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THE SOLUBILITY OF 1-NAPHTHOL IN WATER AT DIFFERENT TEMPERATURES

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ABSTRACT

The solubility of 1-naphthol in water has been determined in the temperature range 10.00–45.00°C. The heat of solution (-2.23×10^4 J mol^{-1}) and the entropy of solution (35.7 J mol^{-1} K^{-1}) have been calculated. The free energy of solution decreases steadily with increase of temperature. An equation is presented for the solubility of 1-naphthol in water in the range 10–45°C.

INTRODUCTION

There are no quantitative data in the literature on the solubility of 1-naphthol in water. The present paper reports the solubility of 1-naphthol in water at different temperatures and the characteristics of this process. This data was collected during research in this laboratory while studying the solubility of 1-naphthol in 1,1,3,3-tetramethylurea–water mixtures which will be reported in a later paper.

EXPERIMENTAL

Saturated solutions were prepared by stirring pure recrystallized 1-naphthol in 25.00 cm^3 volumetric flasks filled to the mark with distilled, deionised water. Stirring was carried out through the bottom of a glass aquarium by means of magnetic stirrers with stirring bars in the flasks. The aquarium was thermostated to within ±0.02°C by means of a Haake thermoregulator. Saturation was attained overnight. At all temperatures investigated, an excess of solid remained on the bottom of the vessel. The transparent

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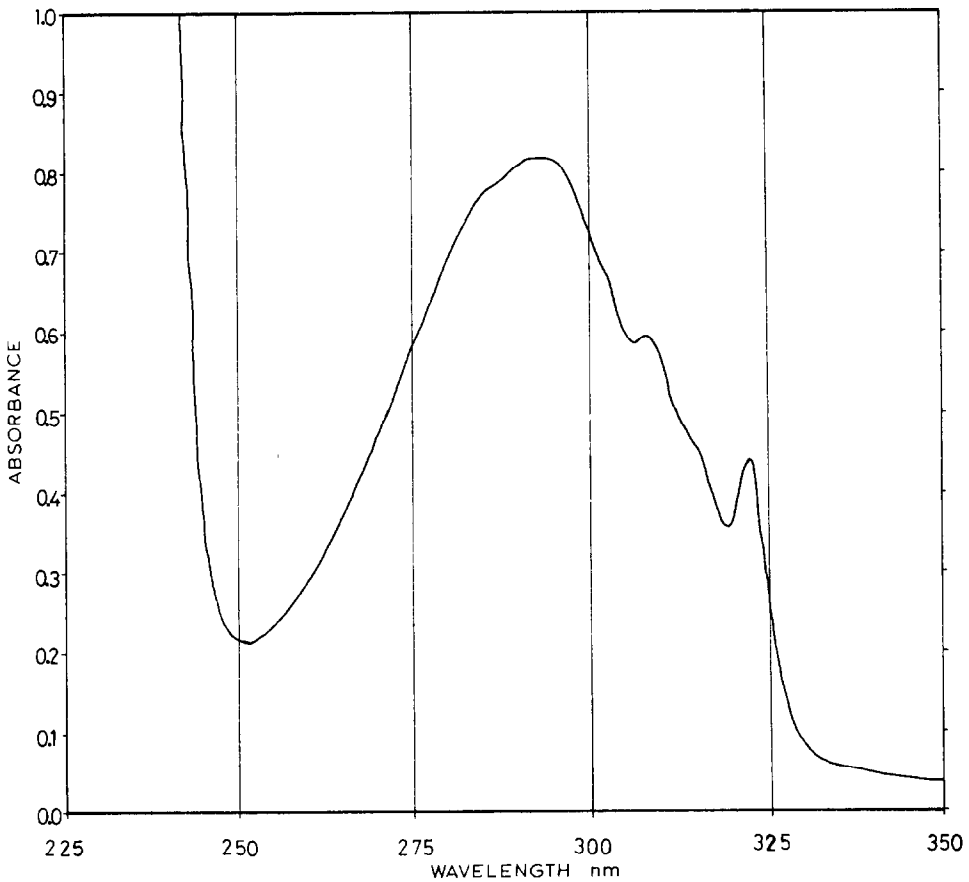

Fig. 1. Absorption spectra of aqueous 1-naphthol.

saturated solution was removed at the given temperature by using a 5.00 cm^3 pipette. The solution was transferred to a volumetric flask and diluted with distilled water by a factor of 10. The concentration of 1-naphthol was determined spectrophotometrically in the resulting solution in the UV region at $\lambda = 322$ nm. The absorption spectra was determined in a 1-cm fused quartz absorption cell at $\lambda = 322$ nm. A typical absorption spectra is given in Fig. 1. The UV was done using the Unicam SP 8000 and Zeiss. The content of 1-naphthol in the sample was found with the aid of a calibration graph and the concentration of the saturated solution was calculated taking into account the dilution. The solutions follow the Lambert–Beer law plot as shown by the linearity of the concentration vs. absorbance plot shown in Fig. 2.

We did not use other methods for the analysis of the saturated 1-naphthol solutions. The gravimetric method is inapplicable because of the appreciable volatility of the test substance; the titrimetric determination by reaction with alkali is impossible because of the low ionization constant of 1-naphthol.

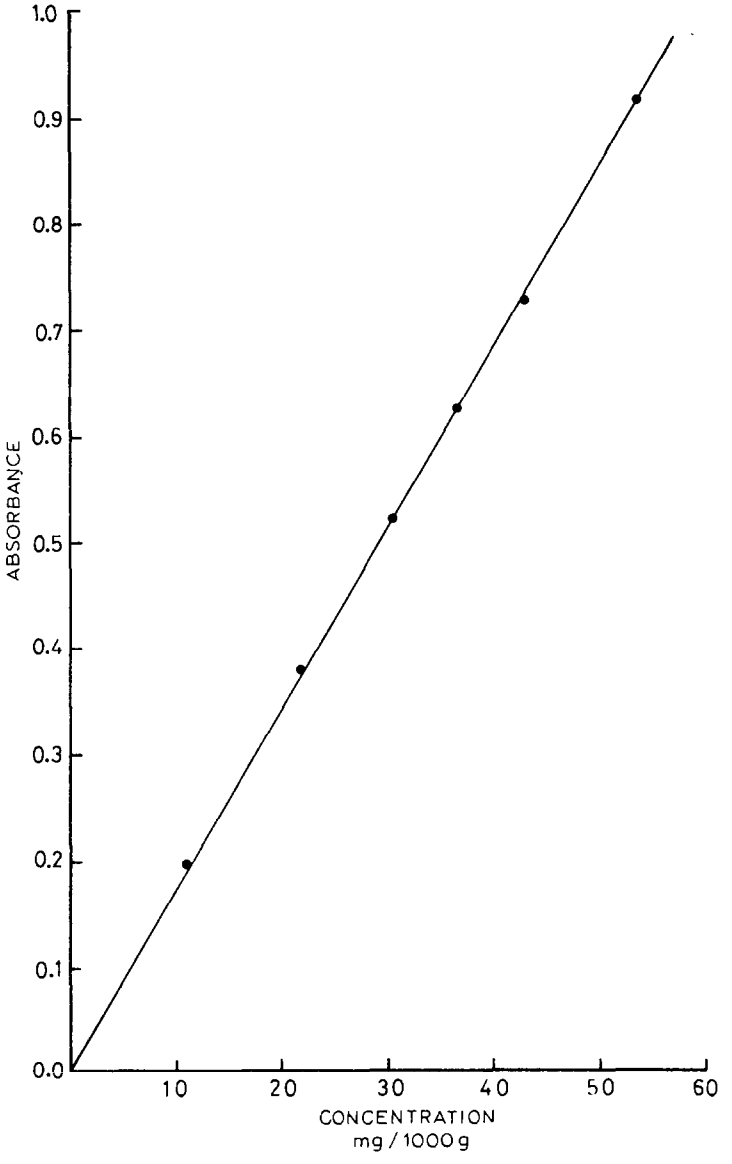

Fig. 2. Calibration plot for 1-naphthol on SP 8000 at 322 nm.

The determination of 1-naphthol concentration by a photoelectric colorimeter is tedious and subject to error.

RESULTS

At each temperature 4–5 concordant experiments were performed. The equilibrium solubility data are tabulated in Table 1 and are plotted in Fig. 3

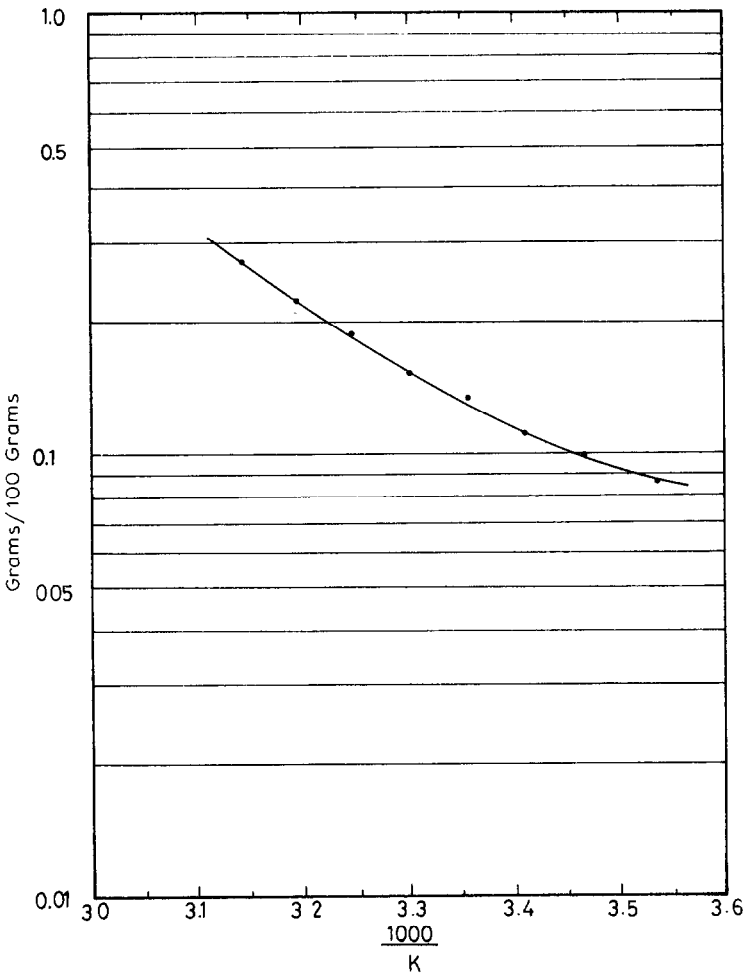

Fig. 3. Solubility of 1-naphthol in water.

TABLE 1

Solubility of 1-naphthol in water

Temp. (°C ± 0.02)	Conc. (g/100 g)	$10^4 \Delta G$ (J mol^{-1})	ΔS (J mol^{-1} K^{-1})
10.00	0.088	1.31	36.1
15.00	0.102	1.30	36.0
20.00	0.113	1.29	35.4
25.00	0.135	1.28	35.2
30.00	0.153	1.25	35.0
35.00	0.187	1.24	35.5
40.00	0.220	1.21	35.9
45.00	0.275	1.19	35.9

over the temperature range 10.00–45.00°C. The results were used to plot log L (g/100 g) against $10^3/T$. The experimental points fit quite satisfactorily on a straight line whose correlation coefficient is 1.03 and which has a slope of -1.16×10^3. Its equation is

$$\log L_{T_2} = \log L_{T_1} - 1.16 \times 10^3 \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

where L_{T_1} is the solubility at 10°C and L_{T_2} is the solubility at higher temperatures. The above equation gives the solubility of 1-naphthol in water at any temperature in the range 10–45°C.

Certain thermodynamic quantities for the solution process can be calculated from the experimental data. The heat of solution is -2.33×10^4 J mol^{-1} obtained from the slope of the above plot. The free energies (ΔG) and entropies (ΔS) were calculated by means of familiar equations (Table 1).

DISCUSSION

Thermodynamic theory of ideal solutions indicates that the slope of the log solubility vs. reciprocal temperature plot should be constant and equal to the heat of fusion of the solute. The solubility data, as shown in Fig. 3, give a smooth curve when plotted, and over short temperature ranges the curve approaches a straight line, but nowhere does the slope approach the heat of fusion of the solute. This is not unexpected, however, because both the solvent and solute are polar molecules and their interaction is expected to be nonideal.

As seen in Table 1, the free energy (ΔG) decreases steadily as the temperature rises, and the entropy (ΔS) remains virtually constant. The constancy of ΔS confirms the attainment of thermodynamic equilibrium in the saturated solution. The decrease in free energy with increasing temperature indicates that the dissolution is more favourable at higher temperatures.