MODEL FOR CALCULATING VISCOSITIES IN MAGMAS FOR THE TEMPERATURE RANGE 400 TO 800°C. J.M. Wu, Energy and Mining Research, Industrial Technology Research Institute, Taipei 105, Taiwan, ROC, and L.C. Klein, Dept. of Ceramics Rutgers-The Sate University of New Jersey, P.O.Box 909, Piscataway, NJ 08854.

Introduction Over the past several years, the viscosities of iron-containing silicates have been measured under identical conditions in a beam-bending viscometer equipped with atmosphere control(1,2,3). The importance of collecting data in a well characterized system is to insure that the viscosity measurements are consistent and can be used in formulating an empirical model for viscous flow. The temperature range covered by this model is 400 to 800°C. The viscosity range is 10^8 to 10^{14} poise. The composition range is total metal oxide ($FeO+Fe_2O_3+Na_2O$) less than 35 mole %. In all cases, the mole % Na_2O is greater than mole % Al_2O_3. The compositions are recalculated in terms of $NaAlO_2$ as suggested by Bottinga and Weill(4). In addition to experimental data which appeared previously(1,2,3), data for the compositions listed in the Table were included in refining the coefficients in the model. The viscosities were measured in air(O), in forming gas $95\%N_2$-$5\%H_2$(N) and in forming gas with carbon in the glass(R). The iron in the analyzed compositions is listed as FeO and Fe_2O_3 and the Fe^{3+}/Fe^{2+} ratio approaches equilibrium for these melting conditions(5). An example of the viscosity-temperature relation for four glasses with nominally 15 mole % Na_2O is shown in the Figure.

Mechanisms Three mechanisms have been considered in the formulation of the empirical model. The model involves the breaking and reforming of Si-O bonds. The first mechanism involves a Si bonded to 3 O's and a bridging O between 2 Si's with an associated metal ion, either Na or Fe. The second mechanism involves a non-bridging O and a bridging O. The third mechanism involves 2 non-bridging O's. The population of each species is calculated from the analyzed composition at selected temperatures. Using the calculated mole fractions, the viscosity is obtained from an expression which has appropriate activation energies for each of the three mechanisms(3).

Calculating Viscosities The calculation of the equilibrium mole fraction of each species and the determination of the temperature dependence have been combined into one expression of the type:

$$\log \eta = \sum_{i \neq SiO_2} A_i X_i + 1/T \sum_{i \neq SiO_2} B_i X_i$$

The coefficients A_i and B_i have been obtained by excluding X_{SiO_2}. The best fit to the data is:

$$\log \eta = -0.43+3.68X_{NaAlO_2}-86.6X_{Na_2O}+5.22Fe_2O_3+1/T(11{,}010+60{,}300X_{Na_2O}-9{,}740X_{FeO})$$

Notice that the coefficients for some of the species are zero. While the viscosity decreases as Fe^{3+} is reduced to Fe^{2+}, the mole fraction Fe_2O_3 appears only in the preexponential and the mole fraction FeO appears only in the temperature dependence. This equation provides a quick way of estimating viscosities in iron-containing silicates, in particular, or in more general families of compositions where divalent cations can be grouped together and trivalent cations can be grouped together(6). The predicted viscosities in this low temperature model can be connected with a smooth interpolation of the viscosity-temperature relation to viscosities calculated from high temperature empirical models(4,6,7).

References 1.Klein L.C. Fasano B.V. Wu J.M.(1981)Proc.Lunar Planet.Sci.Conf. 12th 1759-67. 2.Ibid.(1983)Proc.Lunar Planet.Sci.Conf.13th in JGR 88,p.A880-886. 3.Wu J.M. Klein L.C.(1983) Lunar Planet.Sci.XIVp.865-6. 4.Bottinga Y. Weill D.F.(1972)Am.J.Sci. 272,438-75. 5.Sack R.O. etal.(1980)Contib.Mineral. Petrol.75,369-76. 6.Shaw H.(1972)Am.J.Sci.272,870-93. 7.Urbain G. Bottinga Y. Richet P.(1982)Geochim.Cosmochim.Acta 46,1061-72.

VISCOSITY MODEL

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Table of Analyzed Chemical Composition in Mole %

Glass No.	Atmosphere	SiO_2	Na_2O	Al_2O_3	FeO	Fe_2O_3	($NaAlO_2$)
75-15-5-5	O	74.4	16.5	4.1	1.5	3.4	8.3
	N	74.0	16.5	4.1	2.6	2.8	8.2
	R	73.1	16.3	4.1	5.0	1.6	8.1
70-15-5-10	O	71.1	15.8	4.0	2.5	6.7	7.9
	N	70.7	15.7	3.9	3.5	6.1	7.9
	R	68.6	15.3	3.8	9.4	2.9	7.6
65-15-5-15	O	67.8	15.1	3.8	4.1	9.2	7.5
	N	67.4	15.0	3.8	5.2	8.7	7.5
	R	64.6	14.3	3.6	13.5	4.0	7.2
60-15-5-20	O	64.3	14.3	3.6	7.0	10.8	7.1
	N	64.1	14.2	3.6	7.8	10.3	7.1
	R	61.3	13.6	3.4	16.0	5.6	6.8

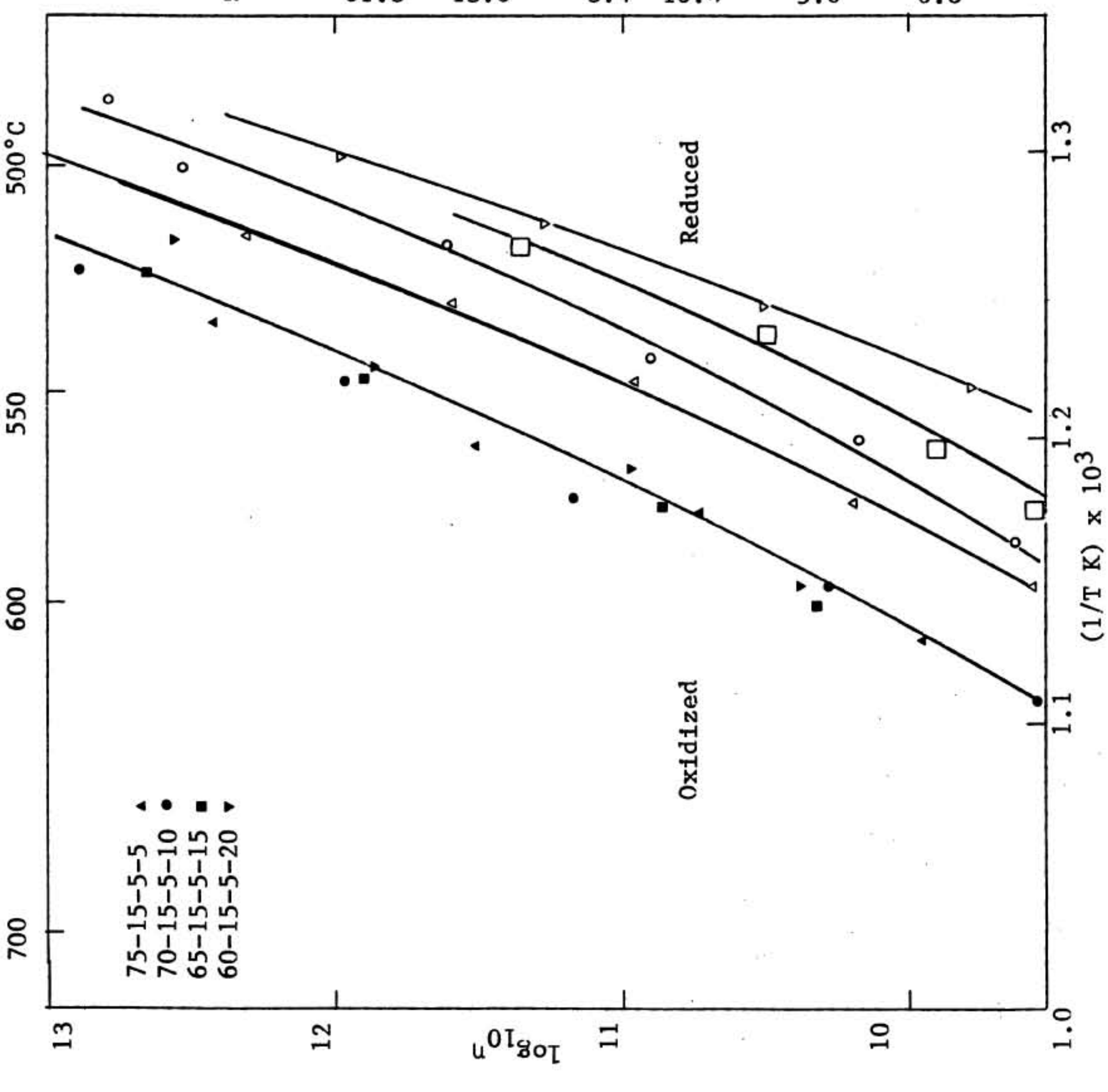

Figure - Viscosity vs temperature relations for glasses with Na>Al