

The Solubility of Strontium Carbonate in Water

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Values have been determined for the solubility of SrCO_3 in water, by use of both radiometric and flame emission spectrophotometric methods. The two methods gave essentially identical results. For water free from atmospheric CO_2 the solubilities/ mg l^{-1} were 5.34 ± 0.014 at 5°C , 6.94 ± 0.018 at 15°C , and 8.95 ± 0.029 at 25°C . For water in equilibrium with the atmosphere at 25°C the solubility was $42.7 \pm 0.048 \text{ mg l}^{-1}$. These results agree satisfactorily with calculated values based on a dissociation constant for SrCO_3 of $10^{-9.15}$ at 25°C , which can be derived from data on standard free energies of formation.

THERE are substantial differences in the values reported¹⁻⁶ for the solubility of strontium carbonate in water. Assessment of these differences is complicated by uncertainties, in some cases, as to the comparability of the data. Some variations may be due to differences in the partial pressure of carbon dioxide. Further, because of the association of carbonate and hydrogen ions, more strontium can enter aqueous solution than would be indicated by the dissociation constant for SrCO_3 . Interconversions between observed saturation concentrations and values expressed as 'solubility products' may thus introduce additional ambiguity, unless the procedures are rigorously defined. Kapustinsky and Dezideryeva,⁶ from conductimetric measurements on a system from which atmospheric carbon

dioxide was fully excluded, found a solubility of SrCO_3 of 7.68 mg l^{-1} at 25°C . This value is in reasonable agreement with that of 8.16 mg l^{-1} under the same conditions, obtained by Townley, Whitney, and Felsing⁴ from titrimetric measurements.

This communication gives the results of determinations of the solubility of SrCO_3 in water in equilibrium with atmospheric CO_2 and in water from which atmospheric CO_2 was excluded. The solubility was measured through labelling of the SrCO_3 with radioactive ^{85}Sr ($t_{1/2} = 65$ days). In view of the anomalous results obtained^{7,8} in some measurements of the solubilities of radioactively labelled compounds, an independent flame emission spectrophotometric method was also used.

¹ A. F. Holleman, *Z. phys. Chem. (Leipzig)*, 1893, **12**, 125.

² F. Kohlrausch and F. Rose, *Z. phys. Chem. (Leipzig)*, 1893, **12**, 234.

³ H. N. McCoy and H. J. Smith, *J. Amer. Chem. Soc.*, 1911, **33**, 468.

⁴ R. W. Townley, W. B. Whitney, and W. A. Felsing, *J. Amer. Chem. Soc.*, 1937, **59**, 631.

⁵ H. Wattenberg and E. Timmermann, *Kieler Meeresforsch.*, 1937, **2**, 81.

⁶ A. F. Kapustinsky and I. P. Dezideryeva, *Trans. Faraday Soc.*, 1946, **42**, 69.

EXPERIMENTAL

Strontium carbonate was prepared, from analytical grade reagents, by slow addition of the stoichiometric amount of $(\text{NH}_4)_2\text{CO}_3$ in dilute solution to a stirred, hot, dilute solution of SrCl_2 . For preparation of the labelled compound, sufficient $^{85}\text{SrCl}_2$ was added to give a specific activity of about 1 mCi g^{-1} of solid. The solid was thoroughly washed with water and dried at 250°C . Water was deionized by ion exchange, distilled from glass, and redistilled from quartz; CO_2 was removed, when necessary, by passage of high-purity nitrogen.

In each experiment SrCO_3 (ca. 0.1 g) was shaken with water (250 ml) in a flask immersed in a water-bath at constant temperature, which was reproducible to better than $\pm 0.1^\circ\text{C}$. In the experiments with exclusion of atmospheric CO_2 , water was transferred under nitrogen and the flask then sealed. In experiments at atmospheric partial pressure of CO_2 the solutions were aerated. Aliquot portions of solution were withdrawn through membrane filters ($0.45 \mu\text{m}$ average pore diameter) after ca. 24 h, preliminary work having shown that saturation was complete within 6 h.

γ -Rays emitted from the radioactively labelled solutions were measured with a scintillation detector and the count rates compared with those given by known amounts of the solid, dissolved and measured under identical conditions. Measurements on the unlabelled solutions were made by flame emission spectrophotometry, the method being calibrated by use of aliquot portions of a solution prepared from Specpure SrCO_3 . Replicate measurements were made in each experiment and with both methods the individual values lay within $\pm 1\%$ of the mean.

RESULTS AND DISCUSSION

The results are in the Table. Each value is the mean obtained from five independent equilibration experiments. The standard errors are shown. The results of the flame emission spectrophotometric and radiometric methods agreed well, showing that there was no anomalous effect due to radioactive labelling. Effects

⁷ V. I. Spitsyn, E. A. Torchenkova, and I. N. Glazkova, *Doklady Akad. Nauk S.S.S.R.*, 1960, **132**, 643.

⁸ V. I. Spitsyn, E. A. Torchenkova, and I. N. Glazkova, *Doklady Akad. Nauk S.S.S.R.*, 1960, **133**, 1111.

⁹ R. W. Ramette and O. Anderson, *J. Inorg. Nuclear Chem.*, 1963, **25**, 763.

¹⁰ C. H. Bovington, *J. Inorg. Nuclear Chem.*, 1965, **27**, 1975.

of this kind were reported for BaSO_4 by Spitsyn Torchenkova, and Glazkova^{7,8} but in later work^{9,10}

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Conditions	Solubility/mg l ⁻¹		
Water free from atmospheric CO_2	Radiometric determinations	Flame emission spectrophotometric determinations	Combined results
$t = 5^\circ\text{C}$	5.35 ± 0.022	5.34 ± 0.018	5.34 ± 0.014
$t = 15^\circ\text{C}$	6.94 ± 0.028	6.94 ± 0.027	6.94 ± 0.018
$t = 25^\circ\text{C}$	8.94 ± 0.056	8.96 ± 0.026	8.95 ± 0.029
Water in equilibrium with atmosphere			
$t = 25^\circ\text{C}$	42.7 ± 0.073	42.6 ± 0.066	42.7 ± 0.048

such anomalies have been found to be of little, if any, significance.

The mean solubility of $8.95 \pm 0.03 \text{ mg l}^{-1}$ at 25°C in water free from atmospheric CO_2 is significantly higher than the values of 7.68 and 8.16 mg l^{-1} obtained for the same conditions by Kapustinsky and Dezideryeva⁶ and Townley *et al.*,⁴ respectively. From the dissociation constant for SrCO_3 of $10^{-9.15}$, which can be calculated from data on standard free energies of formation,¹¹ and the first and second dissociation constants for H_2CO_3 ,^{12,13} the solubility of SrCO_3 at 25°C in the presence or absence of atmospheric CO_2 has been calculated in a way analogous to that described by Garrels and Christ¹⁴ for CaCO_3 . The calculated solubilities are 41.3 mg l^{-1} for water in equilibrium with the atmosphere and 9.27 mg l^{-1} for water free from atmospheric CO_2 . They agree satisfactorily with the experimental values obtained in this work.

This work was supported by the Natural Environment Research Council.

[2/608 Received, 15th March, 1972]

¹¹ F. D. Rossini, D. D. Wagman, W. H. Evans, S. Levine, and I. Jaffe, National Bureau of Standards Circular 500, U.S. Department of Commerce, Washington, D.C., 1952.

¹² H. S. Harned and F. T. Bonner, *J. Amer. Chem. Soc.*, 1945, **67**, 1026.

¹³ H. S. Harned and S. R. Scholes, *J. Amer. Chem. Soc.*, 1941, **63**, 1706.

¹⁴ R. M. Garrels and C. L. Christ, 'Solutions, Minerals, and Equilibria,' Harper and Row, New York, 1965, pp. 76-88.