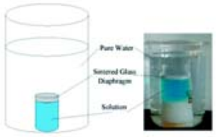
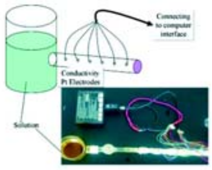
Measurement of Diffusion Coefficients of Metal Salts Using Home-Made Apparatus 1.Introduction Diffusion is an important transport phenomenon. The driving force leading to dif fu sion is the chem i cal potential dif fer ence between regions of dif fer ent con cen tra tions of matters. Many in ter est ing phe nom e na in chemistry and biological sci ence are re lat ed to diffusion. Diffusion has ver sa tile ap pli ca tions in diffusion separation and analysis, electrochemistry, biochemistry, material science, en vi ron men tal science, and medicine, etc. The dif fu sion coefficients at 25 and 1 atm are typ i cal ly for gases, for liq- uids, and they are ex treme ly small for solids. The gas phase re ac tion of NH3 and HCl molecules to pro duce NH4Cl smoke is a typ i cal dem on stra tion for diffusion. Dif fu sion plays an im por tant role for re ac tions in liq uid so lu tion due to the effect of sol vent molecules. For cer tain re ac tions between ions, the rate of chem i cal reaction itself is con sid er ably higher than that of diffusion and the rate of re ac tion is con trolled by the dif fu sion process, e.g. the reaction of H and OH ions in the neu tral iza tion reaction. In order to un der stand the dif fu sion phe nom e na of metal ions in aqueous so lu tion and in the absence of external electric field, We design and make home-made ap pa ra tus for dif fu sion measurement, based on the prin ci ple of (1) electric conductivity, (2) turbidity, and (3) colorimetry, since the commercialized





ap pa ra tus is not available. ? 10^{-9} m^2s^{-1} 10^{-5} m^2s^{-1} + - Fig.1 : Diffusion Apparatus A Fig.2 : Diffusion Apparatus B 2.Experimental Section Material: KNO3 , Cu(NO3)2 , Fe(NO3)3 , NH3 , Egg-White . Apparatus: Diffusion Apparatus A : see Fig.1 Diffusion Apparatus B : see Fig.2 Methods of Measuring Concentration: A. Conductometric Method : The conductivity of metal salt in aqueous so lu tion is measured. (Calibration Curve see Fig.3) B. Turbidimetry Method : The turbidity of solution caused by the complex formation between metal ion and protein of mol e cule of egg-white is measured.(Calibration Curve see Fig.4) C. Colorimetric Method : The transmittance of the solution of ion is measured. The solution of is pre pared by add ing NH3 to the aqueous solution of Cu(II) ion.(Calibration Curve see Fig.5) $Cu(NH_3)_4^{2+}$ $Cu(NH_3)_4^{2+}$

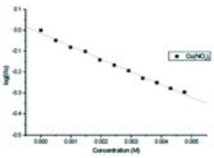
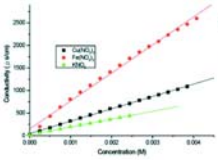


Fig.5 : Calibration Curve (Colorimetry)



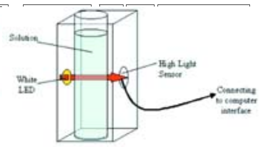


Fig.3 : Calibration Curve (Conductometry) Fig.7 : Detecting Device for Turbidity & Transmittance Measurement

Detecting Devices: Conductivity Measurement :(see Fig.6) * PASCO Scientific Science WorkShop 500 In ter face & Software. *PASCO Scientific Conductivity Sensor. * Pt Electrode.Turbidity and Transmittance Measurement : (see Fig.7) * PASCO Scientific Science WorkShop 500 In ter face & Software. *PASCO Scientific High Light Sensor. * Programmable Linear Power Supply. *White LED.

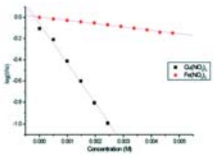


Fig.4 : Calibration Curve (Turbidimetry)

$$\log W_t = -\left[\frac{\pi^2}{2.303(4L^2)}\right]Dt + \log\left[2LAK(C_1 - C_0)\frac{8}{\pi^2}\right]$$

$$\Rightarrow \log W_t = -\alpha D t + \text{constant}$$

Equation.1 Reference.1 W_t=W(t)-W(∞) Equation.1 Reference.1

(α=2.916× 10^2 m^{-2})

Reference. 2

$$C_{(x,t)} = \frac{n_o}{A\sqrt{4\pi Dt}} e^{\frac{-x^2}{4Dt}}$$

$$\Rightarrow \ln C_{(x,t)} = \left(\frac{-1}{4Dt}\right)x^2 + \ln\left(\frac{n_o}{A\sqrt{4\pi Dt}}\right)$$ Equation. 2

3.Treatment of Data A. Diaphragm Technique: Where W(t) is the apparent weight of metal salt at time t and W(8) is the apparent weight after equi lib ri um has been reached. A : effective cross-section area. 2L : effective thickness. C : concentration.a : apparatus constant. B. Fick`s Second Law of Diffusion: 4.Results A. Diaphragm Techniqe:

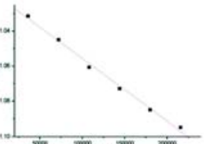


Fig 8 : Diaphragm Technique – $Cu(NO_3)_2$ (Conductometry)

	Theoretical	Conducometry	Turbidimetry	Colorimetry
	$D/10^{-9}m^2s^{-1}$			
$Cu(NO_3)_2$	1.223	1.223	1.223	1.223
$Fe(NO_3)_3$	1.237	2.266	2.009	
KNO_3	1.929	2.394		

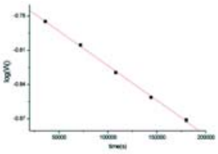


Fig 9 : Diaphragm Technique – $Fe(NO_3)_3$ (Conductometry)

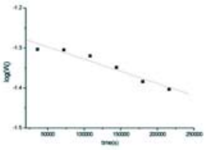


Fig 10 : Diaphragm Technique – KNO_3 (Conductometry)

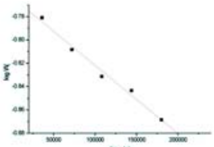


Fig 12 : Diaphragm Technique – $Fe(NO_3)_3$ (Turbidimetry) ($Ksp=1.6\times 10^{-39}$)

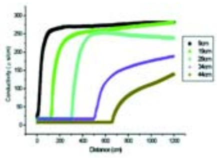


Fig 14 : Conductivity vs. Distance Plot $[Cu(NO_3)_2]$

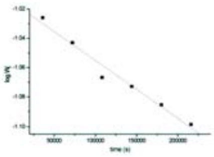


Fig 11 : Diaphragm Technique – $Cu(NO_3)_2$ (Turbidimetry)

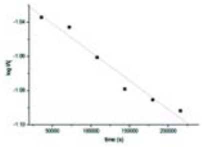


Fig 13 : Diaphragm Technique – $Cu(NO_3)_2$ (Colorimetry)

In contrast, the turbidimetric method is limited to the metal ion which is ca pa ble of forming stable complexes with protein molecules and the col o ri met ric method is lim it ed to the metal ion which can form colored metal ion complexes. Improvement of the diffusion ap pa ra tus is required for the mea sure ment of dif fu sion coefficient of metal salt by applying the Fick`s second law of diffusion. 6.References 1. Shoemaker. Garland. & Steinfeld. , 1974, "Ex- periments in Physical Chemistry" ,Third edition, McGraw-Hill Book Company, page 203~212. 2. Keith J. Laidler & John H. Meiser , 1999 , "Physi- cal Chemistry", Third edition , Houghton Mifflin Book Company, page 895~901.

B. Fick`s Second Law of Diffusion: 5.Dissusion In the diaphragm technique, the methods of conductometry, turbidimerty, and colorimetry give consistent results for KNO3, Cu(NO3)2, and Fe(NO3)3. The formation of colloidal Fe(OH)3 may cause interference in the con duc tiv i ty measurement. Satisfactory results are ob tained in the tubidimetric method using egg-white as the source of protein moleules for complexing with the Cu(II) and Fe(III) ions. The con duc to met ric method has more general ap pli ca tions in study ing the dif fu sion of metal salt in aqueous solution.

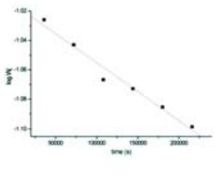


Fig 11 : Diaphragm Technique – $Cu(NO_3)_2$ (Turbidimetry)

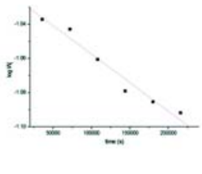


Fig 13 : Diaphragm Technique – $Cu(NO_3)_2$ (Colorimetry)

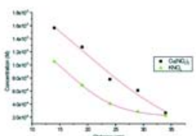


Fig 15 : Concentration vs. Distance Plot