Structure and Attenuation Studies In Phosphate Glasses

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ABSTRACT

Lithium borate glasses containing P_2O_5 are prepared and influence of P_2O_5 on the glass system is analyzed by the values of densities, molar-volumes, oxygen molar-volume and packing densities. Values of mass attenuation coefficients and half value layer of the glass systems estimated & analyzed.

Keywords: Phosphate Glass, Densities, Molar Volume, Mass Attenuation coefficient

INTRODUCTION

Glasses containing P_2O_5 as its constituent are having a wide range of applications in many engineering and medical fields. Phosphate based glasses are utilized in the areas like verification of wastage radioactive materials, photonic, seals (glass to metal) etc [1-5]. Phosphate based glasses have greater advantage as compared to silicate based glasses in terms of low melting point, low transition temperature and high value of thermal coefficient of expansion [5-6].

In the present paper, the structure of Li_2O-P_2O_5-B_2O_3 glasses is analyzed in terms of molar volume and density measurements. Further the values of molar excess volume are determined to get the idea of regarding the openness and compactness of the glass structure. Mass Attenuation coefficients and half value layer parameters are analyzed & effect of composition of P_2O_5 is analyzed.

EXPERIMENTAL & THEORETICAL TECHNIQUE

Glass Systems of compositions Li_2O-P_2O_5-B_2O_3 as per table 1 were synthesized using melt quench method. Suitable measures of $NH_4H_2PO_4$, lithium carbonate & boric acid (AR grade) were uniformly mixed. The mixture was melted and for homogenizing O_2 gas was passed in the melt which was poured in copper mound kept at a temperature of 100°C and then brought to room temperature. Values of the densities were estimated with the help of Archimedes' principle by taking liquid benzene as immersion medium.

To ensure the non-crystalline nature of the synthesized glass system X-ray diffractions studies were undertaken. CuKα radiation was utilized for carrying out the scanning by using Philips PW 1710 diffractrometer was used in investigation. The recording of the pattern was by scanning the samples in the powder form taking scan rate 40 per minute & angle range (2θ) of 10 to 1000. No sharp peak was found in the scanned patterns indicating that the synthesized glasses are non-crystalline in nature. NIST XCOM software is used to estimate mass attenuation coefficients. The half layer values are estimated with the help of mass attenuation coefficients. [7-10]

RESULTS AND DISCUSSION

Molar volumes for synthesized glass systems were estimated by using the equation given by Duddridge et al. [11].The densities increase steeply from 2.38 to 2.50 gcm^{-3} for samples S1 to S5 and then show decrease from the value 2.48 to 2.46 from sample S6 to S7. The values of densities along with composition are listed in table number 1.

Table Number 1 Mole Percentage and the density of the glass systems

Sample Name	Li2O	P2O5	B2O3	Density (gcm-3)
S1	50	50	0	2.385
S2	45	50	5	2.408
S3	45	45	10	2.444
S4	45	40	15	2.485
S5	45	35	20	2.502
S6	45	30	25	2.488

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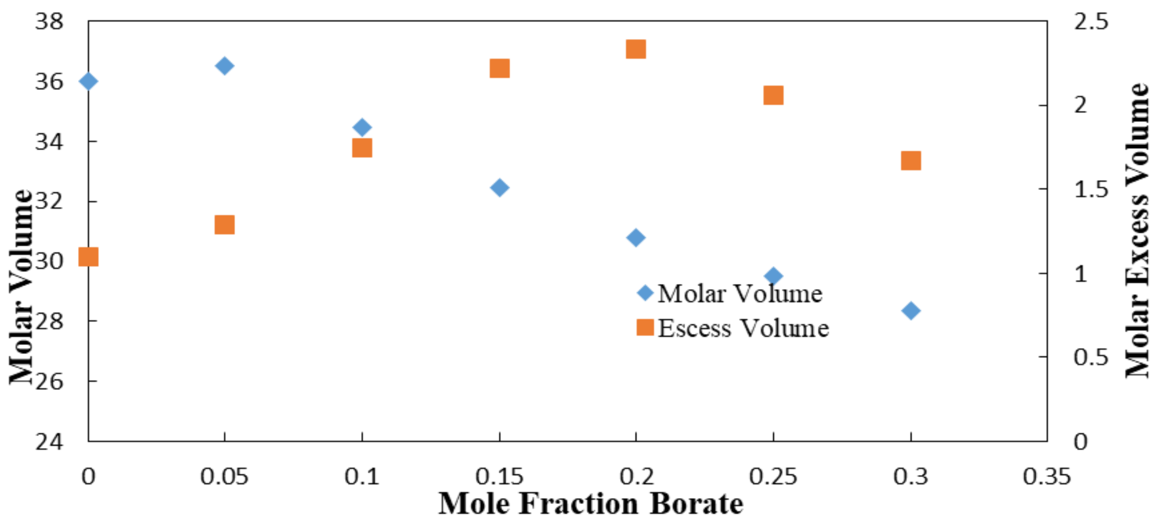
S7	45	25	30	2.463

The values of molar-volume and molar-excess volume are shown in figure number 1.



Figue 1 Molar volume and molar excess volume as function of mole…

As observed in the same graph that molar volume in units of gm cm^{-3} decreases from S2 to S7 with increase in mole percentage of B_2O_3 showing that the compactness of the structural arrangement is increased with increment in mole percent of B_2O_3 at the expense of P_2O_5.

At higher mole fraction of B_2O_3, the structure is associated with the formation of less number of NBOs (non -bridging oxygen atoms) and this result in the openness of the structure.

The values of packing densities for the synthesized samples is estimated with the equation given below:

$V_D = (1/ V_m)\ \Sigma V_i x_i$ **(1)**

Where V_m denotes molar volume and V_i denotes packing factor of the constituent oxide i, estimated with the help of relation as below for oxide X_nO_m as,

$V_i = (4\Pi/3)N_A\ [nR_a^{\ 3}+mR_o^{\ 3}]$ **(2)**

Here, N_A is Avogadro's number, R_a and R_o denotes Pauli ionic radius of cation and oxygen. The estimated value for V_D (packing density), V_o (oxygen molar volume) & σ (Poisson ratio) are given in table number 2.

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Table Number 2 Packing density, poisson ratio and oxygen molar volume values

Sample Name	V_D (**Packing Density**)	σ (**Poision ratio**)	V_o (cm^3 mol^{-1})
S1	0.47474	0.20744	36.021
S2	0.47740	0.20907	34.764
S3	0.49045	0.21681	31.350
S4	0.50523	0.22510	28.227
S5	0.51590	0.23078	25.662
S6	0.52089	0.23336	23.612
S7	0.52426	0.23508	21.805

Estimated values of V_D (packing density) increase from 0.4747 to 0.5242 from Sample S1 to S7. The values of σ (Poisson ratio) increase from 0.2074 to 0.2351from sample S1 to S7 .These values of V_D & σ shows that the density of cross linking for glasses grows from S1 to S7. Oxygen molar volume values as given in table 2 shows decrease from S1 to S7 indicating the formation of less number of NBOS (non bridging oxygen atoms) which results increasing of cross linking density. The increased values of cross linking density is consistent with the molar volume measurements indicating that the structure becomes more and more compact from S1 to S7.

The effect of composition of P_2O_5 on mass attenuation coefficient values and half layer values is also studied. The mass attenuation values for the systems from S1 to S7 are given in table number 3.

Table Number 3. Values of Mass attenuation coefficients (cm^2/gm) at various energies in MeV.

Glass System	μ/ρ (Mass Attenuation coefficient)								
	0.001	**0.01**	**0.1**	**1**	**10**	**100**	**1000**	**10000**	**100000**
S1	3271	17.52	0.1549	0.06223	0.02175	0.02093	0.02503	0.02615	0.02634
S2	3296	17.62	0.1641	0.06237	0.02173	0.02086	0.02495	0.02607	0.02626
S3	3295	16.8	0.1632	0.06232	0.02159	0.02052	0.02452	0.02562	0.02581

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S4	3295	15.9	0.1621	0.06227	0.02144	0.02016	0.02406	0.02514	0.02533
S5	3295	14.92	0.1609	0.06221	0.02127	0.01976	0.02356	0.02462	0.0248
S6	3294	13.84	0.1597	0.06214	0.02109	0.01932	0.023	0.02404	0.02422
S7	3294	12.65	0.1583	0.06207	0.02088	0.01883	0.02239	0.0234	0.02358

It can be observed that values of mass attenuation are high in low energy limits, then shows gradual decrease and corresponding to very high energy values the mass attenuation coefficient becomes steady.

Mean free path of the glass systems are given in figure 2.

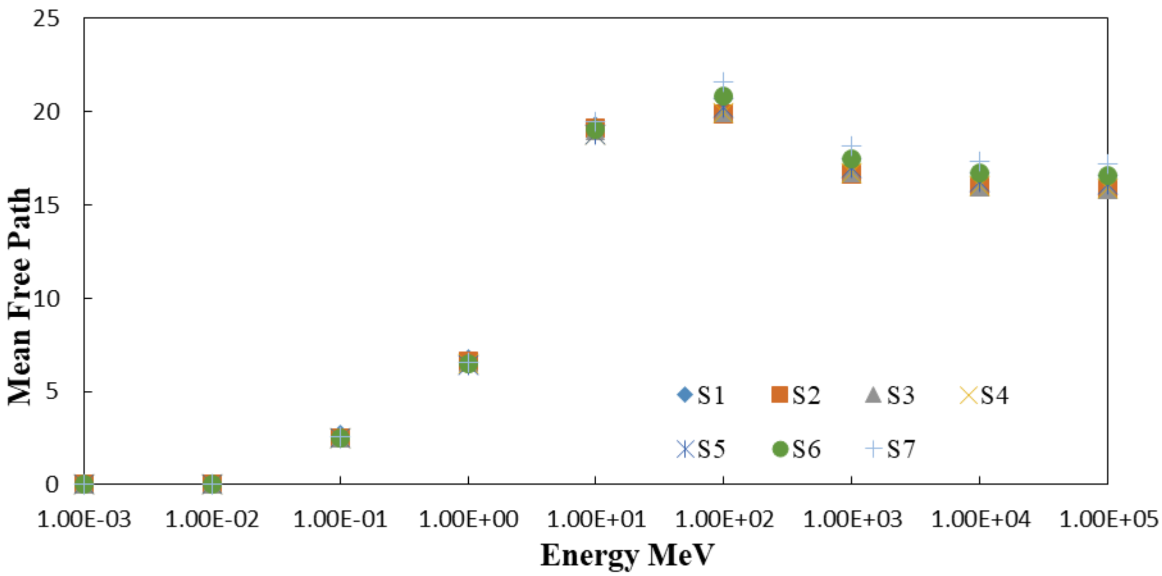

Figure 2. Mean Free Path as a function of Photon energy

Further the values of the half value layer are given in the figure 3 as below:

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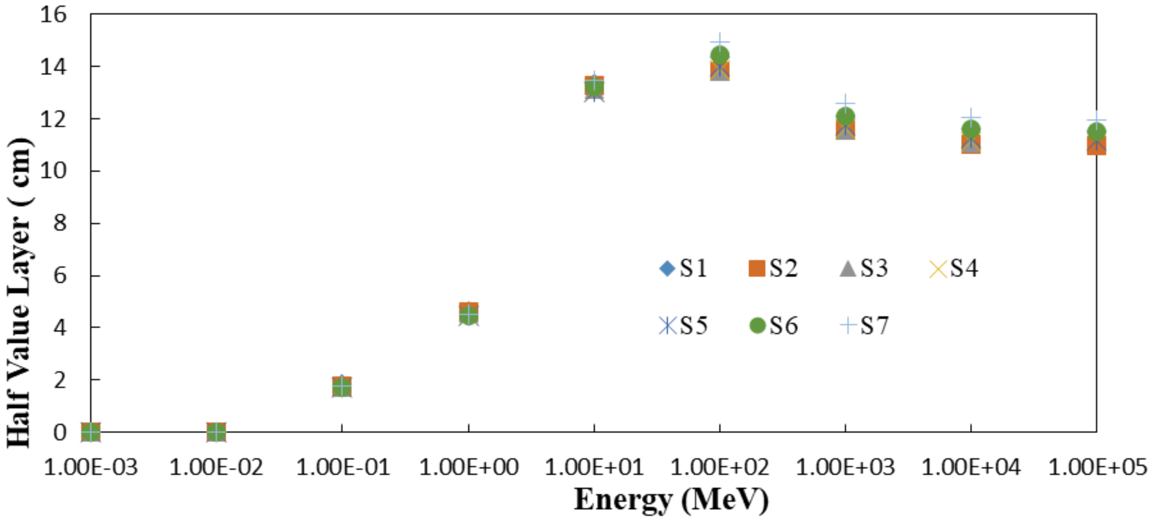

Figure 3 Half value layer as a function of photon energy

As seen clearly the value of mean free path is maximum for S7 is consistent with the maximum HVL value of S7.

CONCLUSIONS

For the glasses of the system Li_2O-P_2O_5-B_2O_3 with varying composition of P_2O_5 it is observed increasing mole fraction of B_2O_3 at the expense of P_2O_5 the structure becomes more compact resulting in the better cross linking of the network. On the other hand the attenuation properties improve with minimum B_2O_3 composition and Maximum P_2O_5 composition.

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