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Reviewing Viscosity of Metals and Their Complexes

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ABSTRACT

Physicochemical parameter i.e. viscosity is studied with the help of various researches done till now. Viscosity describes the internal friction of a moving fluid and it plays an important role in the quality control and various research and development stages in lab, process and research environments as well as a wide range of industries and applications including food, chemical, pharmaceutical and petrochemical, cosmetics, paint, ink etc. Investigation of viscosity of nanofluids has inevitable importance in finding adequate pumping power, Reynolds number etc. Here we studied the viscosity evaluation for many complexes:
Copper(I) Complexes
Copper (II) Complexes
CaO-MgO-FeO-Al_2O_3-SiO_2 system
Aluminium and its alloys
Al_2O_3 and TiO_2 nanofluids
CaO-Al_2O_3 based mold fluxes
Fulvic Acid and its Copper and IRON complexes etc.

Keywords: Viscosity, Viscosity of Metals, Lubrication

INTRODUCTION

Viscosity is a type of bulk property defined as a liquid's resistance to flow, when the intermolecular forces of attraction are strong within a liquid there is a larger viscosity. Viscosity is a major factor in determining the forces that must be overcome when fluids are used in lubrication and transported in pipelines. Viscosity helps to choose oils with low viscosity used in car engines, the highly viscous liquid is used to damp the motion of some instruments and is used as break oil in hydraulic breaks, also the blood circulation in arteries and veins depends upon the viscosity of fluids.

According to the recent research, one of physicochemical parameter such as viscosity was evaluated for copper(I) nitrate complexes in binary mixtures of polar solvents such as Di methyl sulfoxide (DMSO), Pyridine and Nitromethane at variable temperatures (298K-318K) and at 1 atmospheric pressure. Ionic (B) values were evaluated using johns dole equation to determine extent of molecular interaction. Thermodynamic parameters of viscous flow like gibbs energy of activation, enthalpy of activation and entropy of activation were also evaluated using Eryings transition state theory. The copper(I) nitrate complexes with bioactive ligands were tested against Gram positive and Gram-negative strain and fungus. (1)

Cu nuclear magnetic resonance and viscosity studies of copper (I) Perchlorate solutions have been made at 298 K in binary mixtures of acetonitrile (AN) with deuterium oxide, 4-picoline, 3-methoxypropinonitrile and ethylbenzene at several composition if mixtures. The chemical shift (S), linewidth (A)and line intensity (/) of the Cu NMR signal have been measured relative to 0.064 M copper (I) Perchlorate ($CuClO_4$) solution in pure AN. The quadrupolar relaxation rates, reorientational correlation times and quadrupolar coupling constants (QCC) have been evaluated in all cases. The variation of quadrupole coupling constant with solvent composition shows that 4-picoline and deuterium oxide have a strong effect and 3-

methoxypropionitrile and displace preferential solvation by 4-picoline in acetonitrile + 4-picoline mixtures while its shows preferential solvation by acetonitrile in all other cases. (2)

Dipolar ions behave as non-electrolytes and a linear relationship exists between partial molal quantities and concentration, when dilute solutions are investigated. For interpreting viscosity data of aqueous solutions of several dipolar ions tsangaris and martin used the equation:

EQUATION: *rjT* = 1 + + Dm2

so far based on this criterion, seven dipolar ions, i.e. sulfamic acid, taurine, glycine, betaine, serine, glycyl-glycine and triglycine, have been shown to be structure breakers and five dipolar ions i.e. sarcosine, hydroxyproline, proline e-aminocaproic acid and glutathione, to be the structure makers .it was found that dipolar character of the amino acids and peptides disappears when these compounds are chelated with transition metal ions.

The aim of the present research is to investigate the action of the chelated amino acids on the pseudo crystalline structure of water, as it is manifested by viscosity measurements. Glycine and glycyl-glycine chelate of Cu (II) were selected for this task, because glycine is without any ambiguity a structure breaker and the solid structures of both complexes bis (glycinato) Cu (II) and (glycyl-glycinate) Cu (II) are very well established which may help the interpretation of the obtained results. Viscosity measurements of aqueous solutions of chelated compounds are rare. It was found that a relationship exists between viscosity (B) coefficient of the metals chelates and the radius of metal cation as well as the cation electronegativity and the second ionization potential. (3)

In this study seven slags were prepared by the reductive smelting of copper oxide concentrate with different ferrous oxide contents. The viscosity was measured in the temperature range of 1290-1410 degree Celsius. The result shows that there is a strong tendency to form orthosilicate even when the slag composition is acidic.

The slag type must be improved to reduce iron reduction. The crude copper produced by the high-calcium slag has a high grade, but the slag has a high viscosity and requires a higher operating temperature. The study of slag viscosity under different calcium oxide and ferrous oxide contents has important guiding significance for reducing operating temperature. The relation between the slag viscosity and temperature is in accordance with the Arrhenius relation:

ln_ = A*h*+E*h*/RT

viscosity of the liquid is determined by the ability of the structural units to jump over the barrier and the presence of “holes” in the liquid. E*h* and 0 are related to the activation energy of structural units jumping into adjacent holes and the probability of hole formation, respectively. And the addition of basic oxides can transform the random network structure into a more depolymerized structure containing chains and ring. Fincham and Richardson suggested three types of oxygen in silicate melts, including bridging oxygen, non-bridging oxygen, and free oxygen &Based on the Raman spectroscopy and deconvolution technique, Mysen evaluated the degree of polymerization of the melts by distinguishing Q0, Q1, Q2, and Q3 units and their relative abundance.

Therefore, both the ability of structural units to jump potential barriers and the probability of creating “holes” in the liquid are decreased, thus leading toa high slag viscosity value. The lubricant effect and charge compensation effect also have a significant influence on the viscosity by changing the depolymerization degree. For silicate slags, the depolymerization degree depends on the O/Si ratio.

In this work, the viscosity of the slags formed in the smelting process of copper oxide concentrate with different ferrous oxide contents were measured. The relation

between the viscosity and conductivity of slags was analysed. On the basis of the above theory, the reasons for the change in slag viscosity with composition and temperature were discussed. These results will be instructive in reducing the slag viscosity and operating temperature of the copper smelting process. (4)

Recent research also tells us about the models for viscosity of copper electrorefining electrolytes as it effects energy consumption impurity of cathode copper. Decreasing the viscosity increases the rate of mass transfer since the diffusivity and mobility of ion decreases thus lowering viscosity increases the diffusion coefficient of cupric ion as well as falling rate of anode slimes to the bottom of the cell. Viscosity is typically kept sufficiently low in electrorefining processes. This work introduced two new models for viscosity and the experimental work done to build up these new models was carried out as a function of temperature, nickel, copper, sulphuric acid and arsenic concentration was included in the viscosity models. Increasing concentration of Cu, Ni, As and sulphuric acid were found to increase the viscosity whereas increasing temperature decreased the viscosity. The experimental and modelling work carried out in this study resulted in improved viscosity models having the strongest agreement with the industrial electrorefining electrolytes. (5)

The viscosity of aluminium and its alloys were also studied. The data available for the measurement of viscosity of aluminium and its alloys were reviewed in this paper. Most measurements are performed with an oscillating vessel technique and the merits of this technique are discussed. The purity of the aluminium affects the measured viscosity values. Although studies of the viscosity of aluminium alloys are limited, the effects of the elemental additions to the alloys are similar to those for additions to the base metals. Thus, an increase in concentration of Ti, Ni, Cr, Mn, Mg tends to increase the viscosity whereas viscosity decreases with increasing Zn and Si concentrations. Also, purification of an alloy decreases the viscosity. (6)

Experimental investigation on viscosity of water-based $Al_2O_3$and TiO_2 nanofluids. It helps to investigate the influence of temperature, concentration and size of nanoparticles, and addition of surfactants on dynamic viscosity of water based nanofluids containing alumina and titania nanoparticles. Two viscometers, capillary and a falling ball, were used for the measurements in the temperature range of 20-50^{0}celcius. The result indicates that the viscosity of nanofluids is reduced by increasing the temperature, similar to their base fluids and the surfactants which are used to improve the self-stability of nanofluids, more likely increase their viscosity. (7)

Viscosity, density and conductivity of fused silver chloride doped with $MeCl_n$ (Me=Li, K, Cs, Ba) in mole fraction region. the density, conductivity and viscosity of molten silver chloride doped with LiCl, KCl, CsCl, and $BaCl_2$have been measured in the concentration range and the temperature range. the molar conductivity decreases linearly with x_{dopent}, the curve being independent of the charge of the added cation. Only in the case of the LiCl very small increase in the molar conductivity is measured. The viscosity of the metal remains virtually unchanged when doped with alkali halides. Addition of BaCl2 leads to a strong increase of the viscosity. It was found that no correlation exists between conductivity and viscosity and also that there is a strong influence of the long-range coulomb interaction on the viscosity of molten salts. (8)

Densities and viscosities of the binary system of ethylene glycol +dimethyl sulfoxide (DMSO) over the entire composition range was measured at different temperature and atmospheric pressure. Based on density and viscosity data, excess gibbs free energy of activation for the viscous flow, excess molar volume, viscosity deviation and apparent molar volumes can be calculated. These results were fitted to a Redlich-Kister equation to obtain the coefficients and to

estimate the standard deviations between the experimental and calculated quantities. Meanwhile, from the kinematic viscosity data, the enthalpy of activation for viscous flow and entropy of activation for the viscous flow were also calculated. In addition, based on UV visible and FTIR spectral results, the intermolecular interaction of EG with DMSO was discussed. (9)

The effect of titanium carbonitride (Ti (C, N)) on the viscosity of high titanium type blast furnace slag was investigated. The different Ti (C, N) contents were achieved by adjusting the reduction degree of TiO_2 to reflect the real characteristics of high-titanium slag. The result shows that the viscosity of the slag increased with the increasing Ti (C, N) content and decrease with the rising temperature. A deviation between the measured and the fitted viscosity appeared as the content of the Ti (C, N) was beyond 4wt%. The optical microscope and energy dispersive X-ray spectroscopy (EDS)analysis show that numerous bubble cavities were embedded in the slags and the Ti (C, N) particles agglomerated in the solidified samples. This phenomenon further indicates that the high Ti slag is a polyphase dispersion system, which consists of liquid slag, solid Ti (C, N) particles and bubbles. (10)

Flourine and nitrogen are important elements of metallurgical slags and fluxes. Studies on their viscosity have often focussed on the additive effect of fluoride and nitride compounds, whereas the influence of anionic composition (i.e. O, F and N concentrations) with a fixed cationic composition remains unclear. The present study reports the scarcely quantified viscosity variations due to changes in the anionic composition of a sodium silicate system by rotating the crucible method under a controlled atmosphere.The property of viscosity of silicate melts directly contribute to the quality of the resulting products and the stability of the casting process.For instances, the lubrication by silicate melts between the mold and steel strongly depends on the melt viscosity, which should be known to design the function of mold fluxes.

For viscosity measurements, the chemical composition of the quenched samples after viscosity measurement was chemically analysed and compared with those before viscosity measurements. The concentrations of Si, Na, F and Mo were analysed by wet chemical analysis, Si and Mo by inductively coupled plasma atomic emission spectroscopy, Na by atomic absorption spectroscopy and F by an absorption spectrophotometry. (11)

The viscosity of Ti_6Al_4V and TiAl alloy were measured by the oscillating drop method with an electromagnetic levitation device on board a series of parabolic flights. Parabolic flights offer 20 seconds of reduced gravity during which a specimen can be position under nearly force- free conditions and measurements in the liquid phase can be performed. Measurements of the viscosity will be affected by the dissolution of reaction products in the specimen of interest and for viscosity measurements, by the mechanical integrity of sample containers. It has been observed that 20 seconds of reduced gravity are sufficient for heating, melting, heating into the liquid phase and cooling to solidification of many industrial alloys. Thus, parabolic flights have been used for the measurement of viscosity of a variety of industrial alloys. (12)

Since $CaO\text{-}Al_2O_{3\text{-}}$ based mold fluxes are one of the most important mold flux systems in metallurgic processes, it is important to explore their structure characteristics and viscosity. Molecular dynamics simulation is performed to study the effect of $w(CaO)/w(Al_2O_{3)}$ on both the structural and viscosities properties of $CaO\text{-}Al_2O_{3\text{-}}$ based mold fluxes. $CaO\text{-}Al_2O_{3\text{-}}$ based mold flux viscosity decreased, the degree of network structure polymerisation decreases and the complex structure depolymerised. Increasing the water content in the cosolvent is beneficial to reduce the viscosity of the crystalliser. The aim of this study is to investigate the effect of $CaO/AlAl_2O_3$ratio on the $CaO\text{-}Al_2O_{3\text{-}}B_2O_3$ mold flux structure

and viscosity and to provide further fundamental understanding of the effect of this parameter on flux properties which will be useful for developing$CaO-Al_2O_3-B_2O_3$ mold flux. (13)

With the spread of lubricant oils, the usage of viscosity becomes more and more significant in various industries. It is easy to determine the relationship between viscosity and change of concentration and temperature. This research uses the high degree function and exponential function to stimulate the change trend of viscosity due to two variables. In many situations during production, the change of viscosity of lubricating oil can cause the mechanical strain. There are two main factors of viscosity of oil-water fluid, the temperature and concentration. However, the temperature and concentration change will significantly influence the viscosity.in terms of temperature, viscosity changes with temperature are similar. In terms of concentration, the viscosity of the mixed liquid solution will change with the concentration. The change of viscosity results in loss of efficiency. (14)

The viscosity of copper molten slag is decreased by the reduction of magnetic iron, which in turn, accelerates the settling and separation of copper droplets from the slag to improve the recovery of copper. A new technology using waste cooking oil as reductant reducing the magnetic iron in the copper smelting slag and consequently reducing carbon emissions in the copper smelting process. The magnetic iron in the copper slag gradually transformed into fayalite, and the viscosity of the copper molten slag decreased as the magnetic iron content decreased during the reduction process. The reduction of magnetic iron in the copper molten slag using waste cooking oil was a first order reaction, and the rate limiting step was the mass transfer of Fe_3O_4 through the liquid boundary layer. (15)

The viscous flow of $CaO-SiO_2-Al_2O_3-MgO-TiO_2-Cr_2O_3$ slag were investigated to promote understanding of the effect of TiO_2addition on the viscous behaviour of chromium-containing vanadium-titanium blast furnace slag. The viscosity of the slag was measured using a rotating crucible viscometer. Raman spectroscopy analysis was performed to correlate the viscosity to slag structure. The viscosity of slag was found to significantly decrease with increasing TiO_2 content at a fixed basicity. The variation in slag structure is consistent with the change in measured viscosity. (16)

Some oppositely charged polyelectrolyte surfactant mixtures show a remarkable increase in viscosity near charge equilibrium, while other very similar systems do not show any appreciable effect. The exact structural prerequisites to achieve a significant increase in viscosity are still unclear. It was investigated that structure and dynamics of oppositely charged polyelectrolyte surfactant complexes formed from sodium dodecylsulfate and the cationically modified hydroxyethyl cellulose JR 400, which does enhance the viscosity around charge equilibrium enormously. here we study PESCs consisting of SDS and the cationic PE polydiallyl dimethylammonium chloride which do not significantly increase the viscosity of solutions under similar conditions. The PDADMAC is much less strongly bound and possesses much higher dynamics which explains the much lower viscosity. (17)

The effects of B_2O_3 and basicity (CaO/SiO_2) on the viscous behavior and structure of medium titanium bearing blast furnace slag (MTBBFS) were investigated. High temperature viscosimeter was applied to measure the viscosities of $CaO-SiO_2-MgO-TiO_2-Al_2O_3-B_2O_3$ slag system and X-ray diffraction (XRD), NBO/T ratio, and structure parameter Q were employed to analyze its network structure. The results showed that the viscosity decreased and break point temperature increased with increasing basicity to 1.20. However, B_2O_3 addition gave rise to a decrease in slag viscosity and break point temperature inspite of basicity. The more B_2O_3 content leads to the more pronounced variation, especially for the slag with larger basicity. The

conventional NBO/T formula was revised to predict the structure variation of relatively complicated medium Ti bearing slag based on the work of Yanhong Gao and other researchers. The increase of B2O3 content in slag made parameter Q turn from $Q2$ to $Q1$, suggesting that network structure became simpler. It was also noticed that the addition of B_2O_3 could suppress the formation of perovskite. (18)

Planar and flexible electrochemical pH sensors with iridium oxide as the sensing film have been developed by sol-gel and oxidation processes. A reference electrode was prepared by screen printing Ag/AgCl ink on the same polyimide substrate. The small form factors of the planar flexible electrodes provide an advantage in small volume or conformal surface measurements. Cyclic voltammetry was performed in different pH solutions. The electrode originally produced a response of −70.1 mV/pH at room temperature in aqueous solutions. The sensitivities were reduced when salt was added into the buffer solutions, although output potentials were increased. Sensing performances in a wide range of viscous conditions with various concentrations of added salt have been analyzed to study their effects on pH-sensing responses. Suitable calibration techniques using aqueous buffer solutions were studied for output potentials and their respective pH readings in viscous salt-added solutions. The mechanisms affecting output potentials are explained and results matched well for two different thickening agents. Specificity to pH changes measured by the planar IrOx-Ag/AgCl pH electrodes showed how the potential-pH calibration should consider the interference effect of salt. The viscosity effects on pH reading errors became more pronounced as solution viscosity increased. Comparisons of pH readings to those from a commercial glass-bodied pH meter indicated that the planar electrodes provided predictable pH deviations that were confined to a limited range. The planar IrOx-Ag/AgCl electrodes on flexible polyimide substrates have mostly been demonstrated with aqueous solutions in various diagnostic and environmental monitoring applications. This work provides more insights into pH sensing performance when the fluid is viscous and contains salt, which often is the case in biomedical and food-processing applications. (19)

The density, molar volume, apparent molar volume, viscosity and other parameters of Cu (II) surfactant derived from karanj oil in non-aqueous solvents of varying compositions have been determined at constant temperature 298.15 K. The results were used to determine the critical micelle concentration (CMC), soap-solvent interactions and the effect of chain length of the surface-active molecule on various parameters. The CMC values of copper karanj soap solutions decreased with the increase in the concentration of polar solvent methanol in the solvent mixture. These studies were done to study the solution behaviour, micellar features and various interactions of the derived biologically active surfactant with polar and non-polar solvents to understand the applied part of the molecule. The apparent molar volume has been examined in terms of Masson equation, and the limiting apparent molar volume has been interpreted in terms of solute-solvent interaction. The detailed study of aforesaid compounds clearly indicates that the solute-solvent interaction decreases with the increase in ring strain and size of the synthesised complexes. The conclusions with regard to solute-solute and solute-solvent interaction have been discussed in terms of well-known Moulik's and Jones-Dole equations. This vital information plays an important role in the selection of the synthesised molecule for various industrial and biological applications. (20)

New chiral Schiff base Ni (II), Cu (II), Zn (II) complexes (Ni, Cu, Zn) and hybrid materials with azobenzene (AZ) in polymethyl methacrylate (PMMA) were synthesized. Linearly polarized UV light irradiation of these hybrid materials slightly increased their optical anisotropy of AZ as well as the complexes, which were measured with polarized IR and UV is spectra and

discussed based on TD-DFT calculations. Non-linear concentration (viscosity) dependence of PMMA solutions about artifact peaks suggested weak intermolecular interactions due to the flexibility of complexes by inserted methylene chains. Molecular modeling indicated that large spaces around complexes in PMMA resulted in easy molecular orientation (Ni > Cu > Zn) as short-term saturation of the UV light irradiation. (21)

Fluorescence excitation spectra of fulvic acid (FA) and its Cu and Fe complexes showed that fluorophore groups participated in metal complexation with a concomitant reduction influorescence intensities. The two characteristic bands at 360and 465 nm were affected by metal complexation but in addition, the 360-nm band shifted gradually toward longer wavelengths as more metal was complexed. Viscosity measurements indicated decreases in the molecular flexibility of FA with increasing metal complexing. This rigidity or strain in the structure was ascribed to metal complexing with carboxyl and phenolic hydroxyl groups and so bringing the macromolecular segments closer to each other. Viscosity-average molecular weights (Mv) also increased as more metal was complexed possibly because of the formation of metal bridges between FA molecules. The two effects mentioned above were more prominent at pH 6.0 than at 4.0. The flexibility of FA molecules at pH6.0 is greater than at pH 4.0, because of a reduction in intramolecular H-bonding at the higher pH, which allows the FA to interact with metal ions more favourably. (22)

The interaction of three complexes i.e. Zn (II), Cu (II) and V(IV) derived from asymmetric bidentate Schiff-base ligand with DNA and HAS were studied with the help of fluorescence quenching, UV-Visible spectroscopy, viscosity measurements and computational methods and the obtained result shows the DNA and HAS affinities for binding of the synthesized compounds: V(IV)> Zn (II)>Cu (II) and Zn (II)>V(IV)>Cu (II) respectively. Data shows that all metal complexes interact with DNA by groove-binding mechanism. (23)

As the information related to nature of complexes in establishing the principles of SDS-polyacrylamide gel electrophoresis so study was made on viscosity behaviour of SDS-protein polypeptide complexes. Result shows that complexes did not behave like pseudo-homopolymers but behaved as homologous polymers and their viscosity behaviour can only be interpreted in terms of flexible chains instead of series of rigid rods with a constant diameter and variable lengths depending on their molecular weights. (24)

As a function of concentration and temperature measured the viscosity, electrical conductivity, shear relaxation and Raman spectra of aqueous and methanolic sodium thiocyanate solutions. The non-Arrhenius temperature dependence was analysed by using Vogel-Tammann-Fulcher equation. In case of Raman spectra in aqueous sodium thiocyanate solution a broad band appears at 395-403 cm^{-1} region. (25)

As a function of salt concentration and temperature, densities and viscosities of solutions of $NaBPh_4$ in tetrahydrofuran and 2-methyltetrahydrofuran were measured. The concentration dependence of viscosity was described by vand equation for viscosity of concentrated dispersions. (26)

Investigation of viscosity if nanofluids has importance in finding the adequate pumping power, Reynolds number, Prandtl number and heat transfer coefficients in manufacturing systems employing fluid flow. The viscosity values are obtained by using Brook Field LVDVE viscometer with UL adapter for various temperatures ranging from 308 K to 328 K. (27)

Viscosity varies with temperature and composition of liquid. Viscosities of Al-Cu-Si lquid alloys were measured by using experimental techniques like electromagnetic levitation and oscillating cup viscometer. Using all geometrical models such as GSM, Kohler, Muggianu, Toop and Kaptay et al. etc to calculate viscosities for Au-Ag-Cu and Al-Cu-Si liquid ternary alloy systems and found that

Kaptay et al. model displays better performance. (28)

In estimating the viscosity of copper oxide nanoparticles dispersed in ethylene glycol and water mixture results that higher concentrations of nanofluids possess higher viscosity. Relative viscosity diminishes as temp. increases at higher rate for higher concentrations of nanoparticles. And it concluded that viscosity of nanofluids increases when the volume concentration of nanoparticles increases. (29)

During the experimental study on synthesis, stability, thermal conductivity and viscosity of Cu-engine oil nanofluid, it was found that non-Newtonian behaviour of applied nanofluids occurred at temp. 35^0C and lower and the pure base fluid showed Newtonian properties. (30)

A technique is used in which the particle size of about 200 nm using TEM is used for the measurement of viscosity of Cu in ethylene glycol nanofluid with no surfactants to stabilize the nanoparticles. Viscosity is found to be increased four times of that predicted by the einstein law of viscosity, so nanofluids are poorer coolants than base fluids. Here, viscosity is measured using a TA instruments AR-G2 rheometer equipped with a 6cm 1^0 cone rheometer. (31)

Nanofluids have been prepared by dispersing Al_2O_3 nanoparticles in different base fluids such as 20:80%, 40:60% and 60:40% by weight of ethylene glycol and water mixtures. Experiment of thermal conductivity and viscosity have been conducted in temperatures between 20^0C and 60^0C and volume concentrations between 0.3% and 1.5%. Thermal conductivities of nanofluid increases with increase in volume concentration and temperature but viscosity only increases with volume concentration but decreases with increase in temperature. (32)

Under the concentration range of 0.1 to 0.8 mole fraction DMSO and over the temperature range $213<T<293$ K the shear viscosity and density of ten dimethyl sulfoxide-water mixtures have been measured and the maximum in viscosity concentration curve observed at elevated temperatures is found to sharpen at low temperatures. (33)

The non-equilibrium molecular dynamics (NEMD) able us to determine the transport coefficient and calculate the shear viscosity of different alloys. NEMD method have been used to study the properties of such system as molten Nacl, n-alkanes, water, liquid crystals etc. It can be observed that NMED clearly shows non-newtonian behaviour of liquid metals & alloys. This is the asymptotic square root relationship for 3-dimensional simple fluids studied by NEMD under shear. (34)

The bulk glass forming alloys Zr46.75 Ti8.25 Cu7.5 Ni10 Be27.5 is found with a high thermal stability that have a large super cooled region when heat above the glass transition temperature their stability enables thermaphysical properties such as specific heat capacity and diffusion. The first-time parallel plate rheometry has been used to measure the viscosity. The viscosity has been measured as function of temperature over 120k, which correspond to about one-third of the entire supercooled liquid region. (35)

The suspension of the spherical polyethylene beads uniformly dispersed in silican oil and measured the viscosity of the suspension as the function of volume fraction and the mean diameter of beads (162.5um) and the shear rates having viscosity of silican oil (0.5pa).The relative viscosity increased with increasing the volume fraction of beads at the every shear rate,which clearly indicate that the flaw resistance of suspension increased with increasing volume fraction of beads .The relative viscosity decreased with the mean diameter of the suspension is due to decrease in agglomeration degree of beads.(36)

Slag viscosity is well known to be extremely sensitive to temperature, chemical composition and the presence of secondary and dispersed phases such as solids, gases and liquids. Certain solids such as undissolved CaO, attributed to excess added refining agent, its reaction products such as $3CaO.P_2S_5$, $2CaO.SiO_2$ and CaS in supercooled &partially crystallized mild

flux. The investigation has been done on the effect of different sizes of spinel ($MgAl_2O_4$) particles the viscosity of CaO-MgO-Al_2O_3-SiO_2 slag suspension increased with addition of spinel particles, with more than 10% volume of solid particles. (37)

In system showing complete miscibility in solid &liquid states, the viscosity of two elements. Systems with intermetallic compounds show more complex behaviour, with maxima of viscosity in liquid state. For elements, if the atomic diffusivity in the liquid is known, then the viscosity is calculated by using stokes-einstein relation. (38)

Na-K is low melting alloy (eutectic composition 22% Na&78%K by mass, eutectic temperature = -12.8°c) and alloy containing 40% to 90% k by weight is usually liquid as room temperature. the viscosity of molten metal & alloys is structurally sensitive dynamic property which indeed depends upon interaction between cohesive energy by arrangement of the solute atoms in the solution. the calculation of viscosity is based on Maelwyn-Hughes equation and Keptay equation predicated that liquid Na-K alloy at 384k is non-ideal with respect to viscosity. there is negative deviation of viscosity from ideal behaviour. (39)

Viscosity data on Cu – Ni – Fe have been obtained using an oscillating cup viscometer. viscosities are calculated from the time period and the decay of the amplitude. the temperature dependence of the measured viscosities can be described by an exponential Arrhenius law, taking into account an activation energy for the viscous flow. the activation energies for the ternary alloys were found to be linear combinations of the corresponding activation energies of the pure elements Cu, Ni, and Fe. at constant temperature, a non-ideal mixing behaviour was observed. as for the temperature dependence of the self-diffusion coefficient, we observe that the temperature dependence of the viscosity obtained by LDA is close to the temperature dependence of the assessed viscosity while GGA values overestimate LDA. (40)

Viscosity prediction of pure liquid metal related to equations like Andrade, Arrhenius, Eyring equations. There are many assumptions and omissions in the multivariate parameter derivation of thermodynamics and basic physical quantities when constructing the multicomponent alloy viscosity prediction equation, which leads to the divergence in the model. In the further development of viscosity model, both basic molecular methods and semi-empirical methods are irreplaceable. Andrade derivative equation based on quasicrystal theory has become an important branch of semi-empirical equation. Similar models include: Kaptay unified equation, Budai–Benko Kaptay model, and Hirai equation. (41)

Viscosity model developed for slags containing SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, MnO, FeO, PbO, NiO, Cu_2O, ZnO, CoO, and TiO_2 is capable of representing the effects of temperature, silica, and network-modifier cations within a wide range of temperatures and compositions. The models are well applicable to a range of industrial slags (blast furnace, new iron making, base-metal and Platinum Group Metals (PGM) smelting, and coal-ash slags). According to the rate data for silica-rod dissolution in liquid iron-silicate slags at 1573 K, the preferential attack at the slag line diminishes as the linear velocity of flow at the surface of the rotating silica rod reaches 9 to 16 cm/s. (42)

The impact of minor additions of Ni nanoparticles on the dynamic viscosity of the liquid Sn-3.0Ag-0.5Cu alloy (SAC305; in wt%) is examined. The nanocomposite samples were prepared from commercial SAC305 powder and Ni nano powder by cold pressing. However, an excessive amount of nanoparticles could lead to agglomeration and increase in the molten solder viscosity. composites of metals and refractory compounds like Be/BeO and Au/TiN form a local non-wettable barrier, resulting in enhancement of the wetting angle and decrease of spreading. It was shown that

changes in free energy during the formation of IMCs by interfacial reactions (between molten solder and solid substrate) highly impact wetting and spreading behaviour. (43)

Viscosity of liquid mixtures and variation of viscosity with temperature are required for solutions of many problems like heat transfer, mass transfer and fluid flow. It is found that in most of the liquid mixtures there is no linear relationship between viscosity and composition of the liquid mixture. Viscosity of binary and ternary liquid mixtures: acetone-methanol, methanol-ethylene glycol, acetone-ethylene glycol and acetone-methanol-ethylene-glycol was taken at 30^0C. Mc Allister equation was used to correlate data of binary mixtures and equation proposed by Chandramouli and Laddha for ternary liquid systems correlate the data for acetone-methanol-ethylene glycol ternary system satisfactorily. (44)

Viscosity is a difficult property to model since there is no generally accepted theory for the viscosity of liquids. The aim of this model is to review the viscosity models developed or adapted to ionic liquids and their mixtures that are available in the literature. (45)

Under the work it aims to report a combined experimental density, viscosity, FTIR and theoretical density functional theory method of tertiary butyl alcohol + dimethyl sulphoxide, ethanol, DMSO, TBA + DME, ET + DMF mixtures at room temperature. Density and viscosity data over the entire composition range have been used to compute excess molar volumes and deviation in viscosity.it is found that deviation of viscosity is positive over entire composition range of DMF+ET and negative for the DMSO=ET, DMSO+TBA and DMF+TBA. (46)

Investigation of excess molar volume, viscosity deviation and excess Gibbs free energy of activation of viscous flow was done from the density and viscosity measurements of propane-1,2 diol + water over the entire range of mole fractions at 303.15, 308.15, 313.15 and 318.15 K. Here the results were fitted by Redlich-Kister equation. System exhibited the very large negative values of excess molar volume due to increased interactions between unlike molecules or very large differences in the molar volumes of pure components at low temperature. (47)

The intrinsic viscosity of sonicated calf thymus DNA increases and the sedimentation constant decreases with increasing binding of proflavine at 0.2 ionic strength and at 25°C.The measurements corresponding to a linear increase in length of the almost rod like DNA molecules with the amount of proflavine bound is independent calculations from viscosity and sedimentation measurements yield almost identical results. (48)

The ionic equivalent conductivities at infinite dilution, viscosity B-coefficients, partial molal volumes and ionic radii of Nitroamminecobalt (III) complex ions have been determined in aqueous solutions at 25°C.The thermodynamic association constants of the polyvalent complex captions with chloride ions have been calculated from the conductivity data. Also, some factors determining the B-coefficients of complex ions have also discussed. (49)

A scaling formula for size dependent viscosity coefficients for proteins, polymers, and fluorescent dyes diffusing in complex liquids are presented. This formula analyses the mobilities of probes of different sizes in Hela and Swiss 3T3 mammalian cells. It is also helpful in the cytoplasm two length scales for the study of correlation length and the limited length scale which marks the crossover between nano and macroscale viscosity applicable for the length scales from 0.14 nm to a few hundred nanometres. (50)

CONCLUSION

Various studies have been done on viscosity with different solvents at different temperature and pressure conditions but very less work has been done on copper (1)

complexes. Therefore, in future, it will become a great area of research.

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