Silica: Substance of Earth, Substance of Light

Michael Holdrege

Our daily life creates for us a familiarity with many substances that play a role in our earthly existence. Most people have a feeling for basic qualities of characteristic elements such as silver and gold, iron and aluminum, or compound substances such as carbohydrates and proteins. In some instances, the familiarity is a matter of direct experience, for instance with the metals mentioned above. In others, much of it is in the form of mental pictures or concepts that we have been taught by "the experts."

In this essay, I would like to explore the characteristics of a substance, silica,[1] that we all have heard about (Silicon Valley is perhaps the most famous valley on earth these days), but we often have little direct awareness of its qualities or the various ways in which this substance manifests in the realms of nature, in the human being, in human creations. In the course of this exploration, we will be looking for characteristic roles that silica plays in the great web of earthly existence. Let us begin with the solid earth beneath our feet.

The Solid Earth

Most people are surprised to learn that 75% of the earth's solid matter—the crust—is composed of silica. If we break silica[2] down into its chemical elements, silicon and oxygen, we find, incredibly, that 49.2% of the earth's crust consists of oxygen and 26.7% silicon.[3] This amazing fact is not something our normal experience would tell us. It can awaken the question, however, is there any deep significance to the fact that the solid earth upon which we live and work is three-quarters silica?[4]

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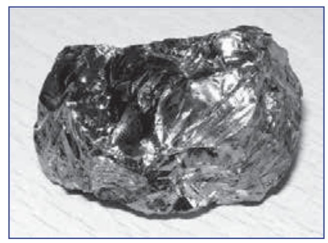
If we want to understand the nature of this all-pervasive substance, we will need to investigate the two chemical elements that contribute to its qualities and characteristics: silicon and oxygen. Although silicon and oxygen have "disappeared" into a new and different substance, silica, a significant echo of this heritage is discernible if we take a close look at the characteristics of these two elements.



What are the properties of silicon and oxygen? Silicon is a semi-metal substance (metalloid) that reflects light almost completely with a dark-silvery metallic luster. It is very brittle and so hard (7 on the Mohs Hardness Scale[5]) that it can be used to cut glass. Silicon requires extreme heat both to melt (2570°F) and to evaporate (4270°F). Surprisingly, despite having a melting point that is higher than most metals, Silicon is very light, with a density of only 2.34 g/cm3.6.

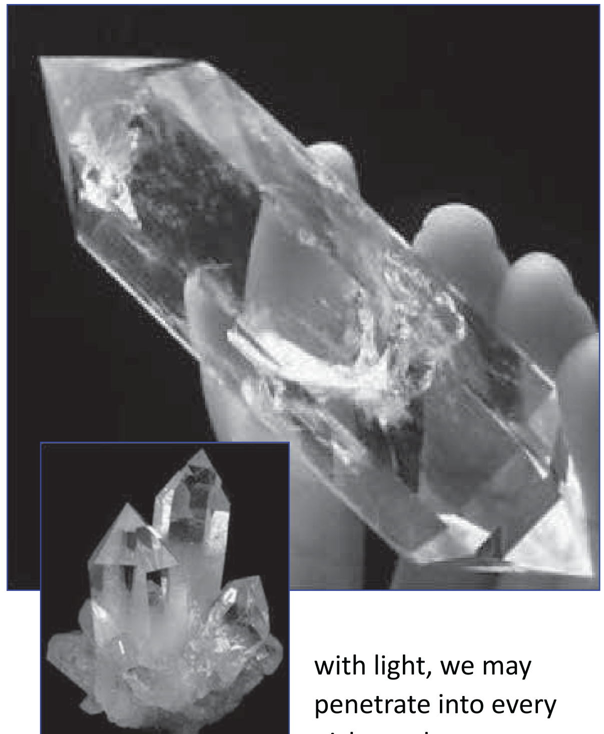
Oxygen, by contrast, presents a very different picture. Although everywhere in the atmosphere around us, we can neither smell it nor taste it, and we walk right through it as if it were not there. Almost always in motion, atmospheric oxygen is constantly heating up and cooling off, absorbing moisture and releasing it. But most important of all in our present context, oxygen is totally invisible. Oxygen's transparency means it is completely open to the sun's light, allowing it to shine unhindered from the cosmic heights all the way through to the surface of the earth below.[7] In stark contrast to silicon, pure oxygen does not want to contract into liquid form, let alone freeze into a solid state. Thus it must be cooled to a temperature below -297°F in order to liquify and below -362°F to become a solid. Ever-present near the earth's surface, its dynamic, life-engendering presence is essential for breathing organisms, and it plays a pivotal role in all processes of combustion (burning), which means it helps transform substances from a solid state into warmth, moisture, and air, with only a small bit of ash left behind.[8]

Remarkably, two such strongly contrasting elements find their way together to produce something totally new, which remains however reminiscent of both. They manifest as silica ($Si0_2$), which appears in its purest form as crystalline quartz, small pieces of which we know as sand.

Let us experience this remarkable substance in the words of geologist Walther Cloos:[9]

> Anyone who has hiked in the mountains, and who has had the good fortune to find a clear crystal in the cleft of a rock, knows the amazement that comes over one when looking at this seemingly unreal creation. Something with the clarity of air, with the transparent purity of a bubbling spring, seems united here with the sternness that reigns in the world of massive rock formations. The dark density of matter, that every stone along the way reveals, seems cast away by a mysterious power that has magically brought forth this crystal out of the bluish-black slate or dense, impenetrable granite.

From another perspective, Fritz Julius observes:[10]



> More than other substances, silica presents its essence in an image. This image is that of the quartz crystal. … The substance is hard, impenetrable, and excludes us from its sector of space, but still invites us to enter. … Along with light, we may penetrate into every niche and cranny. Sometimes we encounter an imperfection, a crack, or a small cloud. But these things seem to be there only to enhance the beauty and play with the light. … The walls are built like the cells of a honeycomb; thus, a six-sided column arises with a pyramid-shaped roof. Gravity had nothing to do with making this form; it is impossible to tell how a crystal was oriented as it grew. …
>
> When we open such a cavity in a seemingly barren rock to discover sparkling crystals pointing from all sides toward the center, then we see that silica's growth gesture is in all directions. … It is no wonder that in this transparent substance the most delicate, pure, and transparent colors can appear, especially the violet of amethyst or the ethereal pink of rose quartz. … Quartz appears to be made from a substance that was created for a never-ending play with light. …[yet it is] found in cavities deep within the darkness of the earth's crust.

Through these descriptions it becomes apparent that the qualities of silicon and oxygen have united with one another in quartz (silica). Although quartz is very hard (7) and brittle, as is found in silicon, it has lost the dark, reflective nature of that metalloid. Indeed, it lets the light pass completely through it without resistance. A solid, earthly substance has been created that is open to the sun—thus revealing a primary quality of oxygen. On the other hand, what was oxygen has given up its dynamic mobility in deference to the strongly formative tendencies of silicon. The largest oxygen reserve on earth (by far) has been fixed in a highly inactive form not only as pure quartz, but also in a multitude of silica-containing rocks known as silicates, which together make up 97% of the earth's crust.[11] This amazing substance silica, that unites, one might say, the realms of heaven (oxygen) and earth (silicon), provides the foundation upon which we live.

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But silica is at home not only in the solid earth. We also find it playing a significant role in the life of organisms that stand in a direct relationship to the light of the sun: the plants.

Silica and the Plant World

Tapping into the kinship between light forces and silica has been part of the methodology of biodynamic (BD) agriculture for decades. Finely powdered quartz crystals used in the BD preparation Horn Silica (501) work on the above-ground, aerial parts of plants[12] both to reinforce the effects of sunlight and to stimulate photosynthesis.[13] They strengthen the stem structure, also improving the quality and disease-resistance of leaf surfaces and fruit skins. For plants grown either in greenhouses or under shady conditions, Horn Silica (501) helps compensate for the shortage of direct sunlight that they receive.[14]

The horsetails (*Equisetum*) and grasses (*Gramineae*), to take just two examples, show high silica concentrations and share a similar linear, ray-like gesture in their sun-oriented central shoots. Basically just segments of stalks rhythmically spaced and put together, horsetails manifest the principles of form and structure to an extreme. The cone-shaped bodies of the first shoots are made up of tiny, flat, hexagonal scales that develop further into a precise series of linear stem segments pieced neatly together with a brittle rigidity. Interestingly, the fine, silica-based structure of the horsetail's surface solidifies as opaline glass, whose lenticular bulges bring the sunlight to focus on rows of chlorophyll-containing cells below them.[15]

This tendency to linearity continues in the silica-rich grasses.[16] Their strong relationship to the sun shows in the predominance of the central shoot. With long internodes, the lower part of the leaf shares in the vertical character of the stem, enveloping it as a sheath before the narrow, parallel-veined leaf unfolds to the side. Their sharp, silica-rich, finger-cutting edges are known to many. The grass stem is a master of static engineering, using a minimum of matter to carry its heavy, seed-bearing upper region upward toward the sun. Since their narrow stems and leaves produce minimal, light-hindering shade, they surpass all other plant groups in their ability to take up the light forces of the sun. Whereas the typical light-utilization-level

of non-grasses is between 5 and 10 percent, the grasses are able to increase their light-immersion-level to 24 percent.[17]

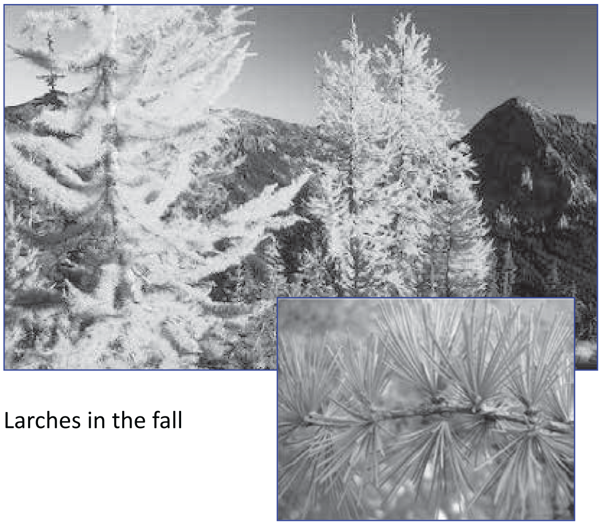
Grasses in the Sunlight

This sunward-radiating tendency appears, of course, not only in the grasses but in plants in general. In the herbaceous plants, the formation of the central shoot, referred to by Goethe as the "vertical tendency" in the plant, shows in particular a relationship to the sun. In many species the growing tip turns directly toward the sun and follows its movement from morning to evening.[18]

A striking example of silica-mediated qualities in an herbacious plant appears in the common dandelion (*Taraxicum officinale*). With their high silica content[19] and light sensitivity, dandelion leaves appear in the most varied forms, depending on the time of year, the climate, the elevation, and the type of soil where the plant finds its home. Under shadowy, moist conditions, the leaves widen gradually toward the ends and take on an undivided, elongated form. In an environment with strong sunlight and nutrient-poor, sandy soil, we find denser shoots, smaller, drier, and much more differentiated, sharply chiseled leaves, together with brighter, more radiant flowers. The "cheerful" yellow flower heads, too, show a close connection to the sun, opening as it rises in the sky, turning with it throughout the course of the day, and closing again as the sun disappears in the evening. On

sunless, dreary days, the flowers stay shut. When the innermost florets have faded, the flower head goes brown and dry, the florets are pushed out, and the receptacle closes like a bud. Several days later it opens again dramatically, folding back toward the ground, while the flower base arches upward to form a transparent, quartz-reminiscent, crystal-like sphere. Totally oriented to the world around, the brightly shining, umbrella-like pappi carry the seeds far out into the light and air.[20]

Let's move briefly to one more growth-form among the plants, those that build very powerful shoots, the trees; the larch (*Larix decidua*) provides an interesting example. Like their fellow conifers (spruces, firs, pines), larches build a strong central shoot (the trunk) to which all peripheral branching appears subsidiary. Among the conifers, the larch distinguishes itself by having the highest silica content. Thus, it is not astonishing to find both that the larch is lighter in color and more open to the passage of light than other conifers and that it shows a very different relationship to the yearly sun-rhythm from its close relatives. Whereas the others are known as "evergreens" because they hold on to their foliage through the darkness of winter and for years to come, the larch, synchronous with the decline of the sun, sheds its linear leaves in the fall with a luminous show of sun-gold color.[21] Not surprisingly, larches seek out the light-intense, high country of the mountains to be their home.[22]



Larches in the fall

Silica and the Animal World

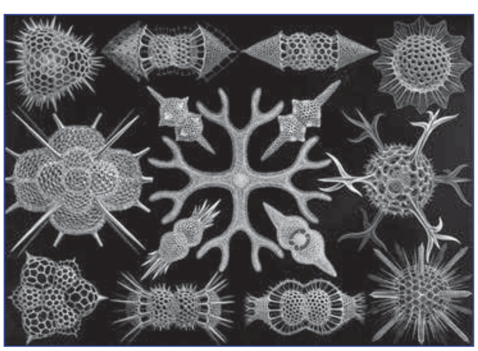
Although at work in all animals, for example in the fur of mammals, the gesture of silica appears in a particularly striking manner in two animal groups: radiolaria and birds.

One group of protozoa, the radiolaria, reveals a striking silica gesture in their miniscule silica-containing exoskeletons, which, corresponding to their name, are very ray-like. This gesture is particularly evident when compared with another group of single-celled marine organisms, the foraminifera. A fundamental difference between the two groups is that foraminifera draw calcium out of the water to form their exoskeleton, whereas the radiolaria draw silica. In contrast to the spiny, ray-like radiolarian forms, the foraminifera have an inward-turned, chamber-like appearance, which is quite typical of calcium-permeated structures such as the shells of snails and clams. The glassy exoskeletons of the radiolaria make a very different impression, one characteristic of silica.[23]

The linear, radial gesture in horsetails, grasses, and radiolaria reaches a new level in the birds. As is commonly known, birds are able, by means of their feathered wings, to lift themselves fully into the realm of light and air, where oxygen is all-present and ceaselessly active. What is less familiar is the detailed, silica-permeated nature of the feathers that makes this possible. Looking at a single feather, we find a central axis, the hollow shaft (*rachis*). From this axis extend many linear branches, the barbs. Each barb branches many times again into barbules. In flight feathers, the barbules contain a series of miniscule hooklets, the barbicels, that connect into the barbicels of the neighboring barbules, thus creating an intricately interwoven, unified surface. Taken together, the overall network of all these barbs and barbules results in the vane of the wing.

If we consider that most birds contain an unusually large number of such complex structures (the house sparrow, [*Passer domesticus*], for example, has approximately 3500 feathers), and that they are replaced yearly, it becomes apparent how a bird is constantly weaving together a silica-rich network of countless radiating and crossing linear feather-elements throughout the course of its lifetime. Amazingly, the intricate web is created out of an absolute minimum of substance. The 3500 sparrow feathers weigh, after all, only two ounces. In this silica-based feather world, form is clearly victorious over matter.

The bird's completed feather "gown" is a nonliving tapestry of astounding complexity that needs no metabolism, no blood circulation, no respiration. The life processes of the bird remain close to its core, while it engages the light-filled atmosphere with a lifeless, silica-rich web of radiating, interwoven fibers.[24,25]



Radiolaria (silica) from *Kunstformen der Natur* (1904) Ernst Haeckel

Foraminifera (calcium)

Silica in Humans

In human beings silica already plays a significant role in the early phases of existence. In the words of anthroposopohical physicians Friedrich Husemann and Otto Wolff,[26]

> …[T]he presence of silica is needed particularly when the human form is being created from the undifferentiated embryonic tissue. The formative forces do not work from within the embryo but from outside via the membranes, where the concentration of silica is exceptionally high.[27]

Human skin is rich in silica, as are hair and nails. Once again, we find ourselves in a realm that engages the light-filled outer world and, in the case of hair, shows significant radiality. The quality of silica is revealed most strikingly in the human eye. Here we see an archetypical expression of silica, reminiscent of the quartz crystal embedded in the density and darkness of the earth's crust. In the human eye, with its crystalline lens, we find light-open substance embedded in hollow cavities of the skull. We see how our silica-rich periphery creates a boundary to the outer world through the all-enveloping skin, and yet, through the sense organs embedded in that skin, opens itself to the manifold qualities of the dynamic, light-filled world around us.[28,29]

The contrast one finds between the silica-permeated periphery of our body and its more internal, calcium-rich skeletal structures is also revealing. Ernst Lehrs sums up the distinctive ways in which silica and calcium work in the human organism with the following image:

> … [O]ne is inclined to speak of two "gestures" of nature: the gestures which we as humans carry out when we either stretch out our arms and spread our fingers while lifting our head with wide-open eyes, or when we contract our whole body, while lowering our head and dropping our eyelids. These are, in fact, precisely the functions exerted by silica and calcium in our organism. Silica is at work wherever the organism opens itself to the outer world: in the ray-like spread of hair, in the skin permeable to air and light, and especially in the eyes. … Calcium in the human organism, however, is always used inwardly for the formation of bones.[30]

Silica in Technology

Looking back, we discover that a non-crystalline form of silica, flint, was central for humankind for thousands of years. This was because, when struck in the right manner, flint flakes into a sharp cutting edge, thus making it very suitable for tools like axes and arrow heads.

More recently, silica has been used as the main ingredient in one of the most beautiful and practical substances on earth: glass. Strong and yet transparent, glass can function in the most varied ways. One in particular, the light-open window in the middle of a solid opaque wall, is strongly reminiscent of the transparent windows of the soul embedded in the middle of the human skull.[31] Not only does glass remind us of the eyes, but it is also used in service of them. More than just allowing light to pass through, glass is able to shape it, thus enhancing our vision through glasses, microscopes and telescopes.[32]

Silica has also revolutionized the watch-making industry, which puts to use quartz's amazing constancy. If you pass electricity through a quartz crystal, it oscillates at a precise frequency of 32,768 times per second. In a quartz clock a battery sends electric signals to a quartz crystal, causing it to vibrate at that frequency. A microchip circuit detects these vibrations and turns them into standard electric impulses that drive the rest of the clock mechanism. Quartz shows amazing regularity here and is essentially independent of temperature variations and the influence of gravity changes, both of which are issues for the pendulum and balance wheel clocks of the past.[33] Quartz's unbelievably consistent micro-vibrations thus provide the basis for an exact, unit-based time, for a translation of spatial movement into time quantities. Our dynamic, cosmic time-keeper, the sun, is thus converted into useful, but rather inflexible, earthly increments. For such tasks we can, literally, count on quartz.

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In the latter half of the 20th century, technology moved beyond silica, as such, to focus on one of its two constituents, silicon. To do this, massive intervention was necessary. The light-open substance that we have considered from various angles was broken down into its chemical elements, removing the oxygen and leaving only the metalloid silicon behind. Due to its significance in the development of electronic devices, this metalloid is seen by many as the most important technological material of our time. Some speak of our era as "the age of silicon."

In order to free silicon from its natural partner oxygen, quartz must be heated to over 2500°F. This is done in special ovens that are purged with argon gas to eliminate any air. The molten silicon is spun in a crucible into which a small seed crystal is placed. Slowly removed as the silicon cools, large crystals result that often weigh several hundred pounds or more, creating ingots some six feet in length. These are cut into extremely thin slices, called wafers, of only a few hundred microns. After further purifying measures, such as buffering, the wafers are etched with circuit designs through a process known as photolithography.[34]

Silicon Ingot

No longer open to the light due to the absence of silica's oxygen characteristics, silicon is now open to the passage of electricity, although not to the same degree as pure metals. It is called a semi-conductor because it can be manipulated in its conductive properties through a process where pure silicon is "doped" with trace amounts of carefully chosen impurities, such as arsenic or boron, which change its properties, allowing it to function between the poles, of openness to electric conduction on the one hand and, on the other hand, of glass-like resistance to it as an insulator. Because the semi-conductor silicon can conduct as well as insulate, silicon chips conform to the on/off form of digital logic (binary code) that is used to transmit information electronically, thus making them the crucial component in today's electronic revolution.[35]

Silicon wafers doped with "impurities" are also used in solar cells. For example, a thin silicon wafer doped with negatively charged phosphorus (N-type silicon) can be placed over a wafer doped with positively charged boron (P-type silicon). When light hits this solar cell, an electric current is created that flows across the juncture of the two layers.[36]

In Conclusion

Looking back at the various manifestations of silica considered above, we can discover certain gestures that tell us about silica's role in the great book of nature. As a starting point, it is not without significance that silica turns out to be the dominant substance in the makeup of the solid earth, but not merely in a quantitative sense. Silica is "the" substance that, despite its earthly nature, opens itself to the light. Silica thus

brings the element of light into the darkness of earth. It does this with great hardness but with surprisingly little density. In short, a relationship between the cosmic light (sun) forces and the depths of the solid earth is mediated by silica.

Moving to the plant world, we find silica opening the green plant to the light-embodying process of photosynthesis, thereby helping to incarnate light forces into living substance. Silica is particularly active in the structural integrity and ray-like linearity of grasses (and other plant stems) that we find growing upward toward the sun. Indeed, the growing tip of the central shoot is "heliocentric" (oriented toward the sun and its movement), in contrast to the earth-centered "geotropism" of the plant's root system.[37] In the dandelions and larches, too, a silica-mediated light affinity is evident.

From the solid earth, to the plants, to animals, and to humans, we find silica mediating between the cosmic light forces that ray down to the earth and the forces of solid matter below. The presence of silica makes possible the interplay, the interpenetration, of the cosmic and the earthly...

In the animal kingdom the linear, ray-like gesture of silica speaks clearly in the minute world of the floating radiolaria and "begins to sing" in the tapestry of silica that carries the birds aloft. In both instances, formative forces of light hold sway over the density of matter. In humans (and higher animals, too), silica resides largely in the periphery, in the hair (fur) and skin, in the sense organs, and, most tellingly, in the light-open cavities of the eyes.[38]

From the solid earth, to the plants, to animals, and to humans, we find silica mediating between the cosmic light forces that ray down to the earth and the forces of solid matter below. The presence of silica makes possible the interplay, the interpenetration, of the cosmic and the earthly in a significant way.

In the technological use of silica, we see this character most clearly in glass windows created so that light can enter into the interior of spaces that otherwise separate us from outer world.

This profound role of silica as facilitator of nature's earthly/cosmic interactions changes when we use artificial means to bring forth a chemical element that does not "naturally" exist in nature: pure silicon. By forcefully removing the oxygen from quartz, we create a substance that is not only not open to the light, but that even reflects it to a large degree. When treated with miniscule amounts of certain substances (doping), it can turn that light into electricity. Rather than letting the light shine through as silica does, silicon captures the light and transforms it into electricity. Since this process transcends anything that we can experience directly, it is interesting to hear Rudolf Steiner's description of what is taking place: "When one drives light into the sub-material, into a level below the material world…then electricity comes about. Light is compressed in the most extreme manner. …"[39] Using the chemical/technological means at our disposal, we have brought about a process that reverses the "natural" effect of silica: Instead of *opening* the material world to the forces of light, the forces of light have been, in Steiner's description, *compressed* to the extreme and driven down into a sub-material realm. We are still working with the relationship of light and the material world, but in a very different way. It is true, of course, that this electricity can be used to create new light sources, as Thomas Edison revealed to the world in a dramatic fashion, but the larger implications of "compressing" light forces into electricity are certainly worthy of further reflection from a spiritual scientific perspective.

ENDNOTES

1. To clarify at the outset, confusion often exists between the terms *silica, silicon,* and *silicone*. As will be explained in the text, silica is another name for quartz. It is a chemical compound found in the earth. Silicon is a chemical element not found in nature, but which arises when silica is analyzed (broken down) into its chemical constituents silicon and oxygen. (See text for more detail.) Silicone is a synthetic polymer used in synthetic rubbers and lubricants.
2. Chemically, silica is known as silicon dioxide, SiO_2.
3. This abundance stands in striking contrast to the third most prevalent element, aluminum (7.5%), the fourth, iron (4.7%), and in fifth place, calcium (3.4%). Further down the line we find such well-known elements as hydrogen and phosphorus at less than 1% and carbon, sulfur, and nitrogen at less than 1/10th of a percent.
4. Hardwick & Bouillon 1997.
5. By comparison, the hardness ratings of gold and copper fall between 2.5 and 3, and iron's between 4 and 5 on the Mohs scale.
6. This surprisingly low density becomes evident when compared with several familiar metals.
   - Iron melts at 2795°F but has a density of 7.87;
   - Copper melts at 1985°F with a density of 8.84;
   - Gold melts at 1948°F with a density of 19.3;
   - Silver melts at 1764°F and has a density of 10.5.
7. These characteristics it shares with nitrogen, its primary partner in making up the earth's atmosphere.
8. Challoner 2015; Parsons & Dixon 2014; Kranich 2005; Julius 2000.
9. Cloos 1976, p. 11.
10. Julius 2000, pp. 154–155.
11. Silicates are a mineral group comprised of a basic silicon-oxygen unit ($Si0_4$) that combines with a range of metals (Al, Fe, Ca, Na, K, Mg, Ti, Mn, B, Be) to form large families of silicates, such as feldspars, olivines, micas, and hornblendes. Hancock & Skinner 2000.
12. Photosynthesis is a process by which light forces are embodied in the plant in conjunction with the synthesis of carbon dioxide and water to form carbohydrates.
13. In contrast to Horn Manure prep (5500), which is applied to the soil. Koepf 1971.
14. Biodynamie Services, 2016; J. Porter Institute 2016; Koepf, 1971.
15. Castelliz 2008; Bockemuehl & Jarvinen 2006; Grohmann 1974.
16. Silica is deposited in the periphery of the plant, strengthening the cell walls and epidermis. Koepf 1971.
17. Holdrege 2009; Kranich 1995.
18. Kranich 1995; Goethe 1988; Julius 1969.
19. The ash of the dandelion is 7% silica. Pelikan 1975.
20. Bockemuehl & Jarvinen 2006; Pelikan 1975.
21. The sun-loving larches also happen to be strong producers of Vitamin C.
22. Where they and the Arve (*Pinus cembra*) populate the uppermost tree-line. Ellenberg 1978; Pelikan 1975.
23. Lehrs 1958.
24. The ash of bird feathers contains 10-40% silica, whereas human hair contains 6–30% silica. Kaufmann 2013.
25. Portmann 1984; Kranich 2005; Julius 2000.
26. Husemann & Wolff 1987.
27. The ash of the amnion is 22% silica, for example.
28. Ernst Lehrs points out that the lens of the eye, "…not for nothing called the "crystalline lens," actually consists of fibres, which in their cross-section have the same hexagonal shape that is found in rocks based on silica." Lehrs 1958, p. 228.
29. Husemann & Wolff 1987; Cloos 1976.
30. Lehrs 1958, p. 226.
31 Challoner 2015; Parsons & Dixon 2014; Julius 2000.
32. Julius 2000.
33 Challoner 2014.
34. Challoner 2014; Huber 1982.
35. Ibid.
36. Challoner 2014.
37. In his *Agriculture Course* Rudolf Steiner characterizes for the farmers the formative influence of silica in the following way: "If we were to assume for the moment that we had only half the amount of silica in our environment, then we would have plants that were all more or less pyramid shaped!...The grasses (cereals) would look very strange, their shoots would be thick and fleshy below, the upper flowering region stunted and incomplete." Steiner 1975, p. 36.
38. In Schiller's (1962) words:

    "Can you name me the crystal?
    To no other can it be compared.
    It sends forth light without ever burning,
    The cosmic all it draws within.
    The sky itself is painted on it,
    Is painted on its wondrous ring,
    And yet what rays forth from it
    Has more beauty than it taketh in."
    (transl. MH)

39. Cited in Gebhard 2005, p. 281.

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