Chapter 2
Effects of Lanthanum on Structure of Sodium Borosilicate Glasses

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ABSTRACT

Nuclear waste management poses a significant challenge in contemporary society, necessitating innovative approaches for confinement and characterization. This chapter addresses the synthesis and characterization of a model glass intended for nuclear waste encapsulation. Specifically focusing on the incorporation of lanthanum into the glass matrix, we detail the synthesis procedures and investigate its structural and mechanical implications. Utilizing advanced spectroscopic techniques including X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), nuclear magnetic resonance (NMR), Raman spectroscopy, and Brillouin scattering, we elucidate the intricate interactions between lanthanum ions and the glass structure. This contribution not only enhances our fundamental understanding

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of nuclear glass compositions but also provides insights into the development of robust strategies for nuclear waste containment.

I. INTRODUCTION

The term “glass” is derived from the Latin word “vitrum” and refers to a transparent material known for its transparency and resistance to atmospheric conditions. Since around 3500 BC in the Middle East, glass has been highly valued for its properties. It is now widely used in various fields such as optical communications, photonics, energy production through photovoltaic cells, electronic equipment, building materials, pharmaceuticals, and the environment. While glass has a long history of use, its study has primarily been based on empirical methods. However, scientific approaches in the 20th century have provided a better understanding of its properties, including its elaboration, structure, demixing, and crystallization phenomena. This knowledge allows for a more accurate definition of its stability range. The term “glass” now encompasses a broader context beyond its current definition as an “inorganic, dielectric, hard, brittle, and transparent material.” It refers to solid products with a non-crystalline structure that undergo a glass transition when heated to a liquid state.

Glass is utilized for containing radioactive waste due to its long-term chemical and mechanical durability. It can incorporate large concentrations of various radioactive substances. Glass is industrially employed for waste confinement and is being considered for long-term storage. The glasses chosen for nuclear waste containment are known for their resistance to self-irradiation and chemical durability, especially in the presence of water. This durability is crucial in deep geological disposal, where glass serves as the first barrier against the release of radionuclides into the biosphere. Studies of ancient natural glasses, such as obsidian and basaltic glass, have validated models predicting long-term behavior. Specific research has also investigated the alteration of glass in aqueous media in the presence of corrosion products from metal containers and clay materials from the surrounding geological formation.

On an industrial scale, various types of glass are used, including alkali borosilicates, aluminoborosilicates, and phosphates. Rare earth-enriched glasses show promise for containing minor actinides (Np, Am, Cm, etc.), rare earth elements, and fission products, thanks to their physicochemical properties. However, formulating these glasses requires extensive experimentation with melting and melting/crystallization processes. Consequently, each type of glass exhibits complex behavior determined by its basic structure (borosilicate, aluminoborosilicate, etc.) and the dopants it contains.