

The Effect of Water Containing the Isotope of Hydrogen upon Fresh Water Organisms

H. S. Taylor, W. W. Swingle, H. Eyring, and A. H. Frost

Citation: *The Journal of Chemical Physics* **1**, 751 (1933); doi: 10.1063/1.1749241

View online: <http://dx.doi.org/10.1063/1.1749241>

View Table of Contents: <http://scitation.aip.org/content/aip/journal/jcp/1/10?ver=pdfcov>

Published by the [AIP Publishing](#)

Articles you may be interested in

[Isotope and temperature effects on the hyperfine interaction of atomic hydrogen in liquid water and in ice](#)
J. Chem. Phys. **102**, 5989 (1995); 10.1063/1.469333

[Hydrogen Isotope Disproportionation in Water and its Effect on IsotopeExchange Equilibrium Constants Measured in Aqueous Solution](#)
J. Chem. Phys. **49**, 1439 (1968); 10.1063/1.1670253

[Isotopic Effects in Liquid Hydrogen](#)
J. Chem. Phys. **43**, 1836 (1965); 10.1063/1.1697024

[Hydrogen Isotope Disproportionation Reaction for Water](#)
J. Chem. Phys. **41**, 2213 (1964); 10.1063/1.1726242

[Hydrogen Isotope Effects in Sonochemical Reactions in Water](#)
J. Chem. Phys. **40**, 608 (1964); 10.1063/1.1725173



the amount of water electrolyzed during this period of operation was about 30 times the amount the cells contained. It would appear from this calculation that these cells had been in operation for a long enough period of time to have nearly reached their equilibrium concentration, this equilibrium concentration being given by the relation deduced by Lewis and Macdonald² as $1/\alpha$ times the concentration of the water added to the cells, where α is the separation factor. This separation factor α must be a function of the temperature at which the electrolysis is taking place, as is shown by the following calculation.

If we assume Dalton's law of partial pressures to apply, the fractional part of a mole of water vapor removed per mole of water electrolyzed will be $3P_W/2(P_A - P_W)$, which quantity we shall call ϵ . Where P_W is the partial pressure of water vapor at the temperature T , and P_A is the atmospheric pressure. Thus the amount of water removed from the cell will be $1 + \epsilon$ moles per mole electrolyzed. If δ_1 and δ_2 represent the amounts of H^1 and H^2 evolved per mole of hydrogen produced, and C_1 and C_2 are the respective concentrations of the two kinds of hydrogen in the electrolyte expressed as mole fractions, then $\delta_2 C_1 / \delta_1 C_2 = \sigma$ is the true electrolytic separation factor. The hydrogen lost by vaporization of the water will be ϵ moles per mole electrolyzed. Thus the α of the Lewis and Macdonald² equation obviously becomes,

$$\alpha = (\delta_2 + \epsilon C_2) C_1 / (\delta_1 + \epsilon C_1) C_2.$$

Assuming Bleakney and Gould's¹ value (1 part in 5000) for the abundance of deuterium in ordinary water, and using Lewis and Macdonald's³ value for the density of pure deuterium oxide, the value of σ can be calculated if we further assumed that the electrolytic hydrogen analyzed by Bleakney and Gould¹ came from a typical

old cell of the type which was referred to above. This calculation gives a value of 0.12 for σ which would agree fairly well with the provisional value of 0.10 given by Urey.⁴ By taking this value (0.12) for σ and calculating α for this cell, ($T = 160^\circ\text{F}$) the value of α obtained is 0.37. The experimental value of α for such a cell will be considerably higher than this calculated value, due to the fact that evaporation from the surface of the electrolyte, which will be considerable at this temperature, has not been taken into account in the calculation. Calculating for Lewis and Macdonald's² cells ($T = 35^\circ\text{C}$) the value of α obtained is 0.16 which is in fair agreement with the experimental value of 0.20 when it is considered that the mechanical loss of water during the electrolysis is neglected, which loss would tend to increase the calculated value of α .

From the above considerations it would appear that commercial cells which are run hot in order to attain high power efficiency must necessarily have a low equilibrium concentration of deuterium, and also that the hydrogen produced by such cells will have a correspondingly low concentration of the heavier isotope.

The author is indebted to Dr. J. G. Aston of the Chemistry Department for the use of the thermostat and conductivity still which made the determinations of specific gravity possible.

D. H. RANK

Physics Laboratory,
Pennsylvania State College,
August 29, 1933.

³ G. N. Lewis and R. T. Macdonald, *J. Am. Chem. Soc.* **55**, 3057 (1933).

⁴ H. C. Urey, *Rev. Sci. Inst.* **4**, 425 (1933).

The Effect of Water Containing the Isotope of Hydrogen upon Fresh Water Organisms

Since the announcement by Washburn and Urey¹ that in electrolysis the residual water is enriched in heavy hydrogen, there has been a greatly increased interest in the separation and properties of isotopes. That the chemical reactivity of two isotopes with such different atomic weights would differ very considerably was of course clear, and the opinion that heavy water would have striking biological effects was generally held.

Lewis² has recently demonstrated that the seeds of tobacco will not germinate in pure $\text{H}^2\text{H}^2\text{O}$ whereas seeds in ordinary distilled water sprouted within two days. We have recently performed a series of experiments to test the action of heavy water upon the vital activities of fresh water organisms. Our results are briefly summarized as follows:

(1) Water containing the isotope of hydrogen in high concentration (92 percent) was found to be toxic for the animals tested.

(a) Tadpoles of the green frog *Rana clamitans* died within an hour after being placed in the water. Control animals in 30 percent heavy water, and in ordinary distilled water, remained unaffected at the end of twenty-four hours.

(b) The common aquarium fish *Lebistes reticulatus* is

killed by the water within an interval of two hours. Neither 30 percent heavy water, or distilled water exerted an effect over a twenty-four hour interval.

(c) Flatworms, *planaria maculata* are destroyed within three hours in the 92 percent heavy water, but were uninjured by the 30 percent heavy water over a period of three days.

(d) The protozoan, *paramoecium caudatum* is killed by the 92 percent heavy water within 48 hours. Water containing 15–20 percent of the heavy isotope of hydrogen did not affect the organisms during a three day interval. *Paramoecium* showed more resistance to the toxic action of the water than the highly organized animals studied.

H. S. TAYLOR
W. W. SWINGLE
H. EYRING
A. H. FROST

Chemical and Biological Laboratories,
Princeton University,
September 15, 1933.

¹ Washburn and Urey, *Proc. Nat. Acad. Sci.* **18**, 496 (1932).

² G. N. Lewis, *J. Am. Chem. Soc.* **55**, 3503 (1933).