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Boiling temperature and the enthalpy of water vaporization exposed to high frequency electromagnetic field

The article is dedicated to the study of the influence of a high-frequency electromagnetic field on the boiling temperature and the enthalpy of water vaporization. It has been established that as a result of exposure to deionized water of the electromagnetic field of ultrahigh frequencies, its boiling point and evaporation enthalpy increase. It has been shown that the effectiveness of electromagnetic exposure depends on the frequency of the field and the exposure time. The maximum increase in the enthalpy of evaporation is observed as a result of exposure to a field with a frequency of 60, 130 and 170 MHz and is 5–10 %. The observed phenomena can be caused by a change in the structural organization of water as a result of electromagnetic interference, effect has a cumulative nature — the value of ΔH_{ev} increases with an increase in the exposure time to 2 hours; the effect of «saturation» is established — an increase in the exposure time over 2 hours does not lead to a further increase in enthalpy. The effect of the electromagnetic field is selective — the properties of water are sensitive to the action of a field of strictly defined frequencies.

Keywords: water, electromagnetic field, frequency, irradiation time, boiling point, evaporation enthalpy.

Introduction

Interest in the study of water and its unique properties has not waned for many decades [1–3]. Numerous studies are focused on changing the properties of water and aqueous solutions under the influence of magnetic and electromagnetic fields [4]. Experimental material accumulates, numerous theories are created to explain the changes in the properties of water and aqueous solutions under the influence of field effects, but there is currently no generally accepted theory about the nature of changes occurring in water as a result of external influences. Numerous experiments on the effects of the electromagnetic field (EMF) of ultrahigh frequencies (30–300 MHz) indicate the sensitivity of the properties of the aquatic environment to this type of exposure [5–8]. Based on the experimental data, it can be assumed that under the influence of the field, the cohesive interaction within the aqueous phase is enhanced, which is manifested in an increase in its surface tension, weakening of the hydration characteristics [6], etc. The enhancement of the intermolecular interaction in the aquatic environment can be fixed by measuring the properties that depend on it. Accurate information on cohesion can be obtained from thermodynamic characteristics related to the energy of vaporization. In the process of evaporation of a substance, a complete rupture of intermolecular bonds occurs; therefore, the work of cohesion is determined by the enthalpy of vaporization (evaporation). The determination of the enthalpy of evaporation of water and its changes as a result of exposure to an electromagnetic field with a variable frequency was the purpose of this study.

Method

Deionized water purified with the deionizer of water WD-301, with an initial specific electric conductivity of $1.4–1.8 \cdot 10^{-4}$ S/m was used in this study.

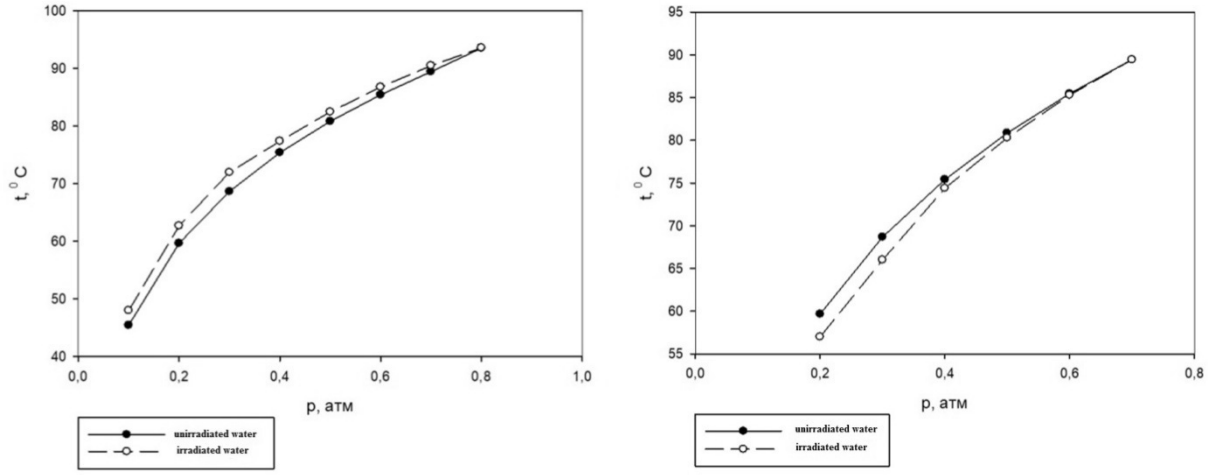
The source of the electromagnetic field was a high-frequency generator G4–119A, which output power was 1 W and its frequency range was 30–200 MHz. The voltage at the high-frequency electrodes was 20–22 V. The cell consisted of a 50 ml teflon beaker, in the center of which an internal high-frequency electrode was located. The high-frequency electrode was a brass rod isolated with teflon. The outer high-frequency electrode was an aluminum cup, closely fitting to the teflon surface. The electrodes through the bottom of the cup were connected to the generator by means of an high-frequency cable. The field frequency was varied in 10 MHz steps. The time of exposure of the field to water ranged from 1 to 3 hours. It was found that the maximum effect was achieved within 2 hours, but the main changes were observed at an exposure time of 1 hour. In the future, precisely this time was chosen for the experiment.

The determination of T_{boil} and the enthalpies of evaporation were carried out using a standard setup [9]. In a round bottom flask, equipped with a reflux condenser and a thermometer (division price 0.1 ºC), 50 ml

of a predetermined frequency of irradiated field or unirradiated water was poured. In the flask, a vacuum was created using a vacuum pump (minimum pressure 0.1 atm), which was monitored with a pressure gauge (graduation value 0.05 atm). The water was kept at a minimum pressure for 1 hour to remove dissolved gases. Then water was heated to boiling at a given vacuum and the temperature was fixed. The pressure was gradually increased up to atmospheric, determining the boiling point at each pressure value with a step of 0.10 atm. Experimental data on the batch of water at different pressures were compared with the table values [10]. A satisfactory agreement of the results was obtained (the discrepancies did not exceed ± 0.2 ºC). The enthalpy of vaporization ΔH_{ev} was determined from the slope of the line in the coordinates $\ln P - 1000/T$ according to the linear form of the Clausius-Clapeyron equation: $\ln P = \text{const} - 1000\Delta H_{ev}/RT$.

Results and Discussion

Studies have shown that as a result of exposure to electromagnetic fields at certain frequencies (60, 130 and 170 MHz), an increase in the boiling point of water is observed. The use of other EMF frequencies either did not change the batch of water, or the changes were expressed slightly. Figure 1 shows the dependences of T_{boil} on the pressure P for non-irradiated and irradiated EMF frequencies of 170 and 80 MHz of water. In the first case (Fig. 1*a*), in the region of low values of atmospheric pressure, the batch of irradiated water exceeds a similar value for unirradiated water at $P < 0.60–0.75$ atm. A similar pattern is observed for frequencies 60 and 130 MHz. Figure 1*b* shows that the effect of an EMF of 80 MHz slightly changes the boiling point of water only at $P < 0.35$ atm.



a) f = 170 MHz *b) f* = 80 MHz

Figure 1. Dependence of the boiling point of water exposed to an electromagnetic field of a given frequency *f*, from atmospheric pressure (T = 23 ºC; t_{exp}= 1 hour)

Table 1 shows the T_{boil} values of unirradiated and irradiated EMF of various frequencies of water at $P = 0.20$ atm (average values from 5 parallel experiments).

Table 1

The boiling point T_{boil} of water at $P = 0.20$ atm, depending on the frequency of the electromagnetic field (exposure time 1 hour)

Frequency *f*, MHz	T_{boil}, ºC	ΔT, ºC	Frequency *f*, MHz	T_{boil}, ºC	ΔT, ºC
0	59.8±0.2	–	120	61.0±0.4	1.2
30	59.8±0.2	–	130	61.6±0.3	1.8
40	60.2±0.3	0.4	140	59.6±0.2	0.2
50	59.6±0.3	0.2	150	60.2±0.3	0.4
60	61.0±0.4	1.2	160	59.8±0.1	–
70	59.8±0.1	–	170	61.7±0.3	1.9
80	60.1±0.2	0.3	180	59.4±0.2	0.4
90	59.7±0.1	0.1	190	59.6±0.3	0.2
100	59.9±0.3	0.1	200	59.6±0.2	0.2

From the experimental dependence of $T_{boil} - P$ (in the range of 0.10–0.70 atm, where the differences in boiling points are quite well expressed), the enthalpies of evaporation of water exposed to EMF of different frequencies were calculated using the Clapeyron-Clausius equation. The correlation coefficient of the linear approximation of the experimental data was 0.997–0.999. Table 2 shows the values of ΔH_{ev} at those EMF frequencies at which its significant change is observed — by 5–10 %. The impact of the field of other frequencies in the studied range did not lead to a noticeable change in ΔH.

Table 2

The enthalpy of evaporation of water exposed to an electromagnetic field (exposure time 1 hour)

Frequency f, MHz	ΔH_{ev}, kJ/mol	Δ, %
0	45.3±0.5	–
30	47.6±0.6	5.1
60	48.2±0.9	6.4
130	49.9±0.9	10
170	48.1±0.8	6.5

The determination of the enthalpy of evaporation was carried out immediately after the electromagnetic treatment of water, then after 1, 2 and 7 days. The results are presented in Table 3 for 2 frequencies of EMF (60 MHz and 170 MHz). It can be stated that with time there is a tendency to a slight increase in ΔH_{ev}. The effect of relaxation is absent, i.e. the original properties of water during the week are not restored.

Table 3

The enthalpy of evaporation of water depending on the time elapsed after exposure to an electromagnetic field

Time after exposure to electromagnetic field, day	ΔH_{ev}, kJ / mol (f = 60 MHz)	ΔH_{ev}, kJ / mol (f = 170 MHz)
0	48.2±0.9	48.1±0.8
1	48.3±0.8	48.3±0.9
2	49.0±0.8	47.8±0.9
7	48.7±0.7	49.0±0.6

Conclusions

Thus, as in all previous studies [5–8], it was shown that the effect of EMF is selective — the properties of water are sensitive to the action of a field of strictly defined frequencies. It was also established that the EM effect has a cumulative nature — the value of ΔH_{ev} increases with an increase in the exposure time to 2 hours; the effect of «saturation» is established — an increase in the exposure time over 2 hours does not lead to a further increase in enthalpy. The enhancement of the cohesive interaction in the aqueous phase as a result of exposure to EMF can be due to several reasons: hardening of the hydrogen bonds between water molecules, an increase in the proportion of water bound into clusters, or an enhancement of the van der Waals interaction. The question remains controversial, since the enthalpies of evaporation characterize the intensity of intermolecular interaction, but do not reveal its nature. Nevertheless, the obtained data are consistent with the results of [6] on the increase as a result of the electromagnetic effect of the surface tension of water by 5–10 %, which is also determined by the intensity of the intermolecular interaction.

References

1 Chaplin M.F. A proposal for the structuring of water / M.F. Chaplin // Biophys. Chem. — 2000. — Vol. 83, No. 3. — P. 211–221.

2 Le Bihan D. Water: The Forgotten Biological Molecule / D. Le Bihan, H. Fukuyama. — Singapore: Pan Stanford Publishing Pte. Ltd., 2010. — 399 p.

3 Dack M.R.J. Solvent structure. II. A study of the structure-making and structure-breaking effects of dissolved species in water by internal pressure measurements / M.R.J. Dack // Aust. J. Chem. — 1976. — Vol. 29, No. 4. — P. 771–778.

4 Стехин А.А. Структурированная вода: Нелинейные эффекты / А.А. Стехин, Г.В. Яковлева. — М.: Изд-во ЛКИ, 2008. — 320 с.

5 Стась И.Е. Физико-химические закономерности эволюции коллоидных наносистем в жидкой дисперсионной среде под влиянием электромагнитных полей / И.Е. Стась, Л.Ю. Репейкова. — Барнаул: Изд-во Алт. ун-та, 2013. — 100 с.

6 Стась И.Е. Физико-химические процессы в электромагнитном поле ультравысоких частот / И.Е. Стась, В.Ю. Чиркова, И.А. Штоббе. — Барнаул: Изд-во Алт. ун-та, 2015. — 101 с.

7 Стась И.Е. Влияние электромагнитного поля высокой частоты на критическую концентрацию мицеллообразования водного раствора додецилсульфата натрия / И.Е. Стась, О.П. Михайлова // Журнал физической химии. — 2009. — Т. 83, № 2. — С. 324–325.

8 Стась И.Е. Влияние высокочастотного электромагнитного поля на адсорбционную способность ионогенных ПАВ / И.Е. Стась, Б.П. Шипунов, О.П. Михайлова // Журнал физической химии. — 2010. — Т. 84, № 12. — С. 2128–2132.

9 Практикум по физической и коллоидной химии / под ред. К.М. Евстратовой. — М.: Высш. шк., 1990. — С. 120–124.

10 Краткий справочник физико-химических величин / под ред. К.П. Мищенко, А.А. Равделя. — Л.: Химия, 1974. — 200 с.

В.Ю. Чиркова, Е.А. Шарлаева, И.Е. Стась

Жоғары жиіліктегі электрмагнитті өріс әрекетіне ұшыраған судың қайнау температурасы және булану энтальпиясы

Мақала судың қайнау температурасы мен булану энтальпиясына жоғары жиіліктегі электрмагнитті өрістің әсерін зерттеуге арналған. Деиондалған суға өте жоғары жиіліктегі электрмагнитті өріс әрекет еткенде оның қайнау температурасы мен булану энтальпиясы артатыны анықталған. Электрмагнитті әрекеттің тиімділігі өріс жиілігіне және экспозиция уақытына тәуелді болатыны көрсетілген. Булану энтальпиясының максималды жоғарылау жиілігі 60, 130 және 170 МГц өрістің әрекетінен байқалады және 5–10 % құрайды. Байқалған құбылыстар электрмагнитті әрекет нәтижесінде судың құрылымдық ұйымдасу өзгеруімен түсіндірілуі мүмкін және электрмагнитті әрекет жинақталатын сипатқа ие екені — булану энтальпиясы мөлшері сәулелендіру уақыты 2 сағатқа дейін артқанда жоғарылайтыны — анықталған; «қануғы» эффектісі — экспозиция уақыты 2 сағаттан артық болғанда энтальпия әрі қарай өспейтіні анықталған. Электрмагнитті өрістің әрекеті таңдаулы сипатқа ие болатыны көрсетілген — судың қасиеттері қатаң белгілі жиіліктегі өрістің әрекетіне сезімтал болады.

Кілт сөздер: су, электрмагнитті өріс, жиілік, сәулелендіру уақыты, қайнау температурасы, булану энтальпиясы.

В.Ю. Чиркова, Е.А. Шарлаева, И.Е. Стась

Температура кипения и энтальпия испарения воды, подвергшейся воздействию высокочастотного электромагнитного поля

Статья посвящена изучению влияния высокочастотного электромагнитного поля на температуру кипения и энтальпию испарения воды. Установлено, что в результате воздействия на деионизованную воду электромагнитного поля ультравысоких частот происходит повышение температуры ее кипения и энтальпии испарения. Показано, что эффективность электромагнитного воздействия зависит от частоты поля и времени экспозиции. Максимальное увеличение энтальпии испарения наблюдается в результате воздействия поля частотой 60, 130 и 170 МГц и составляет 5–10 %. Наблюдаемые явления могут быть обусловлены изменением структурной организации воды в результате электромагнитного воздействия. Также установлено, что электромагнитное воздействие имеет накопительный характер — величина энтальпии испарения возрастает при увеличении времени облучения до 2 часов; установлен эффект «насыщения» — увеличение времени экспозиции свыше 2-х часов не приводит к дальнейшему росту энтальпии. Показано, что воздействие электромагнитного поля носит избирательный характер — свойства воды чувствительны к действию поля строго определенных частот.

Ключевые слова: вода, электромагнитное поле, частота, время облучения, температура кипения, энтальпия испарения.

References

1 Chaplin, M.F. (2000). A proposal for the structuring of water. *Biophys. Chem., 83(3)*, 211–221.

2 Le Bihan, D., Fukuyama, H. (2010). *Water: The Forgotten Biological Molecule.* Singapore: Pan Stanford Publishing Pte. Ltd.

3 Dack, M.R.J. (1976). Solvent structure. II. A study of the structure-making and structure-breaking effects of dissolved species in water by internal pressure measurements. *Aust. J. Chem., 29(4)*, 771–778.

4 Stekhin, A.A., Yakovleva, G.V. (2008). *Strukturirovannaia voda: Nelineinye effekty. [Structured Water: Nonlinear Effects]*. Moscow: Izd-vo LKI [in Russian].

5 Stas, I.E., Repeikova, L.Yu. (2013). *Fiziko-khimicheskie zakonomernosti evoliutsii kolloidnykh nanosistem v zhidkoi dispersionnoi srede pod vliianiem elektromahnitnykh polei [Physico-chemical laws of the evolution of colloidal nanosystems in a liquid dispersion medium under the influence of electromagnetic fields]*. Barnaul: Izd-vo ASU [in Russian].

6 Stas, I.E., Chirkova, V.Yu., Shtobbe, I.A. (2015). *Fiziko-khimicheskie protsessy v elektromahnitnom pole ultravysokikh chastot [Physico-chemical processes in the electromagnetic field of ultra-high frequencies]*. Barnaul: Izd-vo ASU [in Russian].

7 Stas, I.E., Mihailova, O.P. (2009). Vliianie elektromahnitnoho polia vysokoi chastoty na kriticheskuiu kontsentratsiiu mitselloobrazovaniia vodnoho rastvora dodetsilsulfata natriia [Effect of high frequency electromagnetic field on the critical micelle concentration of an aqueous solution of sodium dodecyl sulfate]. *Zhurnal fizicheskoi khimii — Russian Journal of Phys. Chem., 83, 2,* 324–325 [in Russian].

8 Stas, I.E., Shipunov, B.P., Mihailova, O.P. (2010). Vliianie vysokochastotnoho ehlektromahnitnoho polia na adsorbtsionnuiu sposobnost ionohennykh PAV [Effect of high-frequency electromagnetic field on the adsorption capacity of ionic surfactants]. *Zhurnal fizicheskoi khimii — Russian Journal of Phys. Chem, 84, 12,* 2128–2132 [in Russian].

9 Evstratova, K.M. (Eds.). (1990). *Praktikum po fizicheskoi i kolloidnoi khimii [Workshop on physical and colloid chemistry]*. Moscow: Vysshaia shkola [in Russian].

10 Mishchenko, K.P., Ravdel, A.A. (Eds.). (1974). Kratkii spravochnik fiziko-khimicheskikh velichin [Quick reference of physico-chemical values]. Leningrad: Khimiia [in Russian].