THE CHEMICAL DURABILITY OF SODA-LIME-SILICA GLASSES

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All the standard tests for the determination of the chemical durability of soda-lime-silica glasses are emperical. In order to have better reproducibility it has been proposed to study the rate of attack of water on glasses. A method in which fresh water continuously comes in contact with the graded grains of glass has been employed. The results have been arbitarily classified into three grades.

Introduction

It is known that glass, used for containers, is often subjected for a long time to the action of the liquid it holds. It is, therefore, important that nothing should dissolve from the inside walls of the glass into the contents as a result of chemical attack. The stability of chemical glassware is also of great importance, because it has to withstand corrosion by water, acids and alkalis being boiled. Recently Rana and Doughlas[1] have studied the mechanism of reaction between water and the glasses of varied composition. One of their conclusions was that at low temperature the rate of extraction of alkali varies as $\sqrt{t}$.

The object of this paper was to study the rate of attack of water on soda-lime-silica glasses in order to evolve a suitable standard method and also to establish a correlation between the durability and the alkali and lime contents of glass.

Experimental

As shown in Fig. 1, a round bottom flask of 100-ml capacity and condenser with ground glass joints have been used.[2] The above items are made of chemical-resistant glass such as Pyrex. Standard 0.020N H_2SO_4, 0.02N NaOH and methyl red indicator have been prepared according to the A.S.T.M. standard.[3] 500 ml of twice distilled water is added to the round bottom flask. It is heated and then a few drops of methyl red indicator are added, the end point being adjusted by the addition of 0.020N H_2SO_4. Heating is continued for an hour or so in order to attain the equilibrium and for the adjustment of the rate of flow of the syphon type cone. At this moment, time is noted and a known number of ml of 0.02N H_2SO_4 is added. Water vapours rise from the flask, condense and find way into the syphon tube containing glass grains. The hot water attacks the grains and leach out alkalis; this solution of alkalis syphon into the flask. The syphoning is controlled by the Fisher burner in such a way that the complete flow of the solution takes place

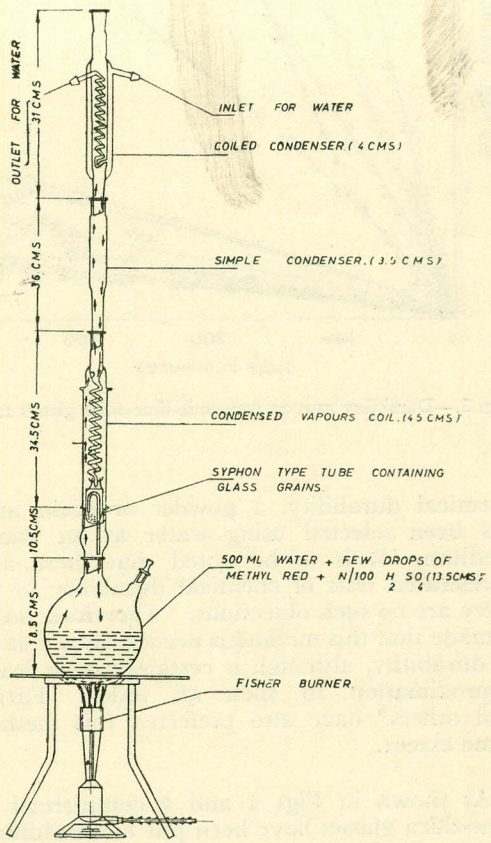

Fig. 1.—Durability apparatus.

in about one minute. This alkaline solution will react with 0.02N H_2SO_4 present in the flask. When the next end point is reached, the time is noted again. The experiment is continued for at least six hours, and various readings are recorded. The results have been presented in Figs. 2 and 3.

Results and Discussion

The durability of glass or its resistance to weathering and chemical reagents is the most important property of glass. For testing the

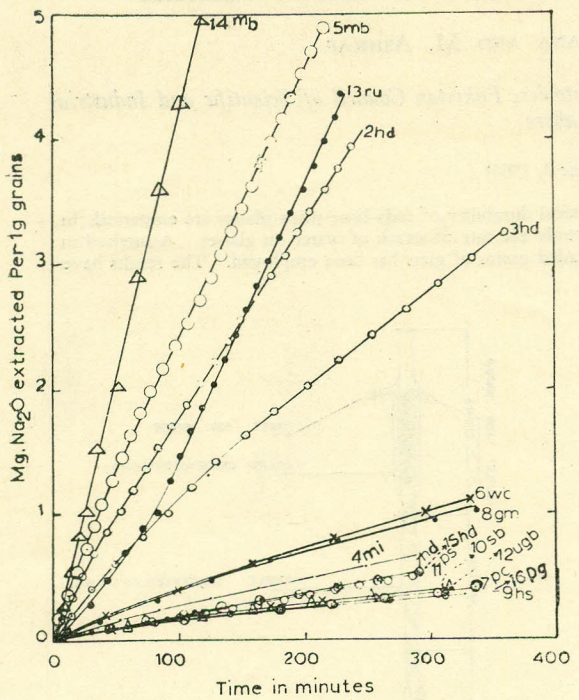

Fig. 2.—Durability runs on con. soda-lime-silica glasses at 100°C.

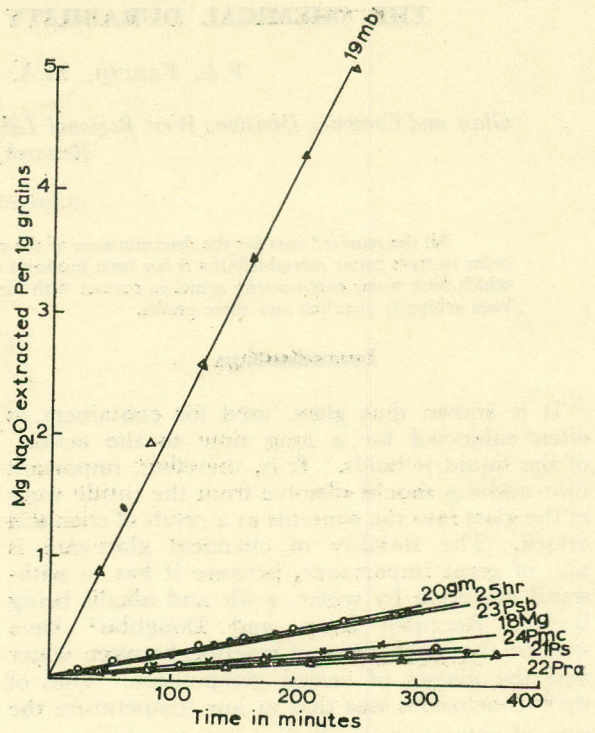

Fig. 3.—Durability runs on con. soda-lime-silica glasses at 100°C.

chemical durability, a powder or grain method has been selected using water as an attacking medium. It is to be noted that there are no accelerated tests of chemical durability to which there are no such objections. Therefore, no claim is made that this method is necessarily a true index of durability, although it certainly is, at least, an approximation to such an index. Turner [4,5] and others[6] have also preferred this method to some extent.

As shown in Figs 2 and 3 commercial soda-lime-silica glasses have been put to durability test. For a detailed study, 10 representative glasses have been selected and their compositions recorded in Table 1. The alkali extracted in mg/min/g grain is also given. With the glasses, arranged in the order of decreasing chemical durability (increasing acid titration) as they are in Table 1, it is interesting to note that they are not only arranged in the order of increasing alkali content but also in order of decreasing lime content. The increase in soda extraction with increase in soda is quite rapid. Graph A of Fig. 4 represents all the glasses of Table 1, plotted in terms of their total alkalis and their durability values. Graph B represents the chemical durability of the same glasses against the soda content alone.

It may be seen from the above graphs that a slight increase in the alkali content results in sudden increase in the rate of attack on the glass. The table of composition shows that the glasses contain 1-2% Al_2O_3. The soda content varies from 17 to 22% and the lime from 2.5 to 9%. This does not seems to cover the whole range of compositions used in bottle and window glasses. As a matter of fact, the actual range is 1-3% Al_2O_3, 14-21% alkalis and 8-13% lime.[7] It may be readily noted from the durability results that compositions containing alkalis upto 18% are very strong against chemical attack. A slight increase, over and above 18%, results in rapid increase in the attack. Similarly when the lime content is compared with the durability values, it is evident that their compositions having lime 7.32, 7.77 and 8.8% respectively, are more durable than those containing less than 5%. Compositions, having lime 5.1, 4.54 and 5.18 respectively, have medium values of chemical durability, those containing 3% or less than 3% of lime have the lowest durability values. The same is true if considered on the basis of alkalis determined. For example, those containing the highest proportions of lime, have the lowest alkali contents and those with the lowest lime have the highest percentages of alkalis and, therefore, the

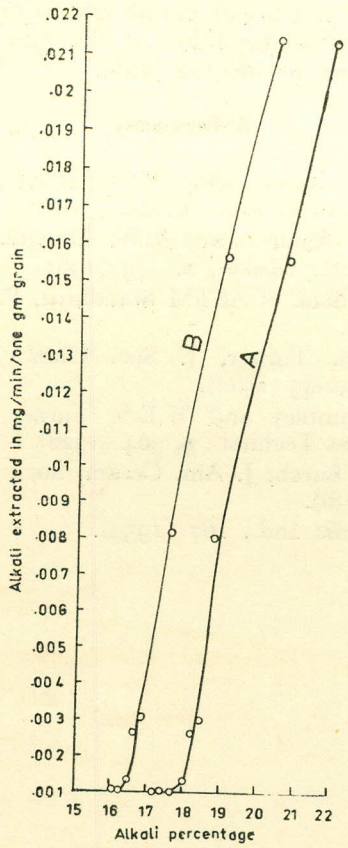

Fig. 4.—Alkali percentage-chemical durability against alkali content.

durability result discussed in the case of lime, stands true. Thus the glasses arranged in the order of decreasing chemical durability are also arranged in the order of increasing alkali content and decreasing lime content. It has been established that chemical durability increases also with an increase in the alumina content of the glass. The ten glasses studied above have the alumina more or less the same, say between 1.5-2.0%. In order to study the effect of alumina, its content should vary from glass to glass while the alkalies and lime etc. should be kept constant which is not the case above. A comparison of the durability of glass in the light of Al_2O_3 is, therefore, difficult.

Finally, according to the extracted alkali in mg/min/g of the sample, containers have arbitrarily been divided into three main grades:

Serial No.	Grades	mg/min/g sample	
1.	Grade No. 1	0.0	—0.001
2.	Grade No. 2	0.001	—0.002
3.	Grade No. 3	0.002	—0.003

The containers having more than 0.003 mg/min/g alkali extracted have been rejected.

TABLE 1.—CHEMICAL ANALYSES AND THE ALKALI EXTRACTION OF COMMERCIAL SODA-LIME-SILICA GLASSES.

S. No.	Graph No.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Alkali extracted in mg/ min/ g grain	Grade Nos.
1.	16 Pg	71.42	1.48	0.10	8.80	0.99	16.15	1.03	0.0008	
2.	10 Sb	71.64	2.62	0.04	7.77	1.14	16.18	1.20	.001	I
3.	7 PC	70.44	2.29	0.04	7.32	2.27	16.18	1.56	0.001	
4.	15 hd	71.87	1.92	0.08	6.10	2.64	16.53	1.52	.0013	
5.	8 gm	75.45	1.47	0.06	4.54	0.35	16.70	1.48	.0026	II
6.	6 Wc	74.04	1.75	0.06	5.18	0.81	16.85	1.61	.003	
7.	3 hd	75.82	1.44	0.06	3.24	0.74	17.52	1.29	.008	
8.	2 hd	74.10	1.59	0.07	3.11	0.44	18.87	1.81	.0156	Rejected
9.	5 mb	73.09	1.83	0.07	2.62	0.61	20.21	1.69	.214	
10.	14 mb	72.24	2.05	0.11	2.45	0.90	20.55	1.56	.0412	

Conclusion

From the examination of a series of soda-lime glasses prepared by the glass manufacturers on commercial scale, tested in regard of their rate of attack towards water, the following conclusions may be drawn:

1. The glasses according to the rate of attack have been classified into three grades and the ideal compositions have been represented by Nos. 1 to 4.
2. Glasses (Nos. 7-10) are too readily attacked by boiling water and their use should therefore be avoided.
3. A part of soda, if replaced by lime in a glass batch, makes the glass much more stable to chemical attack. Similarly a part of soda may also be replaced by feldspar, which due to the presence of potash and Al_2O_3, will increase the durability of the glass without affecting its melting point.

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