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Research Article

Calorimetric and Radiation Diagnostics of Water Solutions Under Intense Light Irradiation

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Abstract

A series of experiments with light irradiation of saltwater solutions and alkalis in special vessels was performed. The sources of irradiation were: a Light Emitting Diode (LED) lamp, a matrix of LEDs, and a laser. All of them were in the red wavelength. Possible calorimetric diagnostics and nuclear radiation (gamma rays, X-rays, and neutrons) were monitored. Liquid scintillation diagnostics of tritium were used. Gamma-ray radiation detection with an NaI scintillation detector, and X-ray radiation detection with Geiger counters was performed. No such radiation was observed. Excess heat was not detected in any experiment. Neutrons were measured with help of ^{3}He counters placed in a paraffin barrel. Small neutron emissions (up to 100 neutrons) was observed in the form of a series of short bursts (lasting a few milliseconds) during some minutes at the background level. The generation of tritium after LED lamp and matrix of LEDs irradiation of water solutions LiOH and Na_2CO_3has been demonstrated in some experiments.
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Keywords: Calorimetry, Erzion model, Gamma-ray, Neutrons, Red light irradiation, Tritium, Water solutions, X-ray

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1. Introduction

This work is an extension of the research [1–4] on the nuclear effects during irradiation of various water solutions. However in these previous tests, a careful diagnosis of the products after light exposure of electrolytes was not carried out. In our present experiments, we performed not only continuous monitoring of possible nuclear emanations (neutrons, gamma rays, and X-rays), but also the calorimetric diagnostics and scintillation diagnosis of tritium after LED and laser irradiation of water solutions of salts and alkalis.

We used the predictions of the Erzion model [5] to define what chemical elements in water solutions can produce nuclear radiation. We reviewed all reactions of Erzion-nuclear exchange for isotopes of light chemical elements from $H^1$to O^{18} and selected those predicted to produce neutrons (1–3) and tritium (8) (with the percentage composition of the parent nucleus in the natural isotope mixture):

$$H^1(E^-, E^0)\ \mathbf{n} + 1{,}65\ \text{MeV} \qquad (100\ \%) \qquad (1)$$

$$H^2(E^-, E_N)\ \mathbf{n} + 5{,}6\ \text{MeV} \qquad (0.016\ \%) \qquad (2)$$

$$Li^6\ (E^-, E_N)\ He^5 + 3{,}2\ \text{MeV} \qquad (7.5\ \%)$$
$$He^5 \rightarrow He^4 + \mathbf{n} + 1{,}36\ \text{MeV} \qquad (3)$$

The reactions (1)–(3) runs with the the negatively charged Erzions E^-, which could generate in the reactions:

$$Li^7\ (E_N, E^-)\ Be^8 + 9{,}5\ \text{MeV} \qquad (92.5\ \%) \qquad (4)$$
$$Be^8 \rightarrow 2\ He^4 + 4{,}8\ \text{MeV}$$

$$C^{14}(E_N, E^-)\ N^{15} + 2{,}4\ \text{MeV} \qquad (-) \qquad (5)$$

$$O^{18}\ (E_N, E^-)\ F^{19} + 0{,}2\ \text{MeV} \qquad (0{,}2\ \%) \qquad (6)$$

$$N^{15}\ (E_N, E^-)\ O^{16} + 4{,}3\ \text{MeV} \qquad (0{,}37\ \%) \qquad (7)$$

To return the Enions E_N into reactions (5)–(8) the closed chains $E_N \leftrightarrow E^0$ can runs on the isotopes H^2, C^{13} and O^{17} in the next reaction pairs:

On the basis of these predictions we decided to use an alkaline solution of lithium (LiOH) with the addition of heavy water (D_2O) to increase the length of the Erzion-nuclear reaction chains. From the Erzion model, deuterium is the best of the nuclei converters ($E_0 \rightarrow E_N$) with maximum cross-section reaction of the Erzion-nuclear exchange [6].

We decided also to perform experiments with solutions of Na (NaOH and Na_2CO_3), which monoisotope Na^{23} effectively turns E_N in the negatively charged E^- like nuclei Li^7 (4).

$$H^2(E_{N,}E^0)\mathbf{H}^3 + 0.1\ \text{MeV} \quad (0.016\ \%) \quad (8)$$

$$H^2(E^0, E_N)H^1 + 3.9\ \text{MeV} \quad (0.016\ \%) \quad (9)$$

$$C^{13}(E_{N,}E^0)C^{14} + 2.0\ \text{MeV} \quad (1.1\ \%) \quad (10)$$

$$C^{13}(E^0, E_N)\ C^{12} + 1.2\ \text{MeV} \quad (1.1\ \%) \quad (11)$$

$$O^{17}(E_{N,}E^0)\ O^{18} + 1.9\ \text{MeV} \quad (0.038\%) \quad (12)$$

$$O^{17}\ (E^0, E_N)\ O^{16} + 2.0\ \text{MeV} \quad (0.038\%) \quad (13)$$

2. Experimental Configuration

A series of experiments were conducted with red LED lamp, matrix of LEDs, and laser irradiation of various water solutions including LiOH, NaOH and Na_2CO_3, with various additives of D_2O. To do this we created a special setup with options for working cells made from plastic, porcelain, or a Dewar vessel, along with the devices for detecting neutrons, gamma rays and X-rays. A schematic of these configurations is shown in Fig. 1.

The main features of the experiments are shown in Table 1.

An alkaline solution of LiOH with molarity 2.5 M and (5–20) M NaOH, and a solution of salt 2 M Na_2CO_3 were used as the working liquids. The solvent was water from various sources – city water (Exp. Nos. 1–13); water treated with a carbon filter (Exp. Nos. 14,15); and snow melt water (Exp. Nos. 16,17). It was predicted from the Erzion model that the water from open-air sources may be saturated with the Erzions from cosmic rays. In aqueous solutions the heavy water D_2O was added to intensify the possible nuclear reactions.

Table 1. The main features of the experiments.

Exp. no.	Solution type	Solution Volume (l)	Additive D_2O	Source of light	Exposure time (min)	Solution temp. rise (°C)	Emitted energy (J)
1	2.5 M LiOH	1.0	–	Lamp	7	1.0	714
2	2.5 M LiOH	1.0	–	Lamp	9	1.0	918
3	2.5 M LiOH	0.5	10%	Laser	61	1.0	18
4	2.5 M LiOH	0.5	10%	Lamp	60	1.0	6120
5	2.5 M LiOH	0.5	–	URC-LED	72	1.0	8640
6	2.5 M LiOH	0.5	–	LED-4	87	1.0	10 440
7	2.5 M LiOH	0.5	–	LED-15	50	1.0	9000
8	2.5 M LiOH	0.5	–	LED-20	70	2.0	14 400
9	2.5 M LiOH	0.5	5%	LED-20	60	2.5	15 120
10	10 M NaOH	0.5	5%	LED-20	63	1.5	14 400
11	5 M NaOH	0.5	6%	LED-20	60	2.5	14 400
12	20 M NaOH	0.5	10%	LED-20	57	1.0	13 680
13	2 M Na_2CO_3	0.5	2%	LED-16	60	1.0	11 520
14	H_2O	0.5	50%	LED-9	60	1.5	6480
15	2 M Na_2CO_3	5.0	4.5%	LED-9	71	1.0	7668
16	2 M Na_2CO_3	10.0	1.1%	LED-9	80	1.0	8640
17	2 M Na_2CO_3	0.8	1.1%	LED-9	62	1.0	6696

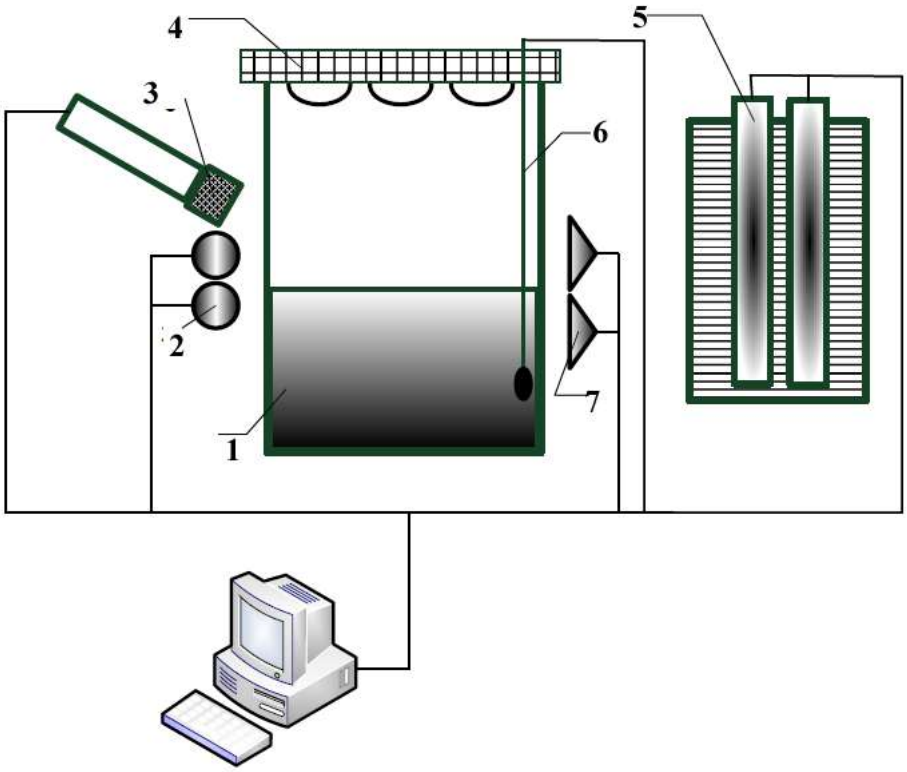

Figure 1. Schematic of the experimental configuration.1–working cell with water solution; 2–Geiger counters type CBM-20; 3–NaI scintillation detector; 4– plate with the sources of red light; 5–He^3 gas neutron counters (Ø3.5 × 35 cm^2) placed in paraffin cylinder (Ø22 × 40 cm^2) or in vessel with water; 6–thermocouple; 7–Geiger counters type CHM-18 with thin window.

The working cells with liquids were placed in the center of a paraffin cylinder with two He^3-counters. These cells were made from plastic vessel (V=1l; Exp. Nos. 1, 2), a porcelain cup (V=0.9l; Exp. Nos. 3–13), or a glass Dewar vessel (V=1l; Exp. Nos. 14, 15, 17). In Experiment No. 16 the working cell was the metal Dewar (V=17.5l) and in this case two He^3-counters were placed in the vessel with water. The efficiency of neutron detectors measured with Cf^{252} – neutron source was 9±0.5%.

The sources of red light were the red LED lamp (with wave length λ=625 ± 25 nm and light power W=1.7 W), the red laser pointer (λ=650 ± 5 nm; W=0.005 W), a matrix of 19 URC-LEDs (λ=665 ± 5 nm; W=0.4 W) and one of the five matrix of LEDs (λ=665 ± 5 nm; W=0.8 – 4.0 W with 4–20 LEDs).

All readings of radiation detectors and thermocouples were recorded continuously with the PC. Tritium registration was conducted with the standard scintillator diagnosis of the 5–10 ml volume solution samples taken before and after each experiment.

The last column in Table 1 is the calculated value of the absorbed (equal to emitted) energy, determined from the source light power, solution volume and exposure time.

A general view of some experimental configurations is shown in Figs. 2 and 3.

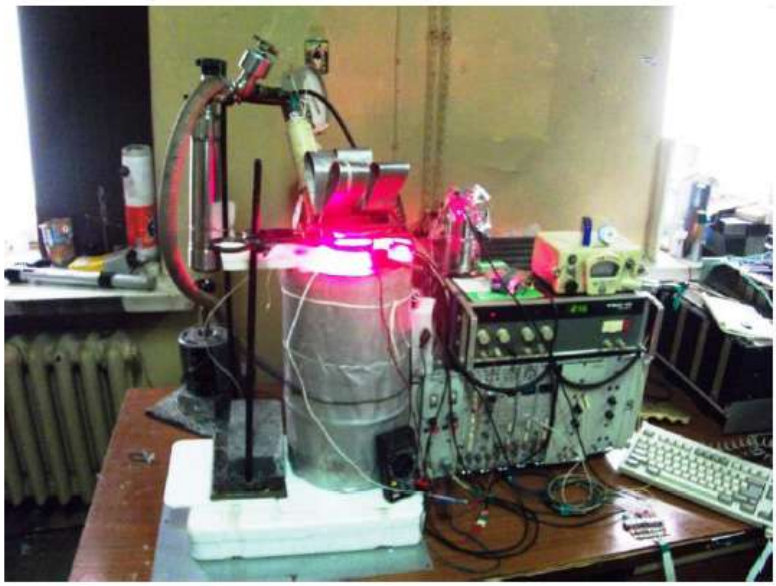

Figure 2. The experimental setup with an array of 20 LEDs and neutron counters placed in a paraffin cylinder.

3. Results, Discussion, and Conclusions

Calorimetric diagnostics. No excess heat was detected in any experiment.

From Table 1, we see that the temperature rise during light irradiation of solutions was in the range of 1.5–2.5°C. There is some correlation between the rise of the temperature in the reactor and the emitted heat energy during light

Table 2. Tritium activity for solution samples taken before ("Background") and after ("Effect").

Experiment number	Solution sample	A (Bq/g)	ΔA (Bq/g)	Solution Volume (l)	Exposure time (s)	N_γ ($\times 10^{19}$)	N_T ($\times 10^7$)	N_γ/N_T ($\times 10^{12}$)
11	"Background" "Effect"	235±1 1158±1	923±1	0.5	3600	5445	170	32
12	"Background" "Effect"	1323±1 1340±1	17±1	0.5	3420	518	3	173
13	"Background" "Effect"	280±1 947±1.5	667±2	0.5	3600	3464	120	36
14	"Background" "Effect"	5.3±0.1 13.6±0.1	8.3±0,2	0.5	3600	2455	2	1227
15	"Background" "Effect"	31.1±0.3 52.5±0.3	24±0,4	5.0	4260	2905	5	581
17	"Background" "Effect"	550±10 626±16	76±19	0.8	3720	2536	22	115

A–activity of tritium, ΔA–the difference between the activity "Effect" and "Background"; N_γ–the number of radiating photons from source of light; N_T–the number of produced tritium in all over the irradiated volume; N_γ/N_T–the number of photons to produce a single nucleus of tritium.

Figure 3. The experimental setup with an array of 9 LEDs and solution in the Dewar vessel.

irradiation of solutions. At the same time, the energetic effect is influenced not only by the power of the lamp, but also the duration of the experiment. Thus, in this series of experiments, we were able to establish an upper bound of 16 kJ of possible energy production. If we take the sensitivity of the thermocouple equal to 0.5°C, we can get an upper bound on the potential to generate additional energy at the level 5 mW, which is comparable with the laser power output ∼1 mW. Thus, we did not reliably detect excess heat in our experiment.

Nuclear radiations (neutrons, gamma rays, and X-rays) were monitored, but none was detected. In all experiments, the measurements of neutron fluence, dose rate and X-rays fluence were at the background level.

Diagnostics of tritium showed the greatest effect.

Liquid scintillation diagnostics of tritium were carried out on the Chemical Faculty (Department of Radiochemistry) of the Lomonosov Moscow State University. The diagnostics took into account the possible impact of alkaline solution ekzoelectrons. The results obtained for tritium activity for solution samples taken before ("Background") and after ("Effect") are given in Table 2.

The tritium generation depends on the composition and concentration of the water solution and the concentration of D_2O. So, the maximum of tritium quality was formed in Exp. Nos. 11 and 13 using alkaline solutions NaOH and

Na_2CO_3 with D_2O. The same result was in the Exp. Nos. 12 and 17. In other experiments with solution LiOH the "Effect" measurements were significantly smaller.

Thus, experiments showed that tritium can be generated in water solutions NaOH and Na_2CO_3 with small additions of D_2O after irradiation by red light with a wavelength of 650 nm. These results correlate with the Erzion model. Additional investigations are necessary to explain the lack of tritium after irradiation of water solutions of LiOH, and the lack of neutrons in the experiments.

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