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CHEMICAL DURABILITY OF SOME GLASSES IN HYDROCYLORIC ACID SOLUTION

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ABSTRACT

Chemical durability of some sodium silicate and sodium boro-silicate glasses in 0.1 N hydrochloric acid solution was studied. The raw materials used were all of chemically pure grade and were finely pulverised. All melts were made in Pt- 2% Rh crucibles in gas furnaces. The temperature of melting ranged from 1400 to 1600°C for four hours. After complete melting, the molten glass was annealed at the appropriate temperature; and then the glass was ground using agate mortar. All the measurements of the chemical durability of the glass powder for each glass sample, was carried out in the usual way using 0.1 N HCl solution as the immersion solution. The experimental results obtained revealed that the change in the weight loss with the gradual increase of the soda content was attributed to the corrosion rate.

INTRODUCTION

Chemical durability of glass or the corrosion of glass has been the subject of investigation by several investigators. Several theories have been advanced for understanding the glass corrosion mechanisms such as those caused by Molland[1], Das[2], Budd and Frackiewicz[3] and Douglas et al[4]. Myluis and Forster[5] studied soda and potash silicate glasses to which lime was added and showed that the chemical durability of a soda glasses was greater than that with the corresponding potash glasses. Peddle[6] remarked useful results from the durability studies of various types of glasses. He summarized that the relative effects of both soda and potash was that the potash glass is always better for weathering than the corresponding soda glass. Modkin and Turner[7] studied the influence of the boric oxide on the chemical durability of lead glasses containing soda or potash. They observed that the presence of the equivalent proportions of soda and potash in soda-potash glasses prevailed su-

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perior durability properties than the presence of either soda or potash alone in the glass.

The action of some different aqueous solutions on some selected sodium borate glasses has been studied by El-Hadi et al[8]. They concluded that the ability of glass to stand with the attack of aqueous solutions depends primarily on the glass composition, immersion time and the concentration of the different aqueous solutions as well. The effects of the glass homogeniety and the contacts with the various geological materials on the glass corrosion behaviour are also examined[9]. In the present work, the action of 0.1 N hydrochloric acid on some sodium and sodium boro-silicate glasses has been studied with the view to bring out more clearly the relation between the chemical durability and the glass composition.

EXPERIMENTAL:

The raw materials used were all of chemically pure grade. The melts were made in Pt-2 % Rh crucibles in gas furnaces at the temperature ranged from 1400 to 1600 °C, depending on the glass composition. The duration of melting was 4 hours. After complete melting, the molten glass was annealed at the appropriate temperature, then each glass sample was ground using agate morter. The chemical durability measurement for each glass sample was carried out as follows:

i. One g. of the glass particles of the required size was weighted in a sintered glass crucible of the Yena 1 G_4 type.

ii. 150 ml of 0.1 HCl were introduced into a 300 ml silica beaker in which the crucible and its content were placed, the beaker was then covered with a silica lid and placed on a boiling water bath for 3 hours.

iii. The particles of the glass were then filtered, washed with hot water, alcohol, ether then dried at 110°C for one hour. The weight of the remaining glass particles was then determined.

iv. The difference between the original weight of the glass particles and its weight after the above treatment will be the total loss in weight due to the attack with the HCl solution.

The chemical durability was calculated as the weight loss of the glass in g / 10 cm^2 of surface area of the glass particles. Each glass particle (grain) was considered as a sphere with a radius of (0.300 + 0.600) m.

RESULTS:

Some sodium silicate and sodium boro-silicate glasses were immersed in 0.1 N hydrochloric acid solution for 3 hours. The weight loss for each glass sample was calculated.

The experimental results obtained are represented diagramatically in Figs. (1-4), from which it can be seen that:

1. In the sodium silicate glasses, table (1), the weight loss increases from 0.49 to 0.86 g / cm^2 with the gradual increase of the soda content, Fig. (1).
2. In the sodium silicate glasses containing one of the monovalent alkali oxides, lithia or potash, table (2), the weight loss decreases from 0.57 to 0.55 g / cm^2 and from 0.70 to 0.42 g / cm^2 with the gradual increase of the lithia or potash content respectively, Figs. (2 and 3).

Table 1. Chemical compositions of sodium silicate glasses.

Glass No.	Glass composition (mole %)	
	SiO_2	Na_2O
1	80	20
2	75	25
3	70	30

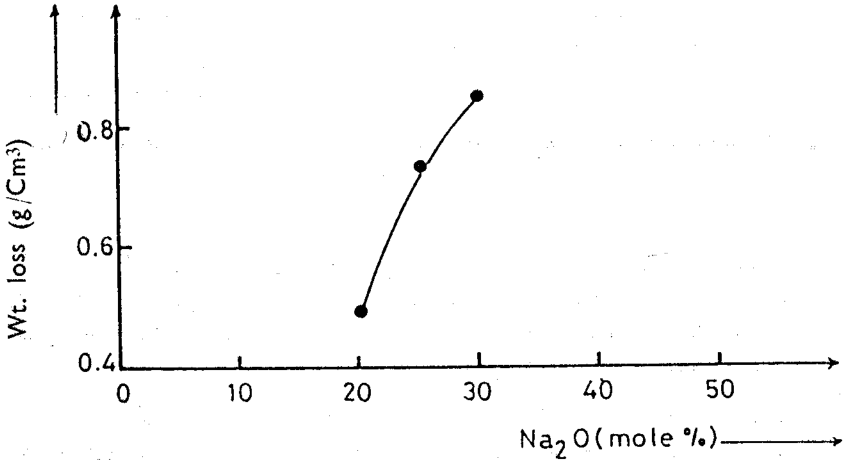


Fig. 1. Solubility of sodium silicate glasses in 0.1 N HCl versus the soda content (mole %)

Table 2. Chemical composition of sodium silicate glasses containing lithia, potash, lime or magnesia.

Glass No.	Glass composition (mole %)		
	SiO_2	Na_2O	Li_2O
4	52.63	26.31	21.05
5	55.55	27.77	16.66
6	58.82	29.41	11.76
7	62.50	31.25	6.25
			K_2O
8	52.63	26.31	21.05
9	55.55	27.77	16.66
10	58.82	29.41	11.76
11	62.50	31.25	21.05
			CaO
12	70	20	10
			MgO
13	70	20	10

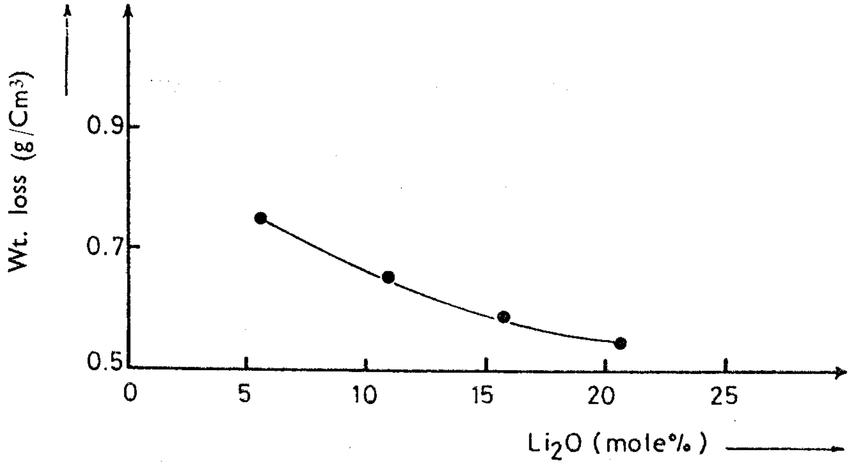


Fig. 2. Solubility of sodium silicate glasses containing lithia in 0.1 N HCl versus the lithia content (mole %)

3. In the sodium silicate of the composition SiO_2 70, Na_2O 20, RO 10 (mole %) where R represents the calcium or magnesium ions, table (2), the weight loss was 0.07 and 0.16 g. cm^2 for the two glasses containing lime or magnesia respectively.

4. In the sodium boro-silicate glasses, Table (3), the weight loss decreases down to a certain limit after which an increase is observed with the gradual increase of the soda content, Fig. (4).

Table 3. Chemical composition of sodium boro-silicate glasses.

Glass No.	Glass composition (mole %)		
	SiO_2	Na_2O	B_2O_3
14	50	10	40
15	50	20	30
16	50	30	20
17	50	40	10
18	66.66	6.66	26.66
19	66.66	13.33	20
20	66.66	20	13.33
21	66.66	26.66	6.66
22	75	5	20
20	75	10	15
24	75	15	10
25	75	20	5

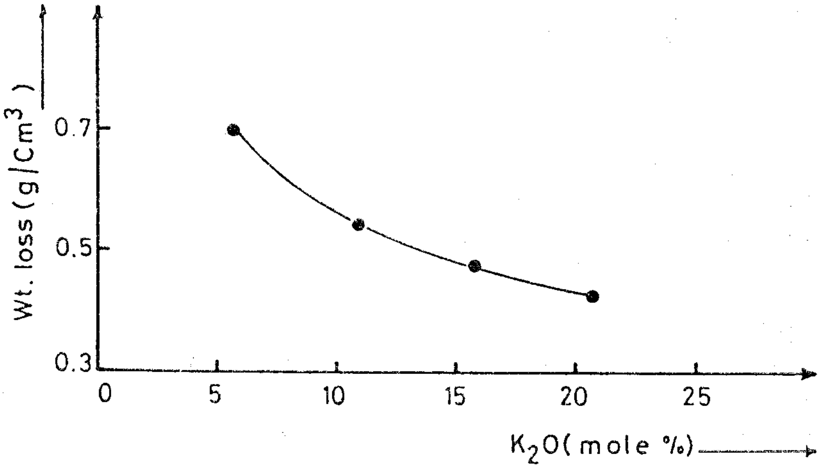


Fig. 3. Solubility of sodium silicate glasses containing potash in 0.1 N HCl versus the potash content (mole %)

DISCUSSION

The chemical durability of different types of glasses depend upon several factors such as the composition and the surface characteristics of the glass, the nature of attacking agent, duration at which it is kept in contact with it and the temperature.

Generally, the interaction occuring between a glass and different types of aqueous solutions clearly and partly depend on the nature

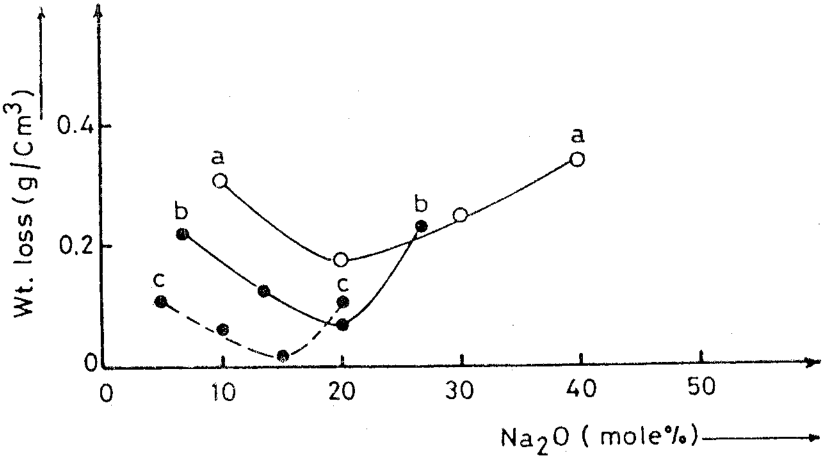


Fig. 4. Solubility of sodium boro-silicate glasses in 0.1 N HCl versus the soda content (mole %)
a) Glasses No. (14–17) b) Glasses No. (18–21) c) Glasses No. (22–25)

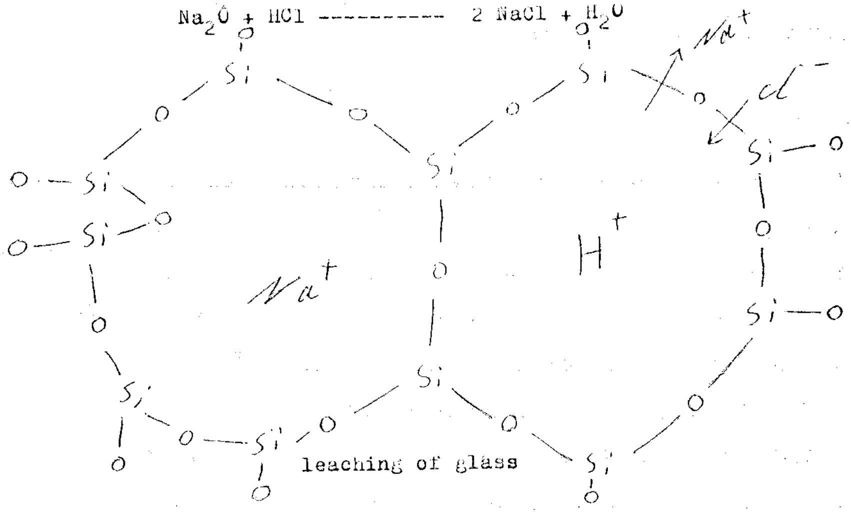
of the glass itself[8] of prime importance is the glass chemical composition while of equal or greater importance is the interface between the glass and the aqueous solution, i.e., the glass surface.

Chemical attack mechanism can be visualized with two concepts, leaching or the selective removal of the soluble glass constituents and etching which involves hydration followed by the total dissolution. In fact, any particular reaction will usually involve both of these mechanisms, one or the other predominating[10].

The leaching process, characteristic of the acid attack, is a diffusion-controlled ion-exchange process, involving the exchange of the hydrogen ion for the alkali present in the glass. In general, there will be selective removal of elements present as glass modifies, that is, those that are present in the interstices of the glass network[10].

According to the above facts, the experimental results obtained can be discussed as follows:

If the glass particles of the composition SiO_2 80, Na_2O 20 mole (%) is immersed in 0.1 N acid solution, a diffusion controlled ion exchange process can take place. On using the hydrochloric acid as the immersion solution, this process can be represented schematically as follows[10].



Thus, from the above reaction it can be concluded that the increase in the weight loss with the gradual increase of the soda contant, Fig. (1), can be attributed to the corrosion rate, i.e., the increase in the possibility of the leaching process[8].

In the sodium silicate glasses containing lithia or potash, the decrease in the weight loss or the decrease in the leaching process, Figs. (2 and 3), can be understood and realized by considering that the mobility of an alkali ion is reduced when another alkali ion is added[11]. The relative effect of the different alkali oxides may be attributed to their mobility and their ionic field strength. In the sodium silicate glasses containing lime or magnesia, the change in the value of the chemical durability can be interpreted as resulting from a blocking of the alkali ion motions by the doubly charged divalent ions that are bound lightly in the silicate network[12].

In the case of the sodium boro-silicate glasses studied, the experimental results obtained can be explained by knowing that these glasses can readily separate into two amorphous phases[13]. This phase separation can strongly influence the chemical durability. Also the formation of boron in strongly packed tetrahedral groups, at first, decreases the corrosion mechanism. When more BO_4 groups are allowed to be formed as expected[14] and the boron ions are present in increasing proportion in the three coordinated state, the corrosion is expected to increase (Fig. 4).

All the above conclusions are in complete agreement with the experimental results obtained[11].

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