# INFLUENCE OF VARIOUS POTENTIALS AT CONSTANT PULSE HEIGHT, AND DIFFERENT VISIBLE LAMPS (IN W) AT CONSTANT POTENTIAL ON THE LIGHT EFFECT IN ARGON**

S. G. PIMPALE

Department of Physics, Barsi College, Barsi,—413401

(*Received* 24 *March* 1975)

Measurements by mirror galvanometer of discharge current in dark and under irradiation in argon at 10 mm pressure excited by low frequency (50 C/s) discharge in all glass ozonizers show a light effect (the photo variation, enhancement— $\triangle Ig$ and diminution $+\triangle Ig$) whose value depends upon various factors, such as the intense ionising zone of an experimental tube, intensity and frequency of irradiation, time of exposure to the discharge, circuit element and pulse amplitude, etc. Theoretical explanation for the observed effects has been attempted on the basis of (*i*) Einstein's photo-electric equation and (*ii*) $\triangle Ig = Ig_D - Ig_L = C\,(\nu - \nu m)$, with $(Ig_D - Ig_L)$, $C$ and $(\nu - \nu m)$ as the change of current in dark and under irradiation; the proportionality constant and the change of frequency of light respectively.

It has been established that Joshi effect $\pm \triangle i$ (the instantaneous and reversible photo-variation enhancement $+ \triangle i$ and diminution $- \triangle i$ of the discharge current $i$ through gases and vapours under electrical excitation) in halogens is observed in all parts of the visible spectrum including infrared[1] and $\gamma$ rays[2]. Just near the threshold potential $V_g$, $+ \triangle I$ increased by increasing $I$ at constant applied $V$ and reached maximum with $V$ at constant $I$ (intensity of radiation. It then diminished and finally inverted to $- \triangle I$. Such type of inversion, i.e. $+ \triangle I_g \rightarrow - \triangle I_g$, has now been investigated in both the argon tubes (A and B) in detail as regards the potentials region for the change of sign and its dependence on (*i*) the optical parameters under varied light intensity $I$; frequency $\nu$, and (*ii*) pulse height-potential.

The current and the applied potential in such a discharge in glass vessels of 1·1 cm diameter and 5-10 cm length (tube A) and of 1·5 cm diameter and 7-11 cm length (tube B) ($P$ of order of 10 mm $Hg$ for both the tubes A and B) was investigated with a Cambridge reflection galvanometer actuated by a crystal rectifier coupled capacitatively as well as resistively through the secondary of step-down bell type transformer. Experimental set up is given in Fig. 1.

Argon at a pressure of 10 mm $Hg$ was excited by transformer discharge in a Siemens type tube. In a first typical series, at 0·28 kV (r.m.s.), i.e., just below $V_g$, the current increase $- \triangle I_g$, which varied instantaneously with continuous aging, was in the range of 359-369 mA. The current enhancement $(- \triangle I_g)$ under infra-red irradiation, obtained from a 250 W incadescent lamp with infra-red filter at a distance of 30 cm from the tube A, and as $V$ increased to 0·35 kV (r.m.s). (<), decreased to almost

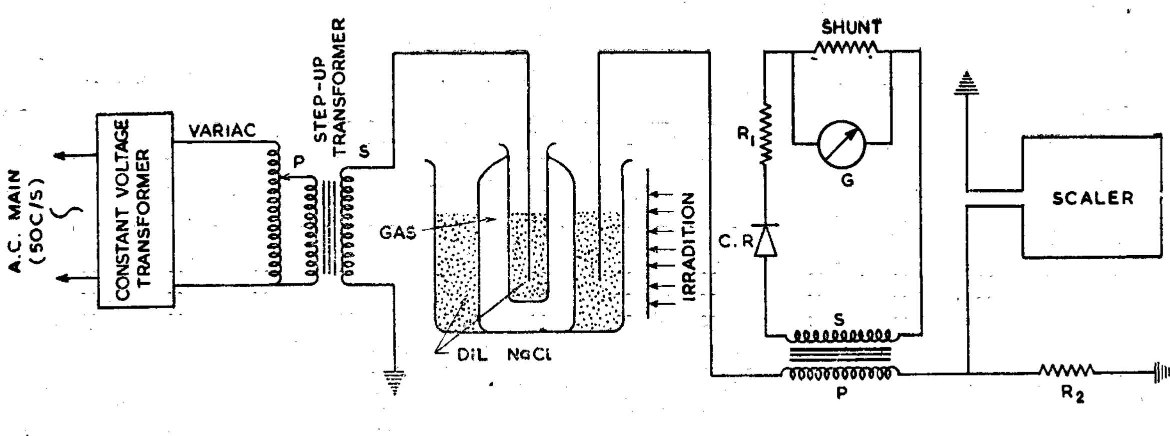


Fig. 1—Static pressure probe.

**The work reported here was carried out in the chemistry Department, University of Poona.

zero when the galvanometer was shunted by 25 $\mu f$ capacitor. Results under visible region obtained by introducing one and four thin white paper filters between a 15 W clear electric glass lamp and the discharge tube A for the same experimental conditions were similar.

In the second series of experiment, the current in tube B was measured with a galvanometer actuated by a semi-conductor diode rectifier and a resistor coupled with a resistance of 600 ohms through a step-down low tension transformer (Table 1). As in other system[3], the light effect $\pm \triangle I_g$ could not be detected below the breakdown potential $V_g$, where $I_g$ under irradiation with a 15 W increased rapidly with $V$ following the onset of discharge. The percentage $\triangle I_g$ increased from—1·8% at 1·75 kV to —7·8% at 2·8 kV (r.m.s.) and then dropped to zero at 3·5 kV (r.m.s.).

The pre-discharge adsorption on the glass walls consisting of molecules held by Van der Waals' forces, on the primary Longmuir layer, on the glass walls is characterized by a low work function $\phi$[4,5]. Occurrance of photo-emission from this layer even under infra-red[1,6], explains — $\triangle I_g$ observed more readily in the first and second series for a pulse height of 5 and 20 volts (Table 1 & 2). Under intense ionisation, the photo-electrons build into a negative space charge close to the instantaneous outer low tension electrode. This lowers the necessary over-voltage, and hence $+ \triangle I_g$[(7,8)]. The increase in $- \triangle I_g$, at $V > V_g$ is a consequence of the reduction in the surface work function $\Phi$ by the applied field caused by the disappearance from the adsorbed layer of molecules held by Van der Waals[9]. As $V$ is progressively increased above $V_g$, chemisorption on the glass walls increases $\Phi$, $- \triangle I_g$, therefore, decreases. This last occurs over a narrow $V$—range owing to negative ion formation at $V > V_g$ and $V$ is greater than inversion—potential when intrisic $- \triangle I_g > + \triangle I_g$, inversion $- \triangle I_g \rightarrow + \triangle I_g$ occurs. These results for the intensity—, frequency—, and amount of irradiation—inversion of $\pm \triangle i$ in an ozonizer discharge are similar to those obtained by Venugopalan[10].

From Table 2 it is seen that larger the pulse height, smaller the $+ \% \triangle I_g$. Thus, for example, $+ \% \triangle I_g$ for pulses of 5 volts (as adjusted by the discriminator bias in volts) at 2·1 kV was 9·7 mA and that for pulses of 15, 35 and 50 volts was 1·16, 0 and 3·85 mA respectively. This relative effect became zero above the excitation potential of 2·1 kV. These results are not in agreement with those obtained by Arnikar and Nene[11] for the pulse height spectrum of hydrogen—discharge in an ozonizer

TABLE 1

INFLUENCE OF DIFFERENT LAMPS AND POTENTIALS OF HEIGHT PULSES ON RELATIVE LIGHT EFFECT IN ARGON

| | |
|---|---|
| Pressure of argon | = 10 mm $Hg$ |
| Source of irradiation | = 15 Watts, 210 Volts, glass bulb |
| Frequency of A.C. supply | = 50 Cycles/Sec |
| Current detector | = galvanometer |
| Temperature of the system | = room temp. (27°C) |

(Annular surface coated with $NaCl$ in $H_2O$ Solution

| V(k/V) | 5 V.D.B. | | | | 15 V.D.B. | | | | 20 V.D.B. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I_{gD}$ (mA) | $I_{gL}$ (mA) | $\triangle I_g$ (mA) | $\% \triangle I_g$ (mA) | $I_{gD}$ (mA) | $I_{gL}$ (mA) | $\triangle I_g$ (mA) | $\% \triangle I_g$ (mA) | $I_{gD}$ (mA) | $I_{gL}$ (mA) | $\triangle I_g$ (mA) | $\% \triangle I_g$ (mA) |
| 0·350 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 0·700 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1·050 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1·400 | 000 | 000 | 00 | 0·000 | 000 | 000 | 000 | 0·000 | 000 | 000 | 000 | 0·000 |
| 1·750 | 218 | 222 | —04 | —1·835 | 230 | 227 | +003 | +1·304 | 230 | 231 | —001 | —0·435 |
| 2·100 | 340 | 350 | —10 | —2·941 | 255 | 250 | +005 | +1·961 | 285 | 288 | —003 | —1·053 |
| 2·450 | 335 | 336 | —01 | —0·298 | 344 | 346 | —002 | —0·581 | 340 | 340 | 000 | 0·000 |
| 2·800 | 338 | 363 | —25 | —7·396 | 357 | 358 | —001 | —0·280 | 342 | 342 | 000 | 0·000 |
| 3·150 | 370 | 370 | 00 | 0·000 | 359 | 359 | 000 | 0·000 | 382 | 382 | 000 | 0·000 |
| 3·500 | 370 | 370 | 00 | 0·000 | 361 | 363 | —002 | —0·554 | 391 | 391 | 000 | 0·000 |

and external sleeve electrode — excitation showed a positive Joshi effect for very short pulses of amplitude < 5 V, changed to a negative effect of—100% for pulses of larger ( > 30 V) amplitude, the negative effect being linked preferentially with large height pulses.

The photo-electrons from activated adsorption, like ionic and molecular layer on the electrodes can possibly possess velocities ranging from zero to $v_m$ obtainable from the Einsteins' photo-electric equation.

$$h\nu = \Phi + \frac{1}{2} m v_m^2$$

$$h\nu = h\nu_0 + \frac{1}{2} m v_m^2 \qquad (1)$$

Here, $\Phi = h\nu_0$ is the photo-electric work function. $h$, $\nu$, $m$ and $\nu_0$ are the Plank's constant, the frequency of light, the mass of photo-electrons and the threshold frequency respectively. $\nu_0$ represents the beginning of the photo-electric activity of the emitter. Further $dN$ the total number of electrons of all velocities ejected in the unit time by unit intensity of absorbed light between frequency range $\nu$ and $\nu + d\nu$ is given by

$$dN = f(s)\, d\nu. \qquad (2)$$

Where $f(s)$ is the spectral distribution of function. The emission is zero at and below $\nu_0$ and increases with $\nu$ $( > \nu_0)$. The observed increase in $\mp \triangle I_g$ with $\nu$ follows. Capture of slow photo-electrons by the electronegative atoms or molecules leads to a negative space charge responsible for causing $+ \triangle I_g$. It is governed by the probability of electron attachment which is an inversion function of the electron energy, i.e. $E/P$ where $E$ is the field employed to the system and $P$ is the pressure of a gas[12]. The density

TABLE 2

INFLUENCE OF POTENTIAL AND PULSE AMPLITUDE ON RELATIVE EFFECT OF LIGHT IN ARGON

Pressure of argon No- B = 1000 mm *Hg*
Source of irradiation = 250 Watts, 210 Volts glass bulb
Frequency of A.C, Supply = 50 Cycles/Sec
Current detector = Galvanometer
Temperature of the system = room temp (27°C)

| | 5 V.D.B. | | | | 15 V.D.B. | | | |
|---|---|---|---|---|---|---|---|---|
| V(k/V) | $I_{gD}$ (mA) | $I_{gL}$ (mA) | $\triangle I_g$ (mA) | $\%\triangle I_g$ (mA) | $I_{gD}$ (mA) | $I_{gL}$ (mA) | $\triangle I_g$ (mA) | $\%\triangle I_g$ (mA) |
| 1·40 | 000 | 000 | 000 | 0·000 | 000 | 000 | 00 | 0·00 |
| 1·75 | 228 | 226 | +002 | +0·877 | 248 | 245 | +03 | +1·21 |
| 2·10 | 310 | 280 | +030 | +9·677 | 258 | 225 | +50 | +1·16 |
| 2·45 | 352 | 350 | +002 | +0·568 | 352 | 352 | 00 | 0·00 |
| 2·80 | 353 | 353 | 000 | 0·000 | 353 | 353 | 00 | 0·00 |
| 3·15 | 354 | 354 | 000 | 0·000 | 355 | 355 | 00 | 0·00 |
| 3·50 | 356 | 356 | 000 | 0·000 | 356 | 356 | 00 | 0·00 |
| | 35 V.D.B. | | | | 50 V.D.B. | | | |
| 1·40 | 000 | 000 | +000 | 0·00 | 000 | 000 | 00 | 0·00 |
| 1·75 | 265 | 250 | +015 | +5·66 | 240 | 239 | +01 | +0·42 |
| 2·10 | 350 | 350 | 000 | 0·00 | 260 | 240 | +20 | +3·85 |
| 2·45 | 353 | 353 | 000 | 0·00 | 353 | 353 | 00 | 0·00 |
| 2·80 | 354 | 354 | 000 | 0·00 | 354 | 354 | 00 | 0·00 |
| 3·15 | 355 | 355 | 000 | 0·00 | 355 | 355 | 00 | 0·00 |
| 3·50 | 356 | 356 | 000 | 0·00 | 356 | 356 | 00 | 0·00 |

of this negative space charge probably decreases with an increase in the electron-energy and consequent reduction in $P$. The simultaneous decrease in $P$ with $\nu$ through an opposite charge in emission energy arises as per result in the plot of current versus frequency of light. It is represented by the following relationship.

$$I_{g}o - I_{gL} = \triangle I_g = C(\nu - \nu_m), \tag{3}$$

where $C$ is a constant depending on $P$; $V$ represents the nature of the wall-surface, $I_{gD}$ and $I_{gL}$ are the r.m.s. values of currents in darkness and light respectively.

The net light effect ($\triangle I_g$) varies linearly with the change in frequency of light as required by the equation (3). Below $V_g$, when the emission is small, the resultant merges with the surface of negative ions and leads to saturation in $- \triangle I_g$ at large $I$. Beyond the inversion—potential, the negative space charge in the intermediate neighbourhood of the photo-active adsorbed gas layer leads to saturation in $+ \triangle I_g$ with respect to $I$.

## ACKNOWLEDGEMENT

The author expresses his grateful thanks to Professor S. S. Joshi for encouragement and making some reprints available during the course of the present study. He is also thankful to Professor H. J Arnikar for providing laboratory facilities and to Mr. S. S. Sardesai for assistance in the experimental work.

## REFERENCES

1. VENUGOPALAN, M., *Naturwissenschaften*, **46** (1959), 553.
2. VENUGOPALAN, M., *Nature*, **193** (1962), 1976.
3. JOSHI, S. S., "Presidential Address" (Indian Sci. Cong., Chem. Sec., Pt. 2), (1943), pp 55-65.
4. MOHANTY, S. R., *Nuovo Cimento*, **2** (1955), 1107.
5. VENUGOPALAN, M., *J. Phys. Soc., Japan*, **14** (1959), 1833.
6. MOHANTY, S. R., RAO, K. R. K. & BHAT, J. R., *Nuovo Cimento*, **3** (1956), 1463.
7. ARNIKAR, H. J., *Proc. Phys. Soc., London*, B **66** (1956), 256.
8. GODBOLE, E. W., *Cand. J. Phys.*, **34** (1956), 316.
9. VENUGOPALAN, M., *J. Phys. Soc. Japan*, **13** (1958), 1544.
10. VENUGOPALAN, M., *Helv. Phys. Act*, **32** (1959), 491.
11. ARNIKAR, H. J. & NENE, M. G., *Intern. J. Electronics*, **18** (1965), 408.
12. VENUGOPALAN, M. & MATHAI, K. U., "Astracts of Science in International Cong. Pure and Applied Chem. Abst.", 71, 46 (1961).