bl} \wedge b = -69^\circ 37'$. Hence Bx_a and the extinction-direction (Fig. 731) inclined a few degrees only to *a*, or the edge *b/c*; thus $+3^\circ$ to $+7^\circ$ usually, or up to $+10^\circ$ or $+12^\circ$ in varieties rich in Na_2O . Dispersion $\rho > v$; also horizontal, strongly marked, or inclined, according to position of ax. pl. Axial angles variable. Birefringence low, $\gamma - \alpha = 0.007 - 0.005$. For *adularia* (Dx).



$\alpha_y = 1.5190$, $\beta_y = 1.5237$, $\gamma_y = 1.5260$,
 $\therefore 2V_y = 69^\circ 43'$, $2E_y = 121^\circ 6'$.

Comp., Var.—A silicate of aluminium and potassium, $KAlSi_3O_8$ or $K_2O \cdot Al_2O_3 \cdot 6SiO_2 =$ Silica 64.7, alumina 18.4, potash 16.9 = 100. Sodium is often also present, replacing part of the potassium, and sometimes exceeds it

in amount; these varieties are embraced under the name soda-orthoclase (Natronorthoklas *Germ.*).

The prominent varieties depend upon crystalline habit and method of occurrence more than upon difference of composition.

1. *Adularia*. The pure or nearly pure potassium silicate. Usually in crystals, like Fig. 725 in habit; often with vicinal planes; Baveno twins common. $G. = 2.565$. Transparent or nearly so. Often with a pearly opalescent reflection or schiller or a delicate play of colors; some *moonstone* is here included, but the remainder belongs to albite or other of the triclinic feldspars. The original adularia (Adular) is from the St. Gothard region in Switzerland. *Valencianite*, from the silver mine of Valencia, Mexico, is adularia.

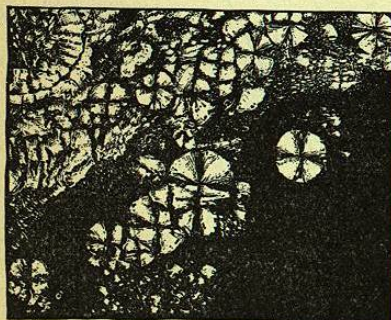
2. *Sanidine* or *glassy feldspar*. Occurs in crystals, often transparent and glassy, embedded in rhyolite, trachyte (as of the Siebengebirge), phonolite, etc. Habit often tabular $\parallel b$ (hence named from *σavis*, a *tablet*, or *board*); also in square prisms (*b, c*); Carlsbad twins common. Most varieties contain sodium as a prominent constituent, and hence belong to the soda-orthoclase.

Rhyacolite. *Eisspath* Werner. Occurs in glassy crystals at Monte Somma; named from *ρυαξ*, *stream* (lava stream).

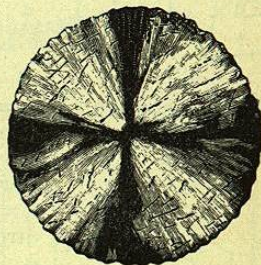
3. *Ordinary*. In crystals, Carlsbad and other twins common; also massive or cleavable, varying in color from white to pale yellow, red or green, translucent; sometimes aventurine. Here belongs the common feldspar of granitoid rocks or granite veins. Usually contains a greater or less percentage of soda (soda-orthoclase). Compact cryptocrystalline orthoclase makes up the mass of much felsite, but to a greater or less degree admixed with quartz; of various colors, from white and brown to deep red. Much of what has been called orthoclase, or common potash feldspar, has proved to belong to the related triclinic species, microcline. Cf. p. 374 on the relations of the two species. Chesterlite and Amazon stone are microcline; also most aventurine orthoclase. *Loxoclase* contains sodium in considerable amount ($7.6 \text{ Na}_2\text{O}$). From Hammond, St. Lawrence Co., N. Y. *Murchisonite* is a flesh-red feldspar similar to perthite (p. 373), with gold-yellow reflections in a direction $\perp b$ and nearly parallel to 701 or 801 (p. 371). From Dawlish and Exeter, England.

The spherulites noted in some volcanic rocks, as in the rhyolite of Obsidian Cliff in the Yellowstone Park, are believed to consist essentially of orthoclase needles with quartz. These are shown in Figs. 732 and 733 (from Iddings; much magnified) as they appear in polarized light (crossed nicols).

732.



733.



Pyr., etc.—B.B. fuses at 5; varieties containing much soda are more fusible. Loxoclase fuses at 4. Not acted upon by acids.

Diff—Characterized by its crystalline form and the two cleavages at right angles to each other; harder than barite and calcite; not attacked by acids; difficultly fusible. Massive corundum is much harder and has a higher specific gravity.

Distinguished in rock sections by its low refraction (low relief) and low interference-colors, which last scarcely rise to white of the first order—hence lower than those of quartz; also by its biaxial character in convergent light and by the distinct cleavages. It is colorless in ordinary light and may be limpid, but is frequently turbid and brownish from the presence of very minute scales of kaolin due to alteration from weathering; this change is especially common in the older granular rocks, as granite and gneiss.

Obs.—Orthoclase in its several varieties belongs especially to the crystalline rocks, occurring as an essential constituent of granite, gneiss, syenite, also porphyry, further (var., *sanidine*) trachyte, phonolite, etc. In the massive granitoid rocks it is seldom in distinct, well-formed, separable crystals, except in veins and cavities; such crystals are more common, however, in volcanic rocks like trachyte.

Adularia occurs in the crystalline rocks of the central and eastern Alps, associated with smoky quartz and albite, also titanite, apatite, etc.; the crystals are often coated with chlorite; also on Elba. Fine crystals of orthoclase, often twins, are obtained from Baveno, Lago Maggiore; the Fleimsthal, a red variety; Valfloriana; Bodenmais, Carlsbad and Elbogen in Bohemia; Striegau, etc., in Silesia. Also Arendal in Norway, and near Shaitansk in the Ural; Land's End and St. Agnes in Cornwall; the Mourne Mts., Ireland, with beryl and topaz. From Tamagama Yama, Japan, with topaz and smoky quartz. *Moonstone* is brought from Ceylon.

In the U. States, orthoclase is common in the crystalline rocks of New England, also of States south, further Colorado, California, etc. Thus at the Paris tourmaline locality. In *N. Hamp.*, at Acworth. In *Mass.*, at South Royalston and Barre. In *Conn.*, at Haddam and Middletown, in large coarse crystals. In *N. York*, in St. Lawrence Co., at Rossie; at Hammond (*loxoclase*); in Lewis Co., in white limestone near Natural Bridge; at Amity and Edenville. In *Penn.*, in crystals at Leipserville, Mineral Hill, Delaware Co.; sunstone in Kennett Township. In *N. Car.*, at Washington Mine, Davidson Co. In *Colorado*, at the summit of Mt. Antero, Chaffee Co., in fine crystals, often twins; at Gunnison; Black Hawk; Kokoma, Summit Co., also at other points. Also similarly in Nevada and California.

Orthoclase is frequently altered, especially through the action of carbonated or alkaline waters; the final result is often the removal of the potash and the formation of kaolin. Steatite, talc, chlorite, leucite, mica, laumontite, occur as pseudomorphs after orthoclase; and cassiterite and calcite often replace these feldspars by some process of solution and substitution.

PERTHITE. As first described, a flesh-red aventurine feldspar from Perth, Ontario, Canada, called a soda-orthoclase, but shown by Gerhard to consist of interlaminated orthoclase and albite. Many similar occurrences have since been noted, as also those in which microcline and albite are similarly interlaminated, the latter called *microcline-perthite*, or *microcline-albite-perthite*; this is true in part of the original perthite. When the structure is discernible only with the help of the microscope it is called *micropertite*. Brögger has investigated not only the micropertites of Norway (Orthoklasmikroperthit, Mikroklinmikroperthit), but also other feldspars characterized by a marked schiller; he assumes the existence of an extremely fine interlamination of albite and orthoclase $\parallel 801$, not discernible by the microscope (cryptoperthite), and connected with secondary planes of parting $\parallel 100$ or $\parallel 801$, which is probably to be explained as due to incipient alteration.

HYALOPHANE. $(\text{K}_2, \text{Ba})\text{Al}_2(\text{SiO}_3)_4$ or $\text{K}_2\text{O} \cdot \text{BaO} \cdot 2\text{Al}_2\text{O}_3 \cdot 8\text{SiO}_2$. Silica 51.6, alumina 21.9, baryta 16.4, potash 10.1 = 100. In crystals, like adularia in habit (Fig. 725, p. 370); also massive. Cleavage: *c* perfect; *b* somewhat less so. $H. = 6-6.5$. $G. = 2.805$. Occurs in a granular dolomite in the Binnenthal, Switzerland; also at the manganese mine of Jakobsberg, Sweden. Some other feldspars containing 7 to 15 p. c. BaO have been described (cf. also celsian, p. 381).

β. Triclinic Section.

MICROCLINE.

Triclinic. Near orthoclase in angles and habit, but the angle $bc =$ about $89^\circ 30'$. Twins: like orthoclase, also polysynthetic twinning according to the albite and pericline laws (p. 375), common, producing two series of fine lamellæ nearly at right angles to each other, hence the characteristic grating-structure of a basal section in polarized light (Fig. 734). Also massive cleavable to granular compact.

Cleavage: *c* perfect; *b* somewhat less so; *M* ($1\bar{1}0$) sometimes distinct; *m* (110) also sometimes distinct, but less easy. Fracture uneven. Brittle. $H. = 6-6.5$. $G. = 2.54-2.57$. Luster vitreous, on *c* sometimes pearly.

Color white to pale cream-yellow, also red, green. Transparent to translucent.

734.

