

# Fluorescence of Atomic Hydrogen in Aqueous Media

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## ABSTRACT

It is shown that aqueous solutions of atomic hydrogen fluoresce under the action of UV irradiation. It is also shown that the spectra of this fluorescence have peaks whose maxima are close to the 5<sup>th</sup> and 6<sup>th</sup> lines of the Balmer series. All this made it possible to propose using this fluorescence to determine the concentration of atomic hydrogen in aqueous media, which seems relevant for both hydrogen energy and medicine. In addition, the possible involvement of this fluorescence in such phenomena as the blueness of the daytime sky, Cherenkov radiation and the Kirlian aura is analyzed here.

**Keywords:** Cherenkov radiation, hydrogen energy, hydrogen therapy, Kirlian aura.

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## 1. INTRODUCTION

It was initially discovered that after bubbling with hydrogen, water acquired the ability to fluoresce in the violet region under the influence of UV radiation. More detailed studies have shown that the fluorescence spectrum of this water has a peak with a maximum at a wavelength of  $\sim 410.2$  nm [1], which is close to one of the lines of the Balmer series: 410.12 nm ( $m = 6$ ) [2]. It was soon established that an identical fluorescence peak is characteristic of water in contact with metallic magnesium [1]. Both of these results, as well as the fact that atomic hydrogen is released from water when it comes into contact with metallic magnesium ( $2\text{H}_2\text{O} + \text{Mg} \rightarrow \text{Mg}(\text{OH})_2 + \text{H}_2$  [3]), gave reason to assume that atomic hydrogen present in the aqueous medium is capable of fluorescence [1].

It is probably worth adding that this assumption took into account the absence of theoretical grounds excluding the possibility of such fluorescence. Despite this, this assumption was further verified in a number of experiments.

## 2. MATERIALS AND METHODS

To enrich aqueous media with atomic hydrogen, known chemical reactions were used here, undoubtedly accompanied by the release of hydrogen atoms.

All reagents used in these reactions were purchased from Ukrreahim (Ukraine).

A Cary Eclipse Varian (Austria) fluorescence spectrofluorometer was used to record the fluorescence spectra of wave media containing atomic hydrogen; the fluorescence under study is well excited by UV light in the range:  $220 \div 300$  nm.

## 3. RESULTS

To begin with, it is worth noting that the validity of the proposed assumption was confirmed by a number of experiments; the results of two such experiments are presented below.

The first of the presented experiments studied the fluorescence of an aqueous solution of formic acid containing zinc oxide, using the ability of zinc oxide to catalyze the decomposition of formic acid into gaseous hydrogen and carbon dioxide:  $\text{HCOOH} \rightarrow \text{CO}_2 + 2\text{H}^*$  [3]. Thus, it was established that such decomposition is accompanied by the appearance of a fluorescence peak (Fig. 1), the maximum



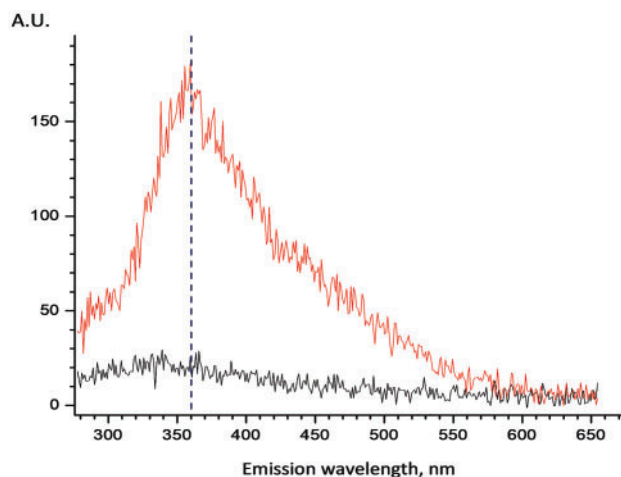


Fig. 1. These are the fluorescence spectra of distilled water (black curve) and aqueous solutions containing formic acid decomposition products:  $\text{HCOOH} \rightarrow \text{CO}_2 + 2\text{H}^*$  (red curve).

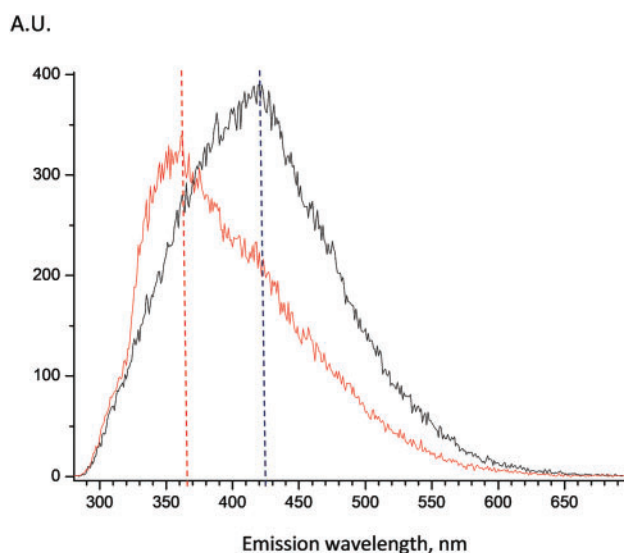


Fig. 2. These are the fluorescence spectra of water that comes into contact with metallic iron and, consequently, decomposes, releasing hydrogen atoms:  $\text{Fe} + 2\text{H}_2\text{O} \rightarrow \text{Fe}(\text{OH})_2 + 2\text{H}^*$ ; the black curve is the spectrum recorded 30 minutes after the onset of such decomposition; the red curve is the spectrum recorded 10 hours after the end of such decomposition.

of which ( $\sim 360$  nm) is located near the short-wave boundary of the Balmer series:  $364.56$  nm ( $m = \infty$ ) [2]; it is worth noting that this fluorescence was excited by UV light with a wavelength of  $230$  nm.

The second of the presented experiments studied the fluorescence of water when in contact with iron powder—in this case, the water decomposes with the release of hydrogen atoms:  $\text{Fe} + 2\text{H}_2\text{O} \rightarrow \text{Fe}(\text{OH})_2 + 2\text{H}^*$  [3]. Thus, it has been established that such decomposition of water is accompanied by the appearance of a peak with a maximum at  $\sim 425$  nm on its fluorescence spectra (Fig. 2, right spectrum); it was further concluded that this peak can be represented as the sum of two peaks, the maxima of which correspond to two lines of the Balmer series:  $410.17$  nm ( $m = 6$ )/ $2 + 434.04$  nm ( $m = 5$ )/ $2 = 844.21$  nm/ $2$  nm =  $422.105$  nm [2]; it is worth noting that this fluorescence was excited by UV light with a wavelength of  $260$  nm.

In the latter case (Fig. 2), the blue dotted line shows a wavelength of  $\sim 423$  nm, which is located midway between two adjacent lines of the Balmer series:  $410.17$  nm ( $m = 6$ ) and  $434.04$  nm ( $m = 5$ ):  $(410.17 + 434.04)/2$  nm =  $844.21/2$  nm =  $422.105$  nm.

At the same time, the latter experiment also showed that the initial peak with a maximum at  $\sim 423$  nm can shift to shorter wavelengths over time, effectively turning into a peak with a maximum near  $365$  nm (Fig. 2, left spectrum), which corresponds to the short-wavelength boundary of the Balmer series:  $364.56$  nm ( $m = \infty$ ); the red dotted line (Fig. 2) shows the short-wave boundary of the Balmer series [2].

It is worth noting here that a similar shift of peaks to the short-wave region was also observed in the study of the fluorescence of water saturated with oxonium ions, namely  $\text{H}_3\text{O}^+$  [4]. Although the reason for these shifts is still unclear, their recurrence forces us to acknowledge their reality.

Thus, there are experimental results demonstrating the ability of excited hydrogen atoms to fluoresce in aqueous media. It is these results that justify the proposed discussion of the practical and scientific significance of this type of fluorescence.

#### 4. DISCUSSION

It should be noted initially that the discovered ability of hydrogen atoms to fluoresce in aqueous media may be of interest to researchers of photolytic, sonolytic and catalytic decomposition of water [5]–[9], who undoubtedly need to determine the productivity of such decompositions. In particular, this same ability of hydrogen atoms may be of interest to supporters of hydrogen energy, who are trying to obtain gaseous hydrogen from water by decomposing it in the ways indicated [6], [8], [9]; in any case, the results of experiments with metallic magnesium give reason to assume that the intensity of the fluorescence in question is proportional to the concentration of hydrogen atoms [1]. Thus, the discovered ability of hydrogen atoms to fluoresce in aqueous media may have practical significance. (It is probably worth adding here that the ability of hydrogen atoms to fluoresce in an aqueous environment can be used to determine the degree of oxidation of the human body, allowing one to assess the patient's predisposition to several diseases [10].)

At the same time, it seems that the discovered ability of hydrogen atoms to fluoresce in aqueous media may be of great importance for “pure” science, since it allows us to explain the nature of a number of optical phenomena, for example, the blueness of the daytime sky (Fig. 3); it is probably worth noting here that the nature of this blueness has been debated for many years [11].

Thus, the recorded intense radiation in the region of  $400 \div 500$  nm (Fig. 2) allows assuming that the blue color of the daytime sky is caused by the fluorescence of hydrogen atoms, which are formed during the interaction of hydrogen ions rising with evaporating water [12] with electrons of the solar wind:  $e^- + H^+ \rightarrow H^*$  [13]. In this case, solar UV radiation also excites the fluorescence of hydrogen atoms, as does the artificial UV radiation used in both the experiments presented here (Figs. 1, 2) and in the previous ones [1].

It is probably also worth considering that hydrogen atoms capable of fluorescing under the influence of solar UV radiation can be formed in the upper layers of the atmosphere under the influence of UV and  $\gamma$ -radiation, in fact, as a result of photolysis and radiolysis of water:  $H_2O \rightarrow H^* + HO^*$  [5], [14]. Given all this, it is entirely possible that it is the fluorescence of hydrogen atoms that saturate the water vapor of the upper atmosphere that determines the blueness of the daytime sky as seen from the Earth's surface. (Certainly, similar considerations also allow assuming that this same fluorescence determines the blue color of the Earth's atmosphere, visible from space.)

It can also be assumed that it is the fluorescence under consideration that is responsible for the occurrence of Cherenkov radiation in water (Fig. 4).

This assumption is supported by the fact that the initiators of this radiation are  $\gamma$ -radiation,  $\beta$ -radiation and sonic boom [2], [15]–[19], that is, factors that have a completely different nature and are united only by the fact that they all cause the appearance of hydrogen atoms in water. Thus, it seems that it is precisely this difference in the physical nature of the factors causing Cherenkov radiation that is the most convincing evidence of the validity of the proposed assumption. So, the discovered ability of atomic hydrogen to fluoresce in aqueous media allows proposing a completely new point of view on the nature of Cherenkov radiation, especially on its source.

It is worth noting that the undoubted advantage of the proposed source of Cherenkov radiation is that it significantly simplifies the whole picture and, in particular, does not require the use of electrons



Fig. 3. This is what the daytime sky looks like when there are no big clouds.

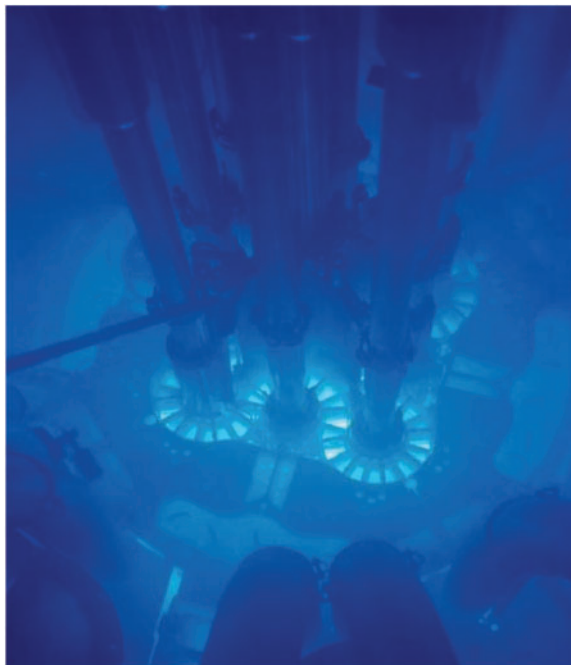


Fig. 4. This is typical Cherenkov radiation of water treated with streams of fast electrons; compare the color of the Cherenkov radiation with the color of the sky (Fig. 3).



Fig. 5. This is what the Kirlian aura of a drop of water looks like.

moving faster than light [2], [17]–[19]. At the same time, this source eliminates the need for numerous equations attempting to describe Cherenkov radiation caused by factors of various natures [2], [17]–[19]; it is perhaps worth noting separately that ongoing attempts to revise these equations [20] show that these very equations are not entirely satisfactory.

Reasoning in the same way, it is quite natural to assume that the same hydrogen atoms cause the Kirlian aura, i.e., the glow that appears around water objects exposed to alternating electric fields with frequencies of  $10 \div 100$  kHz (Fig. 5).

Before analyzing the proposed explanation of the Kirlian aura, it should be taken into account that such alternating electric fields cause a skin effect, which consists of pushing electrons out of conductors [21]. Therefore, the immediate environment of water and water-containing objects that are exposed to such alternating electric fields is enriched with electrons that are capable of reacting with hydrogen ions evaporating from water and, accordingly, generating fluorescent hydrogen atoms:



Fig. 6. (A) These are the tops of the clouds, which have a reddish tint and (B) This is what typical sprites look like in the night sky.

$e^- + H^+ \rightarrow H^*$ . Thus, it turns out that these same variable electric fields simultaneously promote both the expulsion of electrons from water and water-containing objects and the evaporation of water, undoubtedly protonated [12], thereby creating an environment enriched with hydrogen atoms, which generates the Kirlian aura.

For the sake of completeness of the description, it should be remembered that positively charged water, i.e., water saturated with protons or aqueous oxonium ions, namely  $H_3O^+$  [3], [22], is capable of fluorescing red [4], [23]; apparently, the reddish colors of the cloud tops (Fig. 6A), undoubtedly enriched with positively charged water vapor [12] and sprites (Fig. 6B), representing ascending flows of hydrated protons [12], give an idea of such fluorescence.

Thus, it cannot be ruled out that the reddish colors in the Kirlian aura (Fig. 5) are partly due to the fluorescence of water evaporating under the influence of the same electric fields with frequencies of  $10 \div 100$  kHz; at the same time, the existence of an unmistakable red line in the Balmer series: 656.21 nm ( $m = 3$ ) [2] should also be taken into account when explaining the multi-colored Kirlian aura.

## 5. CONCLUSION

Be that as it may, there are experimental data that give grounds to assume that hydrogen atoms are capable of fluorescence not only in the gaseous state but also in aqueous media. It seems that these data are useful to consider for both practitioners and theorists.

## CONFLICT OF INTEREST

Author declares no conflict of interest.

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