THE MECHANISM OF GLASS FORMATION

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Glass formation is one of the essential stages of the complex process of glass making, which in practice determines the time of glass melting.

Immediately after the batch is fed into the tank furnace (temperature about 1300°), the batch components undergo physical and chemical changes, and the first stage of glass making—silicate formation—takes place. At the end of this stage a complex silicate melt is formed, containing grains of excess quartz which has not entered the reactions of silicate formation. Solution of the quartz grains in the silicate melt, and mutual solution of the silicates, form the basis of the next stage of the process, glass formation. Consequently, solution of the crystalline phase in the liquid forms the basis of glass formation.

At the present time crystal dissolution processes are not fully understood even for aqueous solutions. Still less is known about the solution of the crystalline phase in silicate melts, because of the difficulties in conducting experiments at high temperatures, and of the complex structure of the liquid phase. Nevertheless, study of this process is of practical and theoretical interest.

The solution of quartz grains in silicate melts was studied by us by the petrographic method with 20 compositions of three-component glasses. The composition of the glasses used varied in the following ranges: SiO₂ from 70 to 76%; CaO from 8 to 14%; and Na₂O from 10 to 20%. The following pure materials were used as batch components: anhydrous soda (chemically pure), marmarized limestone of Kaskelen origin (99.9% CaCO₃), and Lyubertsy quartz sand of a definite granular composition, beneficiated in a flotation machine (99.5% SiO₂).

The grains were 0.248 to 0.295 mm across. The amount of batch was calculated to yield 20 g of the final glass melt in each experiment.

The glass was melted in a laboratory oil-fired kiln. The batch was charged into fired corundum crucibles specially made for these experiments. The crucibles with the batch were quickly put into the heated kiln and held for a definite time at 1320°.

The heating time was measured to an accuracy of 5 seconds from the moment of charging to the moment of removal of the crucibles from the kiln. Batch of the same composition was charged into five crucibles and melted for different times. The average heating times were 7, 10, 15, 20, and 40 minutes according to the chemical composition of the glass. At the end of the set time the crucibles were removed from the kiln and rapidly cooled in air. Transparent and polished sections were made from the cooled melts and examined under the MP-3 and MP-5 microscopes.

Petrographic examination of the polished sections showed that quartz undergoes polymorphic transitions during the glass melting processes, and is present in the melt in the form of isotropic metacristobalite with refractive index nD = 1.49. After prolonged heating (40 minutes or more) a small amount only of the metacristobalite is converted into tridymite.

The results of the petrographic investigation of the transition processes in quartz are confirmed by x-ray investigations.

The structure of the undissolved quartz grains in the melt is shown in Fig. 1. It is clearly seen that the conversion of quartz into metacristobalite begins in the boundary layers of the quartz grain (the metacristobalite is shaded gray in the figure, while the white islets within the grains are quartz). The transition is irregular.
around the grain periphery; generally it extends to a considerable depth, but sometimes it only involves the surface layer. With increasing time of heating (at 1320°) the transition of quartz into metacristobalite extends deeper into the quartz grains. The quartz residues separate into individual islets, which eventually pass completely into cristobalite.

This observation suggests that on completion of the silicate formation stage the intermediate formation of metacristobalite and the modification transitions in each grain occur simultaneously. However, these processes occur at different rates. The transitions occur more rapidly and penetrate to a considerable depth into the quartz grains, greatly outstripping the solution of the metacristobalite layer in the silicate melt. Therefore in the glass formation process metacristobalite interacts with the liquid phase, dissolves, and gradually enters the melt. This is in full agreement with I. S. Kainarsky’s data [1].

We studied the solution mechanism in polished sections under the MP-5 microscope by reflected light. The reason for the choice of this method was that the thickness of the section then causes no distortion and the observations are made in one plane only.

As the result of examinations of sections made from incompletely formed glasses varying both in composition and in the heating time, we determined certain characteristics of the solution process of quartz grains in silicate melts during glass formation. The destruction of the surface grain layer in the course of solution is shown in Fig. 2.

As has already been stated, quartz sand of Lyubertsy origin, consisting of native β-quartz crystals, was used in these investigations. It is known that real crystals differ considerably from ideal crystals, as they have

![Fig. 1. Transition of quartz into metacristobalite during glass formation at 1320° (x200); a) glass No. 20, time 15 minutes; b) glass No. 20, time 40 minutes.](image1)

![Fig. 2. Solution of cristobalite in silicate melts at 1320° (x200); a) glass No. 4, time 80 minutes, reflected light; b) glass No. 10, time 80 minutes, reflected light.](image2)