Solubility and Density of Silver Iodide in Water and DMF at Various Temperatures as Function of Potassium Iodide.

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Abstract: *The solubility of silver iodide (AgI) in water, dimethyl formamide (DMF), KI + Water, and KI + DMF were measured using an analytical gravimetric method at temperatures ranging from (298.15 to 315.15) K. The densities of the saturated solutions are also reported. The results are interpreted in the form of enthalpy change ΔH.*
Keywords: *Silver iodide, solubility, density, potassium iodide, molar enthalpy, molar entropy, Gibbs energy.*

I.   Introduction

AgI used for cloud seeding [1]. Solubility studies of electrolytes have applications in diverse fields such as the pharmaceutical industry, agriculture, biology, medicine, etc [2]. Solubility data for many inorganic salts in aqueous systems are available [3-5]. However there is no data available for solubility of silver iodide in presence of potassium iodide as additive. Therefore we have undertaken measurements of solubility and densities of silver iodide in presence of potassium iodide at various percentage of KI in Water and DMF at various temperatures. The thermodynamic functions of solution of AgI were calculated by using Van't Hoff equation.

II.   Materials And Methods

The apparatus and procedures used for solubility and density measurement have been described earlier [6-8]. An excess amount of AgI was added to the KI binary solvents mixtures prepared by weight (Shimadzu, Auxzzo) with an uncertainty of ± 0.1 mg, in a specially designed 100 mL double jacketed flask. Water was circulated at constant temperature between the outer and inner walls of the flask. The temperature of the circulating water was controlled by thermostat to within (± 0.1) K. The solution was continuously stirred using a magnetic stirrer for long time (about 1 h) so that equilibrium is assured, no further solute dissolved, and the temperature of solution is same as that of circulating water; the stirrer was switched off; and the solution was allowed to stand for 1 h. Then a fixed quantity of the supernatant liquid was withdrawn from the flask in a weighing bottle with the help of pipet which is hotter than the solution. The weight of this sample was taken and the sample was kept in an oven at 343 K until the whole solvent was evaporated and the residue was completely dry. This was confirmed by weighing two or three times until a constant weight was obtained after keeping the sample in an oven for another 30 min every time. The solubility has been calculated using weight of solute and weight of solution. The saturated mole fraction solubility was calculated using usual equations. Densities were determined using a 15 cm^3 bicapillary pycnometer. For calibration of pycnometer triply distilled and degassed water with a density of 0.99705 g·cm^{-3} at 298.15 K was used. The pycnometer filled with air bubble free experimental liquids was kept in a transparent walled thermostat (maintained at constant temperature ± 0.1 K) for (10 to 15) min to attain thermal equilibrium. The heights of the liquid levels in the two arms were measured with the help of a traveling microscope, which could read to 0.01 mm.

III. Figures And Tables

Table 1: Mole fraction solubility (X) of AgI in KI + Water and KI + DMF solvent.

Temp (°K)	1% KI	2% KI	3% KI	4% KI	5% KI
AgI+KI-Water					
298.15	1.68E-05	2.69E-05	9.44E-05	0.00019	0.00029
303.15	6.61E-05	6.69E-05	0.00011	0.00017	0.00025
308.15	0.00010	8.00E-05	0.00014	0.00023	0.00028
315.15	2.30E-04	6.21E-05	0.00016	0.00022	0.00030
AgI+KI-DMF					
Temp (°K)	0.1% KI	0.2% KI	0.3% KI	0.4 KI	0.5% KI
298.15	0.0009	0.00234	0.00264	0.00335	0.00290
303.15	0.0010	0.00237	0.00326	0.00372	0.00353
308.15	0.0011	0.00234	0.00354	0.00388	0.00548
315.15	0.0011	0.00257	0.00352	0.00398	0.00643

Table 2: Densities of saturated solution of AgI in KI + Water and KI + DMF solvent

Amount of KI taken	ρ AgI+KI-Water			
	298.15	303.15	308.15	313.15
1% KI	1.0035	1.0030	1.0018	1.0004
2% KI	1.0117	1.0108	1.0094	1.0080
3% KI	1.0191	1.0176	1.0162	1.0155
4% KI	1.0259	1.0251	1.0237	1.0223
5% KI	1.0337	1.0325	1.0312	1.0299
Amount of KI taken	ρ AgI+KI-DMF			
	298.15	303.15	308.15	313.15
0.1% KI	0.9473	0.9435	0.9406	0.9383
0.2% KI	0.9513	0.9476	0.9444	0.9395
0.3% KI	0.9521	0.9517	0.948	0.9465
0.4% KI	0.9548	0.9527	0.9495	0.948
0.5% KI	0.9562	0.9537	0.951	0.9487

Table 3: Thermodynamic Functions Relative to Solution Process of AgI at Tmean = 305.65 K

composition	ΔH (KJK^{-1}mol^{-1})	ΔG (KJK^{-1}mol^{-1})	ΔS (KJK^{-1}mol^{-1})	ΔS (JK^{-1}mol^{-1})	$T\Delta S$ (KJK^{-1}mol^{-1})
1% KI	8.1809	24.0360	-0.0518	-51.8731	-15.8550
2% KI	42.3930	24.9143	0.0571	57.1854	17.4787
3% KI	30.3544	22.7802	0.0247	24.7805	7.5741
4% KI	11.7975	21.5668	-0.0319	-31.9623	-9.7692
5% KI	2.9930	20.7446	-0.0580	-58.0782	-17.7516
AgI+KI-DMF					
0.1% KI	3.0928	17.2963	-0.0464	-46.4698	-14.2035
0.2% KI	4.1736	15.3117	-0.0364	-36.4409	-11.1381
0.3% KI	14.7739	14.5688	0.00067	0.6711	0.2051
0.4% KI	11.1407	14.1644	-0.0098	-9.8926	-3.0236
0.5% KI	43.9311	13.79	0.0986	98.6131	30.1411
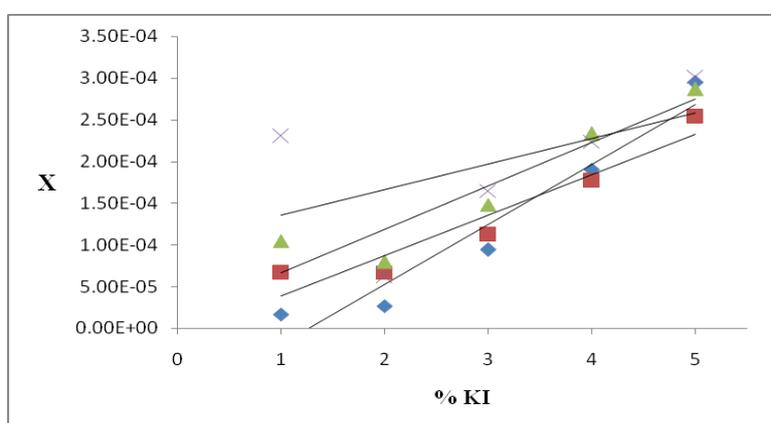
Fig 1: Variation of Mole fraction solubility (X) of AgI with % of KI in KI+ water solvent mixture.
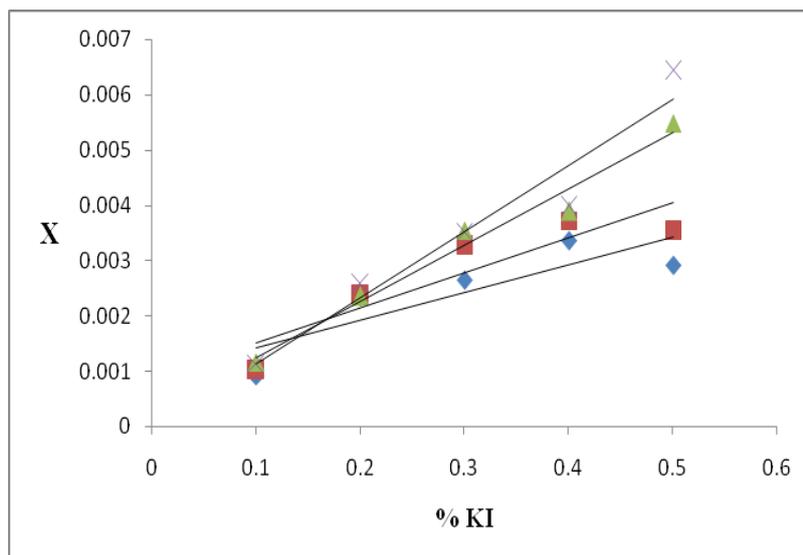
Fig 2: Variation of Mole fraction solubility (X) of AgI with % of KI in KI+ DMF solvent mixture.
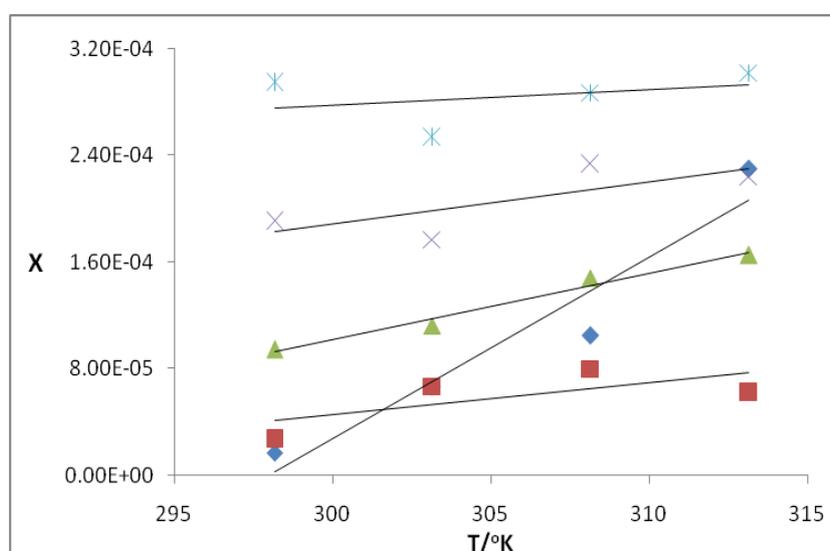
Fig 3:- Mole fraction solubility (X) of AgI in KI + Water solvent with temperature.
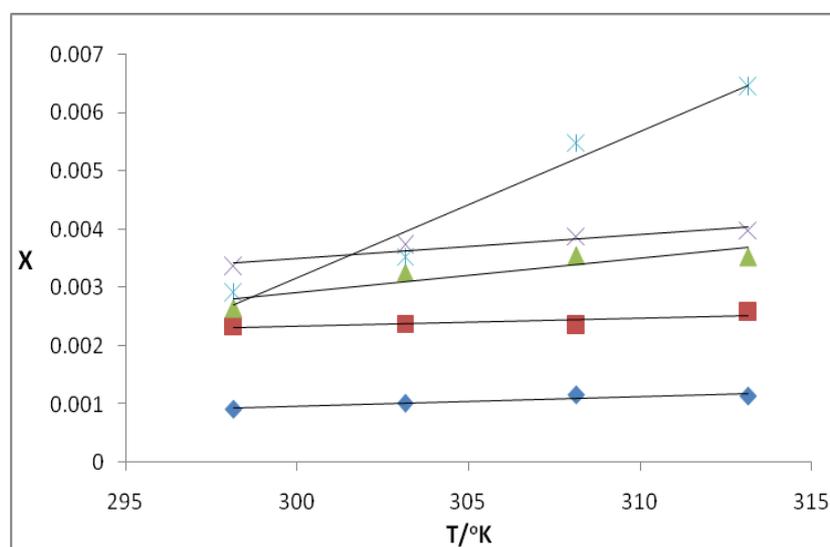
Fig 4:- Mole fraction solubility (X) of AgI in KI + DMF solvent with temperature.

IV. Results And Discussion

The experimental values of solubility (X) and density (ρ) of the saturated solutions at (298.15, 303.15, 308.15, and 315.15) ^{o}K for AgI + KI in water and DMF are given in Tables 1 & 2 respectively. Variation of solubility with composition of KI and that of with temperature in water and DMF are shown in Figures 1 to 4. It can be seen that the solubility of AgI in both KI + Water and KI + DMF mixtures increases with increasing content of KI in solvent mixtures. It can also be seen that the solubility of AgI in KI + Water and KI + DMF mixtures with given initial compositions increases with temperature. But increment of solubility is higher with % of KI as compared to the temperature which can be seen from graph. These indicate that KI is found to be very important additive for increasing solubility of AgI. Solubility of AgI was found to be higher in KI+DMF solvent. The density of saturated solution of AgI in both KI + Water and KI + DMF mixtures is found to decrease with temperature. But density is found to increase with % KI which is usual one.

Thermodynamic functions of solution are important to study the dissolution behavior of the solute in different solvents. The temperature dependence of the solubility allows a thermodynamic analysis that permits insight into the molecular mechanisms involved in the solution processes. In this work the thermodynamic functions in the process of solution of AgI are calculated on the basis of the solubility of AgI in different solvents. According to the van't Hoff equation, the standard molar enthalpy change of solution ΔH is generally obtained from the slope and standard molar Gibbs energy change for the solution process ΔG is obtained from the intercept of the ln X vs 10000 (1/T − 1/Tmean) plot in the way similar to Pawar et al. [9].

Average temperature Tmean is introduced to obtain a single value of ΔG and ΔS in the temperature range studied. In the present work, Tmean = 305.65 K and the temperature range is (298.15 to 313.15) K. The standard molar entropy change ΔS is obtained from eq. as ΔS = [(ΔH – ΔG) / Tmean]. Results are shown in Table 3. From Table 3 it can be concluded that the standard Gibbs free energy of silver iodide is positive in all the studied system as is the enthalpy of solution. Therefore the process is always endothermic and the entropy of solution is negative for AgI in KI + water system while enthalpy is positive, it means enthalpy is the driving force for the systems. For all systems, the main contributor to the positive standard molar Gibbs energy of silver iodide solution is the enthalpy.

V. Conclusion

The solubility of AgI in all solvent system was found to increase with increasing content of additive KI. So KI plays very important role to increase solubility. Also solubility of AgI increases with increasing temperature in all studied systems. The solution process is always endothermic. For all systems the main contributor to the positive standard molar Gibbs energy of silver iodide solution is the enthalpy.

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