Absorption of Photo-Ionizing Radiation of Corona Discharges in Air

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Introduction

The photo-ionizing radiation generated by corona discharges – radiation in the VUV region – has an important role in the mechanism of initiation, development, and sustainment of many discharges used in various applications. A large number of papers are devoted to the generation mechanism and properties of the radiation emitted by low temperature gas discharges in air at various pressures (see e.g. investigations cited in the paper by Bourdon et al.[1]). However, papers about experimental investigation of photo-ionizing radiation in gas discharges are scarce and written many years ago.

One can find in the literature data about absorption of the photo-ionizing radiation generated by corona discharges in air, O₂, N₂ and their mixtures.[2–8] Penney and Hummert[2] investigated absorption at low pressures, up to 18 Torr. As a source of ionizing radiation, they used a steady point corona. Teich[8] investigated absorption in dry air at pressures up to 700 Torr. His source of ionizing radiation was not a steady corona but an electron avalanche developing in a homogeneous electric field at reduced field strength \( E/p = 50–200 \text{ V cm}^{-1} \text{ Torr}^{-1} \).

It is important to point out that Penney and Hummert,[2] Przybilski[4–6] and Teich[8] made measurements in a closed chamber. As mentioned in our earlier report,[9] it is well known that a gas discharge in air produces O₃ and NOₓ, which concentrations in a closed chamber can rise up to high values. Presence of these products can change absorption properties of the gas mixture significantly. Results about absorption of the atmospheric pressure corona radiation in flowing dry air are presented by Aints et al.[10]

Laboratory air used in above-mentioned experiments was dried with help of moisture absorbers or cooling agents. Only few experiments deal with air containing some percent of water vapor.[6,8,9] Water vapor increases the absorption of the photo-ionizing radiation significantly; it increases also the number of the discharge products. The approximate limit for the absorption coefficient \( \mu \) of water vapor is proposed in the literature.[6]
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Experimental Part

Apparatus

Figure 1 presents a sketch of the experimental set-up. A pump sucked air through the test chamber. Laboratory air entering the system passed first through a dust filter. Silica gel dried a part of the air stream; the second part remained humid. A dew-point meter measured humidity of dried air and a thermo-hygrometer that of humid air. In all experiments, the temperature was about 293 K (the room temperature). Valves and flow meters controlled both dry and humid streams that entered the mixer. Thus, the pressure and the moisture content of the air were adjustable to the required level in the ionization and corona chamber.

The point electrode in the corona chamber was a hemispherically capped platinum wire of 0.25 mm in diameter. The distance from the point electrode tip to the opposing endplate of the corona chamber was variable. The diameter of the corona chamber was 20 mm; the aperture in the center of the endplate had a diameter of 1 mm. The DC supply fed the corona point with a voltage of 5–6 kV. The resistor $R = 100 \, \text{M} \Omega$ stabilized the corona current. A micro-ammeter grounded the corona chamber and measured the corona current, which was in the range 10–40 $\mu$A.

Photons generated by the corona discharge passed through the aperture and, if not being absorbed by medium before, reached the ionization chamber designed to detect the photons that cause the ionization. The distance between the corona chamber and the ionization chamber was adjustable with an accuracy of 0.1 mm. In Figure 1, $x$ denotes the distance between the tip of the corona electrode and the grid G1 of the ionization chamber.

Our ionization chamber was similar to that used by Penney and Voshall. It contained a plane collector electrode perpendicular to the point electrode axis (see Figure 1), and two grids G1 and G2 parallel to the collector electrode. Both grids consisted of parallel wires 0.07 mm in diameter. The distance between the grid wires, as well between the grids was 0.4 mm. Wires of one grid were parallel to those of the other grid. The total optical transparency of two grids was $T = 0.65$. The potential applied to the grid G1 was negative ($U_{G1} = -100$ V) and that applied to the grid G2 was positive ($U_{G2} = 100$ V). The distance between the collector electrode and the grid G1, $\Delta x$, was 0.56 mm. The ions generated by photo-ionizing radiation in the space between the grid G1 and the collector electrode caused a current in the circuit of the collector electrode. An electrometer measured this current with a resolution of $1 \times 10^{-15}$ A.

The grid G2 formed an electric field that prevented the arrival of electrons, emitted by the grid G1 due to the photo-effect, to the collector electrode. Electric field of G2 also inhibited positive ions originated in the corona discharge from penetrating through the grids. The 1 l·min$^{-1}$ air stream through the endplate aperture of the corona chamber had the same task. This stream also removed the corona products and ensured so an invariable medium in the ionization and corona chambers.

Measurement Procedure

We measured the collector current $I$ depending on the distance $x$ at various values of the air pressure $p$, humidity and corona current $i$. We changed also the corona polarity. The negative corona appeared in the form of the Trichel pulses at a repetition rate up to some hundreds of kHz. The positive corona was investigated only in the steady glow mode. The discharge mode was identified mostly by visual observation through the windows in the wall of the discharge chamber (see Figure 1), but also observing the corona current waveform with the help of an oscilloscope. We performed...
measurements under pressures, which ensured the stable steady glow localized at the hemispherical tip of the point-electrode only. Increasing the distance between the point tip and the end-plate of the corona chamber helped us to obtain the stable discharge and to prevent breakdowns. During each series of measurement, we changed the distance \( x \) by changing only the distance between the corona chamber and the ionization chamber; the distance between the point tip and the end-plate of the corona chamber had a fixed value in the range of 4–15 mm.

**Results and Discussion**

The dependence of the collector current \( I \) on the corona current \( i \) was linear when the corona mode remained unchanged and the corona was localized at the point tip (the discharge did not spread over the cylindrical part of the point electrode). The upper limit of the region of corona current, where the \( I-i \) characteristics remained linear, was 1–30 \( \mu A \) depending on the pressure and the length of the corona gap.

We present the results of measurements as \( \Psi(xp) \)-curves like authors of earlier papers\(^{[2-8]} \) did. The yield of photo-ions \( \Psi \) is the number of photo-ions generated in a layer of unit thickness at a distance \( x \) from the radiation source at unit pressure per unit of solid angle per one ionizing collision in the discharge:

\[
\Psi(xp) = \frac{I(x)}{\Theta Tip \Delta x}
\]

**Results for Dry Air**

Figure 2 presents the \( \Psi(xp) \)-curves measured in dry air \((p_{H2O} < 0.6 \text{ Torr})\) in incoming air under atmospheric pressure. One can see that the experimental points obtained at a given pressure form a distinct smooth curve. At pressures above 300 Torr, the points obtained in the positive and negative corona lie on the same curve. At pressures below 200 Torr, the values of \( \Psi \) obtained in negative corona are higher than those obtained in the positive corona at the same value of pressure and \( xp \). Curves obtained at different pressures do not coincide – the higher is the pressure at a fixed value of \( xp \), the lower is the yield of photo-ions \( \Psi \).

**Results for Humid Air**

Figure 3 and 4 present the dependence of the yield of photo-ions on humidity in the positive and the negative corona. The total pressure, \( p \), and the partial pressure of water vapor, \( p_{H2O} \), in the chamber are presented in the legend of the graphs. The value of \( p_{H2O} \) was calculated based on readings of the thermo-hygrometer, the dew point meter and the flow-meters installed in the channels of air inlet:

\[
p_{H2O} = \frac{F_1p_{H2O}^H + F_2p_{H2O}^D}{F_1 + F_2} \times \frac{p}{p_a}
\]

Here \( F_1 \) and \( F_2 \) are air fluxes in the channels of humid and dry air, \( p_{H2O}^H \) and \( p_{H2O}^D \) are partial pressures of water vapor in the channels of humid and dry air respectively, \( p_a \) is the pressure of ambient air and \( p \) is the total pressure in the chamber. Points in Figure 3 and 4 mark experimental results. Solid curves are calculated according to Equation 5 (see Section “Approximation Formula for Humid Air”). Figure 3 and 4 show that an increase in humidity reduces the photo-ionization yield \( \Psi \).

**Consideration of Quenching**

As one can see in Figure 2, the curves obtained at different pressures do not coincide. The higher the pressure, \( p \), the lower the yield of photo-ions, \( \Psi(xp) \), which corresponds to a given value of the parameter \( xp \). The reason for that is a quenching of the excited states of molecules due to collisions. The quenching caused by collisions is most effective at higher pressures. The intensity of the ionizing radiation as a function of gas pressure is proportional to the quantity

\[
q = \left(1 + \frac{p}{p_q}\right)^{-1}
\]

where \( p_q \) is a so called quenching pressure. Teich\(^{[8]} \) proposed a value \( p_q = 30 \text{ Torr} \) for air. Division of \( \Psi \) by \( q \) reduces the values of \( \Psi \) obtained at different pressures to low-pressure conditions with no collisional quenching of excited states. Reduced curves \( \Psi(xp)/q \) are presented in Figure 5. One can see that points obtained at a given value of \( xp \) but at different pressures lie closer to each other than...
in Figure 2. However, a small systematic difference can still be seen at $xp < 400$ cm$^3$/Torr. In addition, there is a difference between the positive and negative corona at $xp < 400$ cm$^3$/Torr.

In Figure 5, the slope of the curve decreases with an increase in $xp$. This indicates that the photo-ionizing radiation contains components with different absorption coefficients. Probably the quenching pressures of different components are also different. This is the reason why the above reduction using one universal quenching pressure does not result in a smooth single curve. Another reason for that may be a change of $E/p$ with pressure in discharges. This change in $E/p$ causes the change of electron energy distribution and therefore changes in the excitation efficiency and the photon production rate.

**Comparison with Results Obtained by Other Authors**

According to our knowledge, only few papers (Penney and Hummert,[2] Teich[8]) present the yield of photo-ions for air discharges measured using the methodology similar to ours. We recalculated the yields presented in these papers in order to take into account the quenching by collisions, and plot these results in Figure 6A and 6B (enlarged scale) together with our results.

As radiation source, Teich used a non-self-sustained discharge between parallel plate electrodes. It appeared that the yield of photo-ions depended on the reduced electric field strength $E/p$ in the discharge gap. Teich’s results are presented in Figure 6 for three different values of $E/p$. Points at $E/p = 50$ V$^1$/cm$^3$/Torr$^{-1}$ are obtained in the pressure range from 20 to 700 Torr, points at $E/p = 100$ V$^1$/cm$^3$/Torr$^{-1}$ in the range from 3 to 50 Torr, and points at $E/p = 200$ V$^1$/cm$^3$/Torr$^{-1}$ in the range from 2 to 20 Torr. Figure 6 shows that the photo-ion yield $\Psi/q$ decreases with increase in the reduced field strength $E/p$.

Penney and Hummert investigated the photo-ionizing radiation of the positive point corona in the pressure range from 0.25 to 17.5 Torr. They state that the value of $E/p$ in their experiments was $3500$ V$^1$/cm$^3$/Torr$^{-1}$ at the pressure of 1 Torr. Unfortunately, they do not describe the estimation method of $E/p$ as well as the visual appearance of the low-pressure discharge in their experiments.

The $E/p$ value in our corona discharge was estimated at atmospheric pressure using the intensity ratio of the spectral bands of nitrogen according to the method described by Paris et al.[11] $E/p = 109$ V$^1$/cm$^3$/Torr$^{-1}$ in the positive corona and $E/p = 115$ V$^1$/cm$^3$/Torr$^{-1}$ in the negative corona. For the positive corona, the photo-ion
yield in our experiments at low values of the parameter $x_p$ lies close to those results obtained by Teich at $E/p = 100$ V $\cdot$ cm$^{-1}$ $\cdot$ Torr$^{-1}$ (see Figure 6B). At higher values of $x_p$, Teich’s measurements are limited to the field strength $E/p = 50$ V $\cdot$ cm$^{-1}$ $\cdot$ Torr$^{-1}$. There, at higher values of $x_p$, our results both for the positive and negative corona lie lower than the results obtained by Teich but higher than the results obtained by Penney and Hummert (see Figure 6A). Our results for the negative corona at low values of $x_p$ lie higher than the results obtained by Teich, Penney and Hummert (see Figure 6B). In our opinion, the discrepancy between the results of different authors might be caused by differences both in values of the reduced electric field and in discharge phenomena investigated. The reason for a difference between photo-ion yields of the positive and the negative corona at low pressures (low $x_p$ values; see Figure 2) needs further investigation. In our opinion, the pulsed nature of the negative corona should have no influence on the results of the photo-ion yield measurements.

**Approximation Formulae for Dry Air**

Several formulae describing photo-ion yield are proposed in the literature. Uber and Penney$^{[12]}$ proposed empirical
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A formulae:

$$\Psi_{B&G}(xp) = 2.46 \exp(-9.17 \times 10^{-3}xp) + 28.3$$
$$\times \exp(-3.95 \times 10^{-2}xp) + 528$$
$$\times \exp(-4.025 \times 10^{-1}xp)$$

and

$$\Psi_T(xp) = 3.77 \exp(-4.94 \times 10^{-3}xp) + 24.5$$
$$\times \exp(-1.7 \times 10^{-2}xp) + 27.75$$
$$\times \exp(-4.48 \times 10^{-1}xp)$$

for the results of Penney and Hummert[9] and Teich[8], respectively. In above formulae, the parameter xp is in units of cm · Torr. Unfortunately, Uber and Penney do not specify at which value of E/p their formulae are valid.

Badaloni and Gallimberti[13] proposed a formula that describes the production of photo-ions. From that formula, an expression for the photo-ion yield \( \Psi \) can be deduced:

$$\Psi_{B&G} = \sum_j \eta_j \mu_j \exp\left(-\frac{\mu_j}{p_0} xp\right) \frac{\omega_j}{4\pi}$$

Here the subscript \( j \) specifies the wavelength \( \lambda_j \) of a photon, \( \eta_j \) is the ionization probability for an absorbed photon, \( \mu_j \) is the absorption coefficient of the photo-ionizing radiation at a wavelength \( \lambda_j \) at normal pressure \( p_0 \), and \( \omega_j \) is the photon production efficiency (the number of photons of a given wavelength that are emitted per one ionizing collision in an electron avalanche). Table 1 presents the values of \( \eta_j, \mu_j \) and \( \omega_j \) taken from the literature.[13]

Curve 1 in Figure 6 is drawn according to Equation (3) using the data of Table 1. This curve approximates well our experimental data for the positive corona. The discrepancy between this approximation curve and our data for the negative corona increases with decrease in the parameter xp.

Curves 2–5 in Figure 6 are drawn according to the formula suggested by Zheleznyak et al.[14,15]

$$\Psi_z = \frac{\exp(-k_{O2min}xp) \exp(-k_{O2max}xp)}{4\pi \ln\left(\frac{R_{O2max}}{R_{O2min}}\right)}$$

Here \( p_{O2} \) is the partial pressure of oxygen in air; \( k_{O2min} \) and \( k_{O2max} \) are the minimum and the maximum value of the absorption coefficient of the photo-ionizing radiation in the wavelength range from 98 to 102.5 nm in oxygen, and \( \eta \) is the mean ionization probability for an absorbed photon in this wavelength interval. \( \Omega \) is the number of photons generated by one electron per drift path of the unit length, and \( \alpha \) is the first Townsend coefficient (the number of ionizing collisions executed by one electron per drift path of the unit length). Zheleznyak et al. derived this formula approximating the absorption coefficient in the selected wavelength range from 98 to 102.5 nm by an exponential function

$$k(\nu) = k_{min}\left(\frac{k_{max}}{k_{min}}\right)^{-\frac{\nu-\nu_{min}}{\nu_{max}-\nu_{min}}}$$

The argument of this function, \( \nu \), is the frequency; \( \nu_{min} \) and \( \nu_{max} \) are frequencies that correspond to the wavelengths 98 and 102.5 nm respectively.[15,16] The parameter \( \Omega/\alpha \) is a function of the reduced field strength \( E/p \). Some of its values are available in the literature[14] and they are reproduced in Table 2.

Zheleznyak et al.[14] propose \( k_{O2min} = 0.035 \text{ cm}^{-1} \cdot \text{Torr}^{-1} \) and \( k_{O2max} = 2 \text{ cm}^{-1} \cdot \text{Torr}^{-1} \). However, it appeared that a better fit with experimental points at higher values of xp can be obtained using \( k_{O2min} = 0.028 \text{ cm}^{-1} \cdot \text{Torr}^{-1} \)
(see Figure 5). This value of $k_{O2\text{min}}$ also coincides better with that calculated using the photo-absorption cross-section presented by Chan et al.\cite{17}

In Figure 6, the curves calculated according to Equation 4 are evaluated using $k_{O2\text{min}} = 0.028 \text{ cm}^{-1} \cdot \text{Torr}^{-1}$. The values of the parameter $\Omega \eta / \alpha$ for curves 2-4 are taken from Table 2. For curve 5, the value $\Omega \eta / \alpha = 0.02$ gives the best fit with the experimental points of Penney and Hummert ($E/p = 3500 \text{ V} \cdot \text{cm}^{-1} \cdot \text{Torr}^{-1}$). Based on Figure 6, we can conclude that the curve according to Equation (4) fits any of those series of experimental points if we choose a proper value for the parameter $\Omega \eta / \alpha$.

### Approximation Formula for Humid Air

To take into account the absorption of the photo-ionizing radiation by water vapor, Naidis\cite{18} modified the expression of the photo-ion yield multiplying it by a factor of $Z_{H2O} = \exp(-k_{H2O} P_{H2O} x)$ with $k_{H2O} = 0.26 \text{ cm}^{-1} \cdot \text{Torr}^{-1}$.

This model was validated by comparison with the experimental results obtained at atmospheric pressure in air with 1% H$_2$O for $xp > 400 \text{ cm} \cdot \text{Torr}$. The factor $Z_{H2O}$ increases with the decrease of $p_{H2O}$ but also with the decrease of $x$. For example, if the humidity content in air is 1%, then $Z_{H2O}$ reaches values close to 1 already at $xp < 100 \text{ cm} \cdot \text{Torr}$. Hence, the effect of humidity should become negligible at low values of $x$.\cite{18} Our experimental results do not confirm this speculation: Figure 3 and 4 show that the effect of humidity stays nearly the same over the all explored ranges of $p$ and $xp$.

To account the absorption by molecules of H$_2$O, we modified Equation (4) in the following way:

\[
\Psi_{2M} = \frac{\exp[-x(k_{O2\text{min}} P_{O2} + k_{H2O\text{min}} P_{H2O})]}{4\pi x p \ln \left(\frac{R_{O2\text{min}} P_{O2} + R_{H2O\text{min}} P_{H2O}}{R_{O2\text{min}} P_{O2} + R_{H2O\text{max}} P_{H2O}}\right)} \times \frac{\Omega \eta}{\alpha}
\]

(4a)

Here $k_{H2O\text{max}}$ and $k_{H2O\text{min}}$ are the maximum and minimum values of the absorption coefficient of the photo-ionizing radiation in the wavelength range from 98 to 102.5 nm in water vapor.

Solid curves in Figure 3 and 4 are calculated according to

\[
\Psi = Q \Psi_{2M}
\]

(5)

where the term

\[
Q = \left(1 + \frac{P_{H2O}}{P_{Q} + P_{H2O}}\right)^{-1}
\]

(6)

### Table 1. Values of $\eta_j$, $\mu_j$ and $\omega_j$ for a given wavelength $\lambda_j$. Rows 1–6 correspond to the radiation of the Birge-Hopfield system of a nitrogen molecule excited to the state $b^1\Pi_u$. Rows 7–10 correspond to the radiation emitted by an oxygen atom ($E/p = 100 \text{ V} \cdot \text{cm}^{-1} \cdot \text{Torr}^{-1}$).

<table>
<thead>
<tr>
<th>$\lambda_j$ (nm)</th>
<th>$\eta_j$</th>
<th>$\mu_j$ (cm$^{-1}$)</th>
<th>$\omega_j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>103.3</td>
<td>0.01</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>101.2</td>
<td>0.66</td>
<td>4.6</td>
</tr>
<tr>
<td>3</td>
<td>98.5</td>
<td>0.66</td>
<td>9.1</td>
</tr>
<tr>
<td>4</td>
<td>95.0</td>
<td>0.85</td>
<td>15.3</td>
</tr>
<tr>
<td>5</td>
<td>91.0</td>
<td>0.75</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>89.0</td>
<td>0.72</td>
<td>22</td>
</tr>
<tr>
<td>7</td>
<td>102.8</td>
<td>0.5</td>
<td>6.5</td>
</tr>
<tr>
<td>8</td>
<td>99.0</td>
<td>0.69</td>
<td>7.6</td>
</tr>
<tr>
<td>9</td>
<td>87.9</td>
<td>0.45</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>83.3</td>
<td>0.38</td>
<td>57</td>
</tr>
</tbody>
</table>

### Table 2. Values of parameter $\Omega \eta / \alpha$ for some values of reduced field strength $E/p$.\cite{14}

<table>
<thead>
<tr>
<th>$E/p$ ($V \cdot \text{cm}^{-1} \cdot \text{Torr}^{-1}$)</th>
<th>$\Omega \eta / \alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.05</td>
</tr>
<tr>
<td>50</td>
<td>0.12</td>
</tr>
<tr>
<td>100</td>
<td>0.08</td>
</tr>
<tr>
<td>200</td>
<td>0.06</td>
</tr>
</tbody>
</table>
takes into account the quenching of the excited states by H$_2$O molecules in addition to quenching by "air molecules". Here $p_{\text{H}_2\text{O}}$ denotes the quenching pressure of water vapor. We derived the values of coefficients $k_{\text{H}_2\text{Omax}}$ and $k_{\text{H}_2\text{Omin}}$ from the maximum and minimum values of absorption cross-sections of water molecules in the wavelength region of 98–102.5 nm$^{[19]}$ and altered them a little (not more than 30%) to obtain better coincidence between Equation (5) and our experimental results. The values used in calculations are $k_{\text{H}_2\text{Omax}} = 0.57$ cm$^{-1}$·Torr$^{-1}$ and $k_{\text{H}_2\text{Omin}} = 0.13$ cm$^{-1}$·Torr$^{-1}$. Using two values of the absorption coefficient for H$_2$O ($k_{\text{H}_2\text{Omax}}$ and $k_{\text{H}_2\text{Omin}}$) instead of the mean absorption coefficient $k_{\text{H}_2\text{O}}$ used by Naidis, we take into account changes in the spectral composition of the photo-ionizing radiation with a change of $x_p$. The spectral changes occur due to the absorption of most hard ionizing components of the radiation by molecules of H$_2$O at shorter pathlengths. There is one more essential problem concerning Equation (5). It is obvious that humidity in air acts as an additional absorber of the photo-ionizing radiation and as an effective quencher of molecular excited states. Besides this, presence of water vapor in air may cause changes in the electric field strength and the electron energy distribution function in the active zone of the corona discharge. The last circumstances mean that numerical values of the parameter $\Omega_{\text{H}_2\text{O}}/a$ vary with the partial pressure of water vapor. Unfortunately, we have no reliable data about the dependence of the parameter $\Omega_{\text{H}_2\text{O}}/a$ on the water vapor concentration in air discharges. Therefore we presumed that the reduced field strength in the corona discharge in moist air is the same as in dry air at atmospheric pressure (about 100 V·cm$^{-1}$·Torr$^{-1}$, $\Omega_{\text{H}_2\text{O}}/a = 0.08$). We interpreted the quenching pressure $p_{\text{H}_2\text{O}}$ as a free parameter and chose it such that Equation (5) fitted our experimental data. Curves in Figure 3 and 4 are drawn according to Equation (5) taking $\Omega_{\text{H}_2\text{O}}/a = 0.08$ and $p_{\text{H}_2\text{O}} = 0.3$ Torr. As one can see, the systematic deviation of the experimental results from the approximation curves exists especially for the negative corona at low pressures. Changing the value of $p_{\text{H}_2\text{O}}$, a better match can be obtained for a certain pressure, but the agreement is worse at other pressures. With $p_{\text{H}_2\text{O}} = 0.3$ Torr, the discrepancy between calculated and measured values mostly stays in the limits of the measurement uncertainty of 30%. An exception is the negative corona at pressures below 100 Torr, where the experimental values of $\Psi$ are up to twice as high as the calculated ones. It follows that a good fit between calculated curves and experimental points for all pressures and humidity values is unattainable using a single value for $p_{\text{H}_2\text{O}}$ and a constant value of $\Omega_{\text{H}_2\text{O}}/a$. Rough estimates show that the twofold decrease in values of $\Omega_{\text{H}_2\text{O}}/a$ has approximately the same effect as an increase in $p_{\text{H}_2\text{O}}$ by an order of magnitude (at humidity of about 2%). Changing both $p_{\text{H}_2\text{O}}$ and $\Omega_{\text{H}_2\text{O}}/a$, a better fit between Equation (5) and the experiment can be obtained but based on our experimental data we are unable to give a cause for the choice of these parameters. The more correct application of Equation (5) will be possible, if some future investigation will give a chance to take into account the effect of humidity on the parameter $\Omega_{\text{H}_2\text{O}}/a$.

**Conclusion**

We presented the experimental results about the absorption of the photo-ionizing radiation, originating from the corona discharge, in dry and moist air in a wide region of gas pressure and absorption path length. We compared the experimental data and approximation formulae obtained by different authors. The formula proposed by Zheleznnyk et al. in 1982 seems to be the most reliable one for a wide region of the absorption path lengths. We proposed a modification of that formula for the case of humid air. Numerical values of parameters describing the effect of humidity in this formula need a further specification. The obtained results are suitable for use in the modelling of the discharge development in atmospheric air.

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