CORROSION BEHAVIOUR OF SOME INDUSTRIAL GLASSES BY AQUEOUS SOLUTIONS

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بسم الله الرحمن الرحيم

وَعَلَّمَكَ مَا لَمْ تَكُنْ تَعْلَمُ

وَكَانَ فَضْلُ اللَّهِ عَلَيْكَ عَظِيماً

صدق الله العظيم

سورة النساء آية ١١٣

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TO MY FAMILY

SHERIEF

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ABSTRACT

ABSTRACT

Corrosion behaviour investigations of some selected glasses of industrial applications were carried out with the aim to classify these glasses according to their resistance to the action of acidic, alkaline or neutral solutions. The work is extended to compare and evaluate the different methods used for corrosion resistance measurements.

The studied glasses include varieties of ordinary soda-lime- silicate, borosilicate, glass-ceramic, high lead silicate with variable PbO contents, and cabal glasses.

All glasses were melted in platinum 2% rhodium crucibles in an electric furnace at high temperatures ranging from 1350 - 1550 °C according to the glass composition, then the melts were carefully annealed.

The measurements of corrosion of the different glasses were carried out on specified prepared glass grains by immersing them in various leaching solutions including acidic solutions of hydrochloric, sulphuric, citric or acetic acids beside alkaline solution of sodium hydroxide. Also pure distilled water was used in this investigation.

The tests were conducted for varying times ranging from 0.5 up to 12 hours for measurements performed at temperatures of 95 °C and 65°C. For room

temperature measurements, the leaching time was extended to 24 days. Two leaching methods were adopted in the experimental of this work, namely, the static and solution exchange tests.

The experimental results obtained revealed that the corrosion weight loss increased with prolonged times and high temperatures. Also the corrosion weight loss increased with the introduction of highly mobile alkali- or alkaline earth-cations or lead ions in high contents.

The discussion of the experimental data obtained was given on the basis of the current and acceptable theories of glass corrosion through hydration, hydrolysis, ionic diffusion, depolymerisation and their effects on the glass network. The effects of different acidic or basic solutions on the corrosion weight loss were evaluated and explained taking into consideration the relative dissociation of the acids and the different preferential attack of acidic or basic leaching solutions. Other related factors affecting glass corrosion process were also studied.

All the changes of the glass structure exhibited during the corrosion processes were discussed taking in consideration the different glass compositions investigated.

INTRODUCTION

I. INTRODUCTION

Glass is a material with a theoretically unlimited variety of possible compositions. Thus, its properties are also very variable, a fact that has opened up many areas of applications to glass and that is continually opening up new ones. Over the course of time, the concept "glass" has had various meanings. It can signify a certain condition of a substance (vitreous), a material (e.g. window glass), or an object (e.g. wine glass). Thus, it is quite understandable that many definitions are found in print which to some extent differ greatly from one another. The art of glassmaking is a very old one, but the history of its scientific understanding is very new. In the earliest times(1), natural glasses, e.g. obsidian, was known and used in the production of tools. The interesting and richly varied history of glass can only be touched on here. Most likely it was by accident that humans first made glass. But soon this new material was being manipulated with great creative skill, resulting in the first glass serving chiefly as valuable decorative jewelry. Then came the use of glass as a vessel, for which the glass was predominantly fritted and then, in a molten, viscous condition, formed around a core. Working the glass in a more liquid condition probably failed because of the lack of a crucible material that was sufficiently durable. The earliest man made glass was obtained about 4000 years ago in ancient Egypt. The composition of the old Egyptian glasses is known to be 70 wt.% SiO_2 (with some Al_2O_3), 10 wt.% CaO (with some MgO), and 20 wt.% Na_2O (with some K_2O). The first decisive change in glass production was the invention of the glass blower's pipe. Then better durable crucible material now allowed the glass to be heated higher and then blown; this created for glass its own technology, a technology which underwent scarcely any change for 2000 years. The Romans developed it to a high art and then took it to central Europe where it enjoyed a great flowering. In the time that followed, the production of glass for daily use was emphasized. Then, the development of crystal glass and coloured glasses followed by the introduction of machine production of glass were the next turning point in the history of glass, at the beginning of this century. Then many new glasses were developed, of which those chemically and thermally resistant glasses containing B_2O_3, as well as vitreous silica, were probably the best known. The development of optical glasses contributed numerous other components as ingredients of glass. More recently, theoretical interest led to the production of nonoxide glasses (based for example, on fluoride ZrF_4 or sulfide As_2S_3) and of metallic glasses, which likewise have already been put to use in industry. But there are many additional glasses of unusual composition which often have purely scientific interest. During the last several decades, much has been accomplished in the area of glass research. Without a through knowledge of the relationship between structure and glass properties, no important progress is any longer possible. This has been recognized and modern glass research establishments are being set up all over the world.

I.1. Definition of Glass: (The Glassy State)

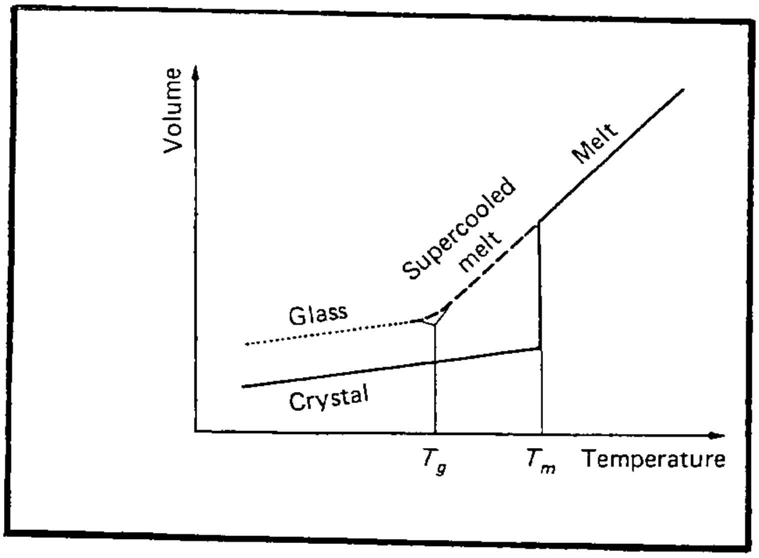

Fig. (1), Schematic diagram of the temperature dependence of volume

When the question of definition is dealt with, different views about the concept of glass exist which differ from each other in part only. The quest for a general definition is a worldwide activity. It is gratifying that opinions in recent years have been coming into closer agreement. Common usage of the term glass follows the definition of Morey(2): "glass is an inorganic substance in a condition which is continuous with, and analogous to, the liquid state of that substance, but which, as the result of a reversible change in viscosity during cooling, has attained so high a degree of viscosity as to be, for all practical purposes, rigid". Similarly, ASTM (American Society for Testing and Materials) defines glass as "an inorganic product of fusion which has been cooled to a rigid condition without crystallizing". Even this definition is too restrictive, as many organic and inorganic materials may form glasses if their structure is noncrystalline, i.e. if they lack long-range order.

This includes some plastics, metals(3,4), and organic liquids(5). In principle, rapid cooling could prevent crystallization of any substance if the final temperature is sufficiently low to prevent structural rearrangement. On the other hand, fusion is not the only technique of making glass(6). The sol-gel process of making glass is a very recent technique which avoids the normally high temperatures employed for the fusion process. Chemical vapor deposition is yet another technique which completely avoids fusion of constituent materials.

In the context of glass definition(1), what distinguishes glass physicochemically is of special interest. That can be most easily explained as one follows the technological process of glass production and, in doing so, observes the behaviour of the viscosity. This should be begun at high temperatures, where a glass melt, that is, a liquid, is present; here the volume should be investigated. In general, as indicated in the schematic diagram Fig. (1), when at liquid or a melt cools, its volume decreases. Normally, crystallization occurs a the melting point Tm, whereby a decrease in volume ensues. As the temperature continues to fall, the volume decreases further, but now with a lower temperature coefficient, that is, the expansion coefficient of the crystal is less than that of the liquid. The complete, solid curve of Fig. (1) corresponds to conditions of thermodynamic equilibrium. When no crystallization occurs at Tm, then the volume continues to decrease continuously along the dashed equilibrium curve. This area of supercooled melt or liquid is thus still in-albeit metastable-thermodynamic equilibrium. The metastable equilibrium curve does not proceed with decreasing temperature indefinitely; rather at a certain temperature one observes that the curve deviates and from that point runs more or less parallel to that of the crystal. From