looking about for the best university or library in which to deposit their own scientific collections. If the wants of our universities and observatories and research stations could be fully made known, *through the columns of* SCIENCE, they would find a ready response on the part of individuals who have been profiting by the generous distribution of expensive volumes during many years past. Such volumes, whether published by the government or by societies, are, as it were, loaned in trust to past recipients, who, having benefited by them, should now in turn pass them on to others, rather than hoard them, or sell them as merchandise.

CLEVELAND ABBE.

THE MENTAL DEVELOPMENT OF INDIVIDUALS.

TO THE EDITOR OF SCIENCE: I wish to learn at what age, under what circumstances and to what extent people of different climes, races, civilizations and temperaments have changed their views as to whence we came, whither we go, and what we are here for. Any statement, elaborate or short, regarding an individual's mental development will be a welcome contribution to a proposed 'Natural History of the Thinker.' I have been obliged to thus appeal to my contemporaries because autobiographical documents so far extant do not yield enough accurate descriptions of the inner life. To illustrate my purpose, I beg to refer to my article on 'The Interpretation of a System from the Point of View of Developmental Psychology,' in the *Journal of Philosophy, Psychology and Scientific Methods,* February 15.

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SPECIAL ARTICLES.

QUARTZ GLASS.

PURE quartz when melted down to a glass has three properties which make it of immense value in the chemical and physical laboratory, and were it not for the technical difficulties attending its production, it would certainly displace ordinary glass wherever a transparent medium capable of withstanding heat is required. It expands less than one tenth as much as common glass when heated; it can be heated to 1,000° C. without softening; and finally, it transmits ultraviolet light freely.

It has not proved easy to make quartz glass, even in small quantities in the laboratory. Quartz is one of those peculiar minerals[1] which show no sharp melting temperature, but soften very gradually, and when pure, never become thin liquids, even at the temperature of the electric arc. Furthermore, quartz begins to vaporize rapidly in air at about the temperature of melting platinum, while it is still much too viscous to release the included bubbles. A mass of quartz fragments, when melted in air in the electric furnace, comes out resembling solidified sea-foam or volcanic pumice. It is quite opaque, dirty and useless for mechanical or optical purposes, and very persistent efforts in a number of laboratories have so far failed to produce a clear product except from single fragments treated individually. Small globules of glass can be obtained from single crystals, pieced together in the oxyhydrogen flame, and blown into thin quartz glass vessels such as are now in quite common use. Discs suitable for small lenses have also been obtained at Jena by heating small clear crystals with such rapidity as to produce a thin enclosing film of liquid before cracks develop in the body of the crystal, thereby preventing the entrance and subsequent enclosure of air. It is, of course, plain that such devices can have but limited usefulness. We must somehow manage to melt larger masses of random fragments to a clear glass before the technical problem can be regarded as solved.

This problem is somewhat outside the proper scope of the Geophysical Laboratory, but our plant is perhaps better adapted to its solution than most others, and the demand for clear quartz glass is so general that it seemed best to spend a limited time in an effort to find the difficulty and to try to ascertain the direction in which the solution lies. No effort at refinement of method has yet been made.

[1] See Day and Allen, 'The Isomorphism and Thermal Properties of the Feldspars,' Publ. 31, Carnegie Institution.

When pure crystallized silica, either quartz or tridymite, is fused in graphite crucibles, there is no difficulty in obtaining quartz glass. The difficulty, as indicated above, is to free it from enclosed air. After a series of experiments at different temperatures, it became evident that there was no probability of obtaining clear glass by direct fusion at atmospheric pressure. It was, therefore, decided to study the effect of pressure upon the fusion of silica.

The experiments were conducted in a large bomb furnace under a pressure of 500 pounds of compressed air, the heat being supplied by passing an alternating current through the walls of a thin graphite box containing the quartz. The heating was at first carried to a much higher temperature than was necessary in an effort to reduce the viscosity sufficiently to release the air bubbles in the normal way, but the attempt failed entirely—the viscosity is but slightly diminished at the higher temperatures, and enough silica is reduced to discolor the mass with free silicon. The appearance of the product also clearly showed that gas was being generated at the hottest points in the retaining walls, and the large bubbles formed by the rapid expansion of this gas were always lined with free silicon. At the highest temperatures (above 2,500° C.), therefore, we not only did not get rid of the air bubbles enclosed in the glass, but introduced a new disturbing factor.

The next step was, of course, to reduce the temperature and lengthen the time of heating. This produced blocks of quartz glass which were quite transparent but which contained a great number of small included bubbles which could not be displaced even when the time of heating was extended over several hours. No large bubbles appeared, however, and no discoloration. An effort to explode the enclosed bubbles by turning on the compressed air before the heat was applied and then releasing the pressure while the material was still molten, also failed. The inflated material could not be brought back to a cake again.

After a number of attempts of this character, with slightly varied conditions of temperature and pressure, a charge was heated rapidly to a high temperature (considerably above 2,000°) before pressure was applied. After the quartz had begun to vaporize freely, it seemed reasonable to expect that the vapor would displace the air between the grains somewhat as mercury vapor is made to displace the air in filling thermometers. Compressed air was then quickly applied to compress the melt into a compact mass, the temperature lowered to the point where it had been found safe to work without discoloration, and held there for perhaps a half hour, after which the current was turned off and the pressure very gradually withdrawn. Plates of quartz glass 3 x 5 x ½ inches were produced under these conditions which were almost entirely free from bubbles, and only occasionally slightly stained by free silicon. The residual bubbles are very small, not more than ½ mm. in diameter, and are not frequent enough (not more than two or three in a cubic centimeter) to interfere with the use of the glass for lenses, mirrors or other usual optical purposes. It is, furthermore, very probable that a little more skill in handling, such as could readily be obtained with longer experience, would get rid of even the few remaining bubbles.

Quartz glass is easily stained by very small quantities of other oxides when present as impurities. In particular, we found that as little as .3 of one per cent. of other oxides was sufficient to make the glass opaque and almost black. It is, therefore, absolutely necessary to start with very pure material, but it does not require to be clear. Pure cloudy quartz serves quite as well.

The volatility may be due to one of two causes: either the vapor pressure of liquid quartz is very great, or the carbon reduces the silica, with the formation of metallic silicon, which at once volatilizes and is subsequently reoxidized on passing into the surrounding atmosphere. This reaction, that is, the reduction to the metallic state and subsequent volatilization, is a very common one at these temperatures, and has misled several investigators into interpreting the volatilization of the oxide to be due to its vapor pressure, when in fact the oxide, heated in the absence of carbon or reducing papers, shows little or no volatility. The volatilization of magnesium oxide is of this class.

Whether the pressure which is essential to the preparation of good quartz glass in quantity acts upon the vapor pressure of the silica, or whether it affects the reduction of the silica to the metal, has not yet been determined. It is not unlikely that both reactions occur, and that the narrow temperature limits within which we found it practicable to work, lie between the temperature of volatilization of the silica and that of its reduction by carbon. This question is not material to the successful production of quartz glass, and will be considered in a later paper.

One other conclusion appears to be reasonably certain from our work, namely, that air once enclosed within the body of a charge of quartz glass can not be displaced, either by long-continued heating or by extremely high temperatures.

Our experience did not suggest that we were approaching any necessary limit in the size of the charge which could be handled. A furnace of suitable size, provided with somewhat more power, would undoubtedly produce clear quartz glass in much larger units than we were able to do in our small furnace.

Summing up the conditions for preparation of good quartz glass, we find them to be: An initial temperature of 2,000° or more, without pressure, to produce sufficient quartz vapor to drive out the air from between the grains, followed by pressure (at least 500 pounds), and a reduced temperature (perhaps 1,800°), with time for the quartz to flow compactly together without being attacked by the graphite.

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April 18, 1906.

METEOROLOGICAL PHENOMENA ON MOUNTAIN SUMMITS.

MUCH of our knowledge of the upper air has been obtained from observations made on the summits of mountains. With the single notable exception of the Prussian Aeronautical Observatory near Berlin, where, for several years, daily observations at great heights have been obtained with the aid of kites and balloons, we are still dependent upon the mountain observatories for information concerning annual and seasonal changes in the upper air at different heights, and for other data not easily secured except by means of continuous observations made at the same place. The chief error arising from any general application of such observations is caused by the unknown influence of the mountain itself upon the meteorological conditions in its vicinity. The results from observations in the free air do not show the same vertical changes that are observed on mountains, the diurnal periodic change of temperature noticeable on all mountains disappearing at a height of 1,000 meters in the free air.

A few approximate comparisons have already been made, of Ben Nevis (1,343 meters high) in Scotland by Mr. Dines, and of the Brocken (1,100 meters high) in Germany by Dr. Assmann, but in both instances the kite or balloon observations apparently were made at a distance exceeding 90 kilometers from the mountain observatory. Also, Mr. Clayton has compared the temperature on Blue Hill with that of the free air.

The data obtained indicated that the temperature on mountain summits is lower than that of the free air at the same height. No information as to differences of humidity or wind velocity is available, although it appears quite probable that the wind velocity is higher on mountains than in the free air at the same height.

During the last week in August, 1905, I was able to make a comparison of the weather conditions on Mount Washington, N. H., with those of the free air, by means of kites flown in the Ammonoosuc Valley 16 kilometers west of and 1,500 meters lower than the summit of