Features of radiation gas discharge with liquid electrolyte cathode by using aqueous solutions of sodium chloride

Kh K Tazmeev, I M Arslanov and G Kh Tazmeev
Branch of Kazan Federal University in Naberezhnye Chelny, 68/19 Mira Street, Naberezhnye Chelny, 423810, Russia

E-mail: tazmeevh@mail.ru

Abstract. Experimentally investigated the spectral characteristics of the gas discharge between the liquid electrolyte cathode (aqueous solution of sodium chloride) and a metal anode at high currents (up to 20 A). Found splitting yellow doublet of sodium and the factors affecting the splitting.

1. Introduction
Practical interest in the gas discharge with liquid electrolyte cathode conditioned by the fact that it allows to create a plasma with a significant geometric volume at atmospheric pressure using a comparatively simple technical means. In this regard, it may find application in plasma-technology, in particular in the plasma gasification of waste polymeric materials [1]. For the rational use of plasma gas discharge are required its detailed characteristics in a wide range changes of energy parameters. The objective of this research was to study the spectral characteristics of the gas discharge at high currents.

2. Experiment
The experimental setup is shown in figure 1.

Figure 1. Gas discharge unit. The arrows indicate the direction of movement of the electrolyte.
The discharge was initiated between the liquid electrolyte cathode 1 and the metal anode 2. Electrolyte flowed out of cylindrical passage 3, which has been mounted inside the graphite plate 4 for supplying current. As the electrolyte was used salt solution in distilled water.

The power supply has served three-phase full wave rectifier was connected to the secondary windings of the boosting transformer. Voltage ripple smoothed out by C-L-C-filter. Current is changed by a step variation of ballast resistance.

The radiation spectra were recorded on a high-speed fiber-optic spectrometer AvaSpec-3648 in the wavelength range 484-708 nm with a resolution of 0,15 nm (diffraction grating 1200 lines/mm, the input optical gap is 10 microns). The radiation from the discharge area 5 projected onto to the input optical cable 6 by the collimating lens installed on the receiving end of it. Spectrometer 7 was functionally connected with a computer 8.

3. Results and their discussion

On figure 2 shows the spectrum of the discharge and its fragments amplified in the visible radiation region. On the spectrum shows the leading line of the principal series of sodium (yellow D-line). The spectrum can be considered as almost a single line. Compared with the D-line intensity of the other components are negligibly small. Against the background of D-line, they are indistinguishable. In the mode with the increased integration time (with a CCD detector saturation in the central region of the spectrum) obtained the spectra in which are observed doublet lines of the sodium atom. Among them, the most intense diffuse series doublet formed by transitions $4^2D_{3/2} \rightarrow 3^2P_{1/2} (568,3\text{ nm}), 4^2D_{3/2} \rightarrow 3^2P_{3/2} (568,8\text{ nm})$ and $4^2D_{5/2} \rightarrow 3^2P_{3/2} (568,8\text{ nm})$. Doublet relating to the sharp series has a lesser intensity. It consists of lines $5^2S_{1/2} \rightarrow 3^2P_{1/2} (615,4\text{ nm})$ and $5^2S_{1/2} \rightarrow 3^2P_{3/2} (616,1\text{ nm})$. Still less intensity has doublet sodium, consisting of lines 497,9 and 498,3 nm.

In the strong chunk of spectrum (on the right edge of the bottom of figure 2) clearly stands hydrogen Balmer line $H_\alpha (656,3\text{ nm})$. This line corresponds to the radiative transition from the level with excitation potential 12,088 eV [2]. Therefore, the presence of lines in the spectrum of $H_\alpha$ suggests a presence in the plasma of high-energy electrons that can convert hydrogen atoms from the ground state to the excited state with electron configuration 3d.
Exploration of the spectrum in a narrow range of wavelengths indicated that the yellow D-line of sodium has a fine structure. According to the Grotrian diagram [2] it should be a doublet (called "yellow sodium doublet"), consisting of lines $^3{P}_{1/2} \rightarrow ^3{S}_{1/2}$ ($\lambda = 589.6$ nm) and $^3{P}_{3/2} \rightarrow ^3{S}_{1/2}$ ($\lambda = 590.0$ nm). In itself observation multiplet splitting yellow sodium D-line to form a doublet is quite natural and expected, since the resolution of the spectrometer AvaSpec-3648 used in experimental studies, allows us to see such a result.

Features of radiation, which appeared in the experiments lies in the fact that in a gas discharge except the multiplet splitting of the yellow sodium D-line subjected to a supplementary splitting. While the number of components is not permanent and depends on the discharge mode. What is remarkable is that the splitting of spectral lines occurs in the absence of external electric and magnetic fields.

On figure 3 shows the fragments of the spectra obtained at different values of the discharge current. As can be seen, at low currents there is no splitting (figure 3a). It occurs at higher currents (figure 3b) and increases with increasing current (figure 3c). Since additional splitting of spectral lines caused by the nature of the discharge, it can be assumed that it is present and at low currents. Its detection is possible with using a spectral instrument with larger resolving power.

![Figure 3](image1.png)

**Figure 3.** Splitting of the yellow doublet of sodium depending on the discharge current.

$I = 4\ A$  
$I = 9.5\ A$  
$I = 16\ A$  

![Figure 4](image2.png)

**Figure 4.** Splitting of the yellow doublet of sodium depending on the electrical conductivity of the electrolyte $\sigma$. $I = 9.5\ A, l = 7\ sm, D = 75\ mm$. Anode – copper.

A similar pattern is observed with an increase in the electrical conductivity of the electrolyte (figure 4). Under the influence of these two factors, improving $I$ and increasing $\sigma$, the splitting of the line $^3{P}_{1/2} \rightarrow ^3{S}_{1/2}$ ($\lambda = 589.6$ nm) is greater than the line $^3{P}_{3/2} \rightarrow ^3{S}_{1/2}$ ($\lambda = 590.0$ nm). This is...
clearly seen in Figures 3b and 4b. It should also be noted that the current increase, and increase the electrical conductivity of the electrolyte lead to increased intensity of the gas discharge. Quantitatively, this effect is confirmed by the expansion of the spectral band in figure 3 and 4.

While simultaneously increasing \( I \) and \( \sigma \) an additional splitting of spectral lines of yellow sodium doublet increases (figure 5). It is comparable to the multiplet splitting. Two lines of the spectrum, located in the middle, superimposed on each other. The result is a triplet. The intensity of the triplet midline decreases with the increasing of splitting. Its relative intensity is considerably smaller than the outer lines (figure 5c).

4. Conclusions
In the gas discharge with the liquid cathode electrolyte, when used as electrolyte aqueous solutions of sodium chloride there is a splitting doublet yellow sodium. Increasing the discharge current and the increase of electrical conductivity of the electrolyte lead to increased splitting the spectral lines.

References
[1] Friedland S V, Tazmeev A Kh, Miľakov M N and Tazmeev Kh K 2006 Vestnik mashinostroeniya 7 72
[2] Babichev A P, Babushkina N A, Bratkovskij A M et al 1991 Fizicheskie velichiny: Spravochnik (Moscow: Energno atom izdat)