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Note

The effect of a weak rotational magnetic field on oxygen solubility in water

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This work describes the applied rotational magnetic field effect on the equilibrium solubility of pure oxygen in water at 25 °C. It was found that the applied weak rotational magnetic field does not change the solubility of oxygen in water within experimental accuracy of about 1 % in spite of already reported data on the magnetic field effect on the solubility. This supports recent findings on the smallness of effects of weak magnetic fields on the physico-chemical properties of pure water and/or water solutions as well as on pure gases.

The solubility of atmospheric oxygen in water under the effect of a magnetic field was investigated by Klassen et al.[1]. However, in this work the kinetics of the oxygen dissolution was measured rather than equilibrium solubility shift due to a magnetic field. In his further papers Klassen claims[2, 3] several times that the magnetic field increases the solubility of gases in water. This was not verified experimentally. Also, several similar findings concerning the solubility of oxygen in water under the effect of a magnetic field remain on a qualitative level, see, for example, refs. 4 and 5, or they were disproved by experiments, as shown for example, by the results given by Minenko and Petrov[6] which were disproved by Rempel and Burakov[7]. This is analogous to the fate of numerous results relating to other physico-chemical properties of water and/or water solutions induced by some kind of magnetic field. The reported changes in pH, viscosity, absorption spectra, etc., were not reproduced in careful experimental studies, compare, for example, refs. 8–11, 14 and 15. There exists a number of reproducible experimentally found changes in some physico-chemical properties of water, water solutions or pure gases. Although these are too far from being theoretically well explained, some of them seem to be compatible with thermodynamic or quantum-mechanical analyses of the interaction between the substance studied and the corresponding magnetic field. So it is with the weak effect of high magnetic fields on viscosities and diffusivities in water solutions[10, 11], on the crystal growth or dissolution rates[12], on the chemical equilibrium, see, for example, ref. 13, etc.

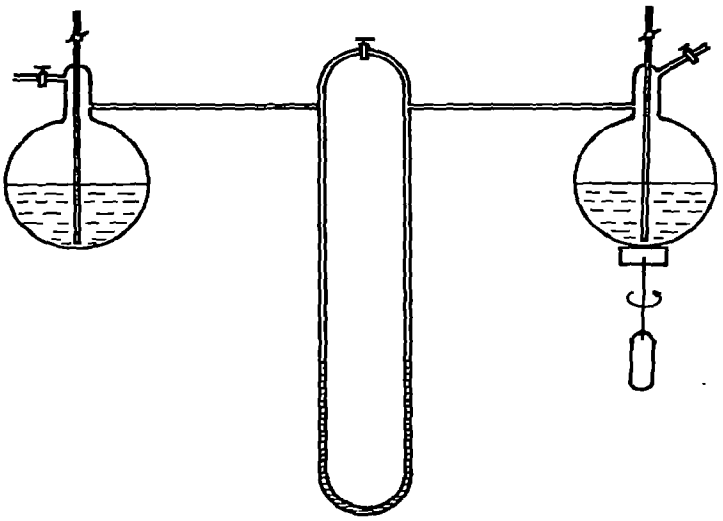

Fig. 1. Simple glass apparatus for testing the effect of a magnetic field on equilibrium solubility of gases in liquids. U-Tubing is filled with the same liquid as both the flasks.

The aim of this work was to find out experimentally whether the oxygen solubility in water at room temperature and atmospheric pressure can considerably be altered by a weak rotational magnetic field.

Distilled water taken from laboratory supply was used (conductivity $5 \times 10^{-6}\Omega^{-1}\text{cm}^{-1}$) for two kinds of experiments. First, the simple apparatus depicted in Fig. 1 was used. Each of two 600 ml flasks was filled with 250 ml water. The water was then repeatedly (six times) exposed to a vacuum for 9–10 min and then saturated by pure oxygen, again for 9–10 min. The apparatus was then closed; the water levels were equal in both arms of the glass U-tube connecting the flasks. A permanent magnet was placed below one of the flasks. The magnet was composed of two and/or eight ferrite slabs $30 \times 45 \times 5$ mm in size. Maximum intensity of the field at the slab surface was 550 Gauss, and 5 mm above the slab edge it was 230 Gauss. In a series of four experiments (with and without a glass-covered nail as a stirrer inside the flask) the magnet was rotated 14 days at 200–1000 rpm. No effect of the magnetic field on the oxygen solubility in either flask was found in this apparatus. The apparatus sensitivity was under 0.5% of the oxygen volume dissolved in equilibrium under the experimental conditions used. Simultaneously, another apparatus was used where 100 ml water was repeatedly deaerated in vacuo and saturated by pure oxygen. The apparatus was then closed and maintained at constant temperature (25°C) and pressure (about 760 torr). The apparatus allowed the monitoring of the volume of the oxygen–water system over a long period of time. Here again, no effect of the weak rotational magnetic field described above (both two-slab and eight-slab magnets were used, with and without stirrer) was observed during 30-day experiments.

DISCUSSION

Following Schieber's derivation[1,2] of the thermodynamic Clausius–Clapeyron

analogue, in our case for the influence of a magnetic field on the equilibrium oxygen solubility in water, the change in the magnetic induction ΔB between oxygen and its water solution is given by

$$\Delta B = 4\pi H(\chi_{ox} - \chi_{sl})$$

where χ_{ox}, χ_{sl} are volume susceptibilities of pure oxygen and its water solutions, respectively, and H is the field intensity in Oersteds. Defining the thermodynamic potential

$$\varphi(P, T, H) = U - TS + PV - BH/8\pi$$

where symbols have their usual meaning, see ref. 12, and using

$$dU = TdS - PdV - H\,dB/8\pi$$

it follows

$$d\varphi = -SdT + VdP - B\,dH/8\pi$$

so that in equilibrium, i.e. for $d\varphi = 0$, it holds

$$\left(\frac{\partial T}{\partial H}\right) = -\frac{\Delta B}{4\pi\Delta S}$$

Integrating the last equation between equilibrium temperatures without and with applied magnetic field, $T_{H=0}$ and $T_{H>0}$, respectively, and substituting for ΔB from the first equation, we obtain

$$\Delta T = T_{H>0} - T_{H=0} = -\frac{H^2}{4\Delta S}(\chi_{ox} - \chi_{sl})$$

Replacing ΔS by Q/T, where Q is the latent enthalpy of oxygen dissolution per unit volume and T is the equilibrium temperature at $H = 0$, the last relation will become

$$T = -H^2T(\chi_{ox} - \chi_{sl})/4Q$$

Assuming that Wiedemann's law is valid here, the volume magnetic susceptibility of solution χ_{sl} is taken as the weighted sum of the volume susceptibility of oxygen gas and that of pure water. Introducing the values of Q, χ_{ox} and χ_{H_2O} taken from a standard textbook[16] the last relation yields the results for ΔT at 25 °C, which are summarised in Table 1. The application of a field of 10^5 Gauss has the same effect as a temperature change of 0.12 °C. The shift in solubility is so small that it is below the detection limit of the experimental arrangement used. It is probable that the microstructural processes in the aqueous solution of oxygen are similar to those connected with observed changes in shear viscosity (the relative kinematic viscosity of pure water increases up to 0.25% in a field of 12000 Gauss[10]) and that the oxygen solubility is slightly altered. However, the quantitative determination of such subtle differences was not the aim of this work.

TABLE 1

CALCULATED VALUES OF THE MAGNETIC FIELD EFFECT ON THE SOLUBILITY OF OXYGEN IN WATER

H (*Oersted*)	ΔT (*K*)
10^3	-1.2×10^{-5}
2×10^3	-5×10^{-5}
10^4	-1.2×10^{-3}
2×10^4	-5×10^{-3}
10^5	-1.2×10^{-1}

$Q = 3300$ cal mole^{-1}
$= 5.35 \times 10^6$ erg cm^{-3}
$= 0.86 \times 10^{-6}$ cm g^{-1}.

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