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Research Article

Studies on Solubility of Second Solute in Saturated Solution

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Abstract

Studies on solubility of two or more solutes in single/mixed solvents find wide range of applications in pharmaceutical industries. The objective of the present work is to study the solubility of binary solute system. The effects of temperature and concentration of first solute on the solubility of second solute were investigated. Sodium Chloride (NaCl) and Potassium Chloride (KCl) were the two solutes used in the study. Solubility studies were carried out at three different temperatures namely 30, 40 and 50 °C respectively. Saturated solution of first solute was used in addition to its concentration on weight percentage from 10 to 30%. It was observed that the solubility of single solute increased with increase in temperature. It was also noticed that the dissolution of second solute influenced the solubility of the first solute. The results also showed that irrespective of the number of solutes present in a solution, the solubility increased with increase in temperature.

Keywords: Solubility; Saturated solution; Second solute; Multi-component system.

Introduction

The Solubility of a solid solute in liquid solvents forms the basic principle of crystallization operation [1]. Crystallization is concerned with the evolution from solution or melt of the crystalline state [2]. Measurement of solubility is the first step in the crystallization process and often involves the evalution in multiple solvents [3]. The selection of appropriate solvent is of great importance since there is a wide range of industrially used solvents [4]. In addition to various factors affecting the crystallization, the availability of solubility data plays an important role in optimizing the purity and yield of crystallization operation [5-7]. Moreover, solubility is a crucial physicochemical parameter in the process of medicine discovery and development [8]. When a soluble salt is added to water, there is a point where solid-liquid equilibrium is reached and any further addition of salt does not increase the concentration of salt dissolved in water [9,10]. Any extra amount of salt added simply remains undissolved and goes to the bottom of the vessel after the system attains equilibrium [11]. The equilibrium concentration of salt dissolved in water in equilibrium with the solid phase of the salt is denoted as the solubility limit of the salt, or simply the solubility [12].

The value of the solubility depends on the salt, the solvent, and the thermodynamic conditions (i.e., the temperature and pressure) [13]. One of the important property that determines the solubility of a solute in the selected solvent is polarity. The general rule of solubility is like dissolves like i.e., polar solutes are soluble only in polar solvents whereas non-polar solutes are soluble only in non-polar solvents. When the solvation polarity is reversed, then the system becomes either sparingly soluble or completely insoluble [14]. Therefore, solubility measurement of solid solute at required conditions is an integral part of many industrial unit operation and processes. The measurement of solubility mainly involves the determination of solute concentration in the solution at equilibrium [15]. Some of the common techniques available for determination of solute concentration are gravimetry, conductivity, turbidity, transmittance, spectroscopic and HPLC measurement [16].

The accuracy of measured solubility values depend on several factors like temperature, solute-solvent interaction, equilibrium time, agitation etc., Pressure does

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not have any significant effect on solid solubility in liquid solvent [17]. There were many authors in the past and present who are constantly working on solubility determination of many solid and liquid solutes in various pure and mixed solvents. But there is no evidence for the solubility data of solutes in a saturated solution. The objective of the present work is to experimentally determine the solubility of solute 2 in a saturated solution of solute 1 in addition to its varying concentration to weight percentage. The experiments were also repeated by reversing the solutes. It is believed that these solubility data will be very much helpful in the design and development of many pharmaceutical products.

Materials and methods

Experimental set-up

The experimental set-up consists of a magnetic stirrer (REMI- 2MLH) with varying rotational speed and temperature. A glass calorimeter set-up provided with cotton wool and thermocol insulation was placed on the magnetic stirrer. The solvent used was double distilled water and the solid solutes (NaCl and KCl) of purity greater than 99% were purchased from Loba Chemie Laboratory Reagents & Fine Chemicals. The solutes were used without any further purification. Two digital temperature indicators were used for continuous measurement of solution temperature and placed inside the calorimeter set-up.

Fig. 1. Experimental set-up

Experimental procedure

The glass calorimeter set-up was cleaned well and positioned on the magnetic stirrer. About 100 ml of the solvent (double distilled water) was taken in the calorimeter set-up and the required temperature was set constant by adjusting the temperature knob in the magnetic stirrer. To determine the saturation solubility of solute 1, excessive amount of solute 1(NaCl) were added to the solvent kept at a certain temperature. To reach the solid liquid equilibrium state, the solutions were continuously stirred for at least 2 h in the stirrer set at a constant rotational speed. The saturated solution of solute 1(NaCl) was then separated from the undissolved solute by using a syringe filter (0.22 µm). The total weight was weighed immediately by the analytical balance. To determine the solubility of solute 2 (KCl) in a saturated solution of solute 1 (NaCl), the solid free saturated solution of solute 1 was added to the glass calorimeter set-up, to which excess of solute 2 (KCl) was added. Once the solid-liquid equilibrium state was achieved, the solid solute was removed from the solution and the total weight of the solution was measured. The experiments were carried out in the temperature range of 30, 40 and 50°C .In addition to saturation solubility, the solubility of solute 2 (KCl) on varying concentration to weight percentage (10, 20 and 30%) of solute 1 (NaCl) was also determined. The entire procedure was repeated by reversing KCl as solute 1 and NaCl as solute 2.

Results and discussion

The graphs were drawn between the solubility of KCl in saturated solution of NaCl, in addition to concentration to weight percentage of NaCl in the range of 10, 20 and 30% and temperature. The temperature was varied from 30 to 50°C. The graphs were also drawn between the total solubility of solutes in the solvent and temperature.

The effect of temperature on the solubility of KCl in various concentration of NaCl Solution is represented in Fig.2. It can be seen that the solubility of KCl increases with temperature irrespective of the initial concentration of NaCl. The solubility of KCl remains the least in saturated in NaCl solution. Fig. 3. indicates the variation in solubility of NaCl in various concentration of KCl solution as a function of temperature. From Fig.2 and Fig.3, it can be concluded that the solubility of KCl in NaCl solution is higher when comparing to that of NaCl in KCl solution. Fig. 4 and Fig. 5 represent the variation between total solubility of solutes and temperature. Though the total solubility is irrespective of the initial solute concentration, the total solubility of KCl in NaCl solution reaches a maximum value when comparing to that of NaCl in KCl solution.

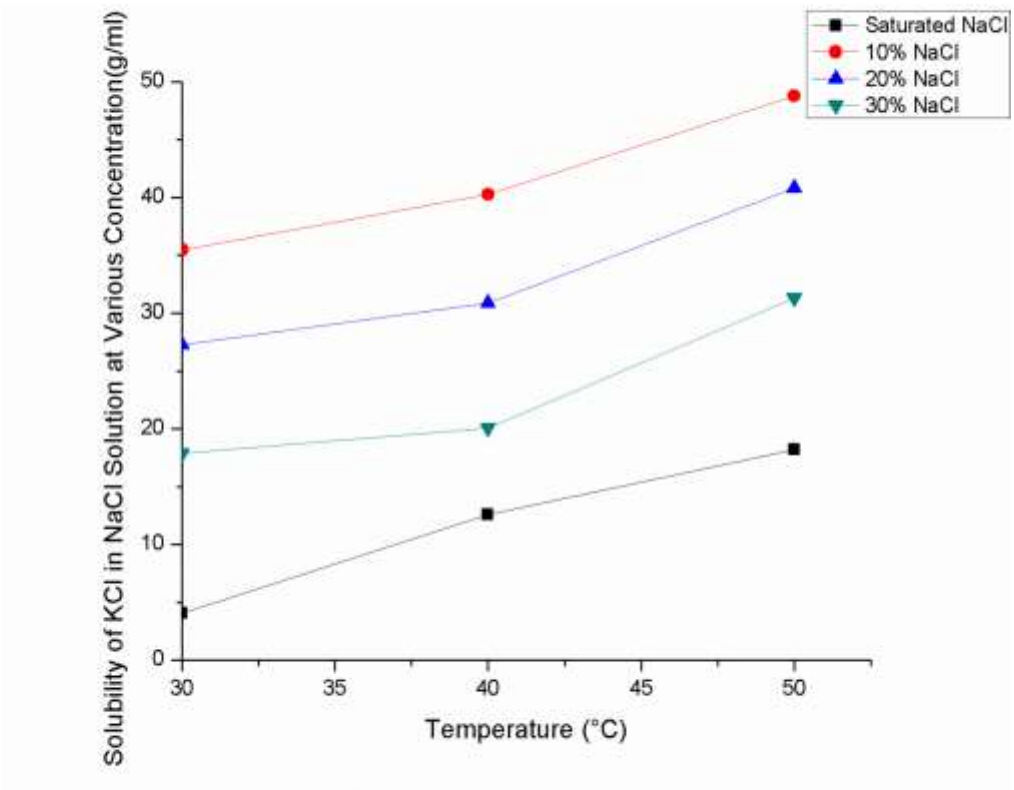

Fig. 2. Solubility of KCl in various concentration of NaCl Solution versus Temperature

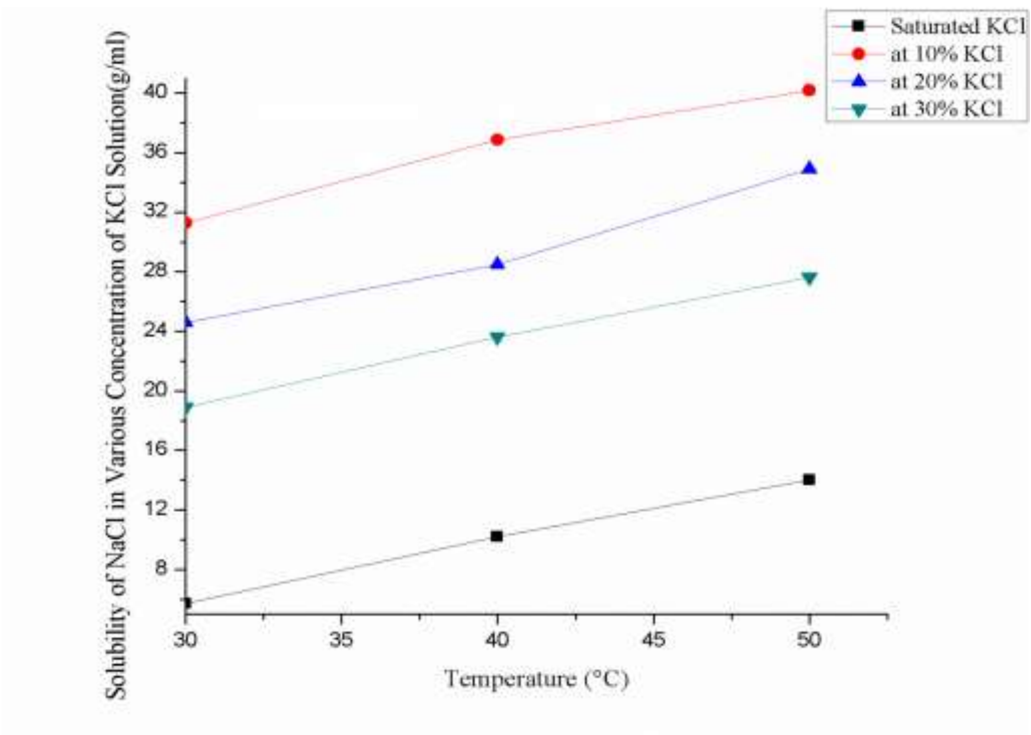

Fig. 3. Solubility of NaCl in various concentration of KCl Solution versus Temperature

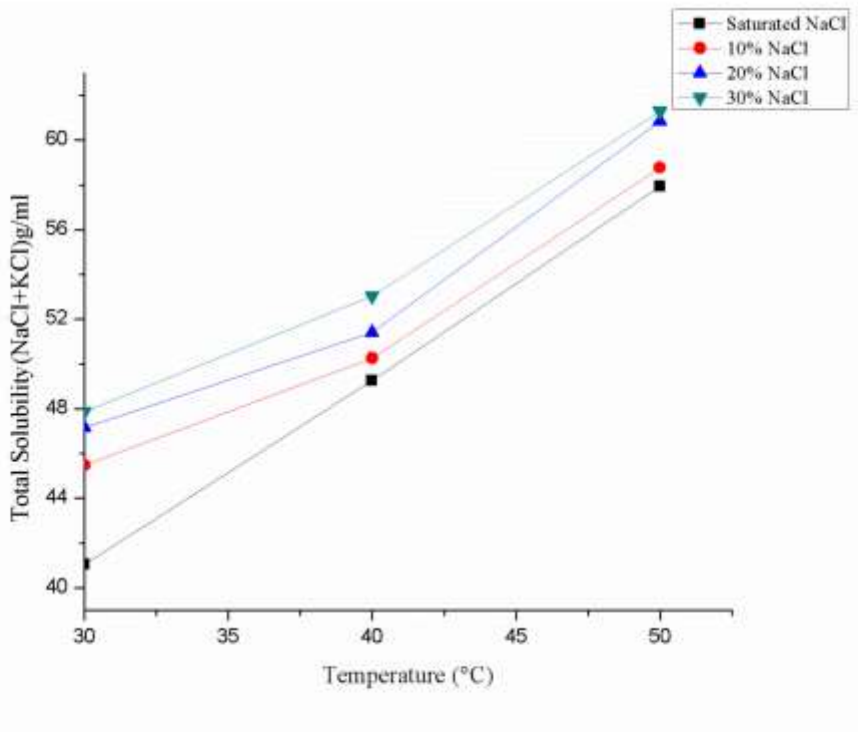

Fig. 4. Total Solubility of solutes (for KCl in NaCl solution) versus Temperature

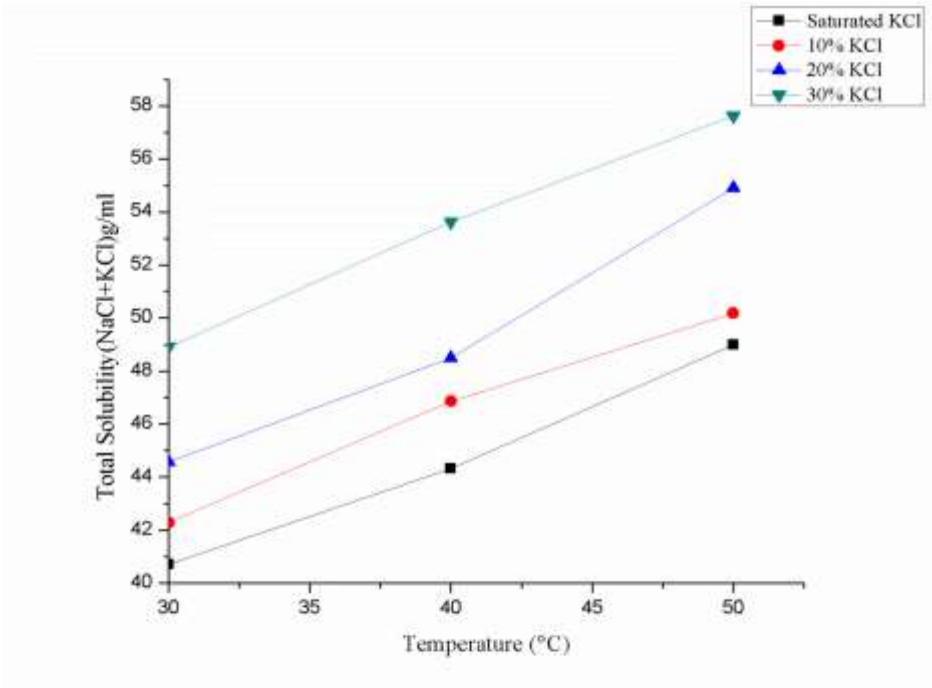

Fig.5. Total Solubility of solutes (for NaCl in KCl solution) versus Temperature

Conclusions

Experiments were carried out determine the variation in solubility of solute 2 in various concentration of solute 1 in the temperature range of 30, 40 and 50 °C. It can be seen from the experimental result that the solubility of solute 2 is very much less in the solution when comparing to its solubility in pure solvent (double distilled water). Added, the solubility of solute 2 is least in saturated solution of solute 1. Among the two combination of solutes, the solubility of KCl is higher in comparison to that of NaCl. It can be concluded that in addition to temperature, the initial concentration and type of solute will also affect the solubility of second solute. It was observed that the solubility of single solute increased with increase in temperature. It was also noticed that the dissolution of second solute influenced the solubility of the first solute. The results also showed that irrespective of the number of solutes present in a solution, the solubility increased with increase in temperature.

Conflicts of interest

Authors declare no conflict of interest.

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