

Physics. — *On the increase of the sparking potential of a gas mixture by irradiation.* By F. M. PENNING. (Communicated by Dr. G. HOLST.)

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Some time ago measurements were published elsewhere ¹⁾ on the sparking potential of neon and argon to which very small amounts of other gases had been added. It was shown that in general for large values of pd (pressure \times distance between the electrodes) the sparking potential was much lowered if the ionisation potential of the admixed gas was smaller than the excitation potential of the main gas. For the explanation of this phenomenon it was assumed that metastable atoms of the main gas ionise the atoms of the admixture ²⁾).

An unambiguous proof for the correctness of this explanation was found in the influence of radiation on the sparking potential of such a gas mixture. This will be shown in what follows. When neon is used as the main gas, metastable atoms in the $2s_3$ - and $2s_5$ -state will be formed. In case an admixture of for instance 0.001 % argon is present, these metastable atoms with their long life time ³⁾ will have a considerable chance of ionising argon atoms. If, however, the life time of the metastable atoms is shortened artificially, the probability of the ionisation of an argon atom becomes smaller and the sparking potential increases. This shortening of the life time can be brought about by irradiation with neon light, for instance that of a positive column. Such a column emits for a large amount spectral lines of the type $2s_5-2p$ and $2s_3-2p$ ⁴⁾; by the light of these lines metastable atoms in the $2s_5$ - and $2s_3$ -states may be brought into one of the not metastable $2p$ -states. It is true that for the greater part they will fall back from this state into the $2s_5$ -state ⁵⁾, but a considerable number will also return, by way of the $2s_2$ - and the $2s_4$ -state, into the normal state. This latter number will not be able to ionise argon atoms; so, in order to obtain the wanted number of positive ions the potential on the tube must be made higher. In other words, illumination by the light of a neon tube will increase the sparking potential of the gasmixture.

In fig. 1 these processes are shown schematically. For the sake of

¹⁾ F. M. PENNING, *Naturwissenschaften* **15**, 818, 1927; *Zts. f. Phys.* **46**, 335, 1928.

²⁾ In the meantime this ionisation by metastable atoms has been demonstrated also optically, see R. FRERICHES, *Ann. d. Phys.* **85**, 362, 1928.

³⁾ H. B. DORGELO and T. P. K. WASHINGTON, *These Proceedings* **30**, 33, 1927.

⁴⁾ H. B. DORGELO, *Physica* **5**, 90, 1925.

⁵⁾ H. B. DORGELO and W. DE GROOT, *Zts. f. Physik* **36**, 897, 1926.

clearness only the two most important $2s$ -states ($2s_4$ - and the metastable $2s_5$ -state) are given, while the tenfold $2p$ -state is represented by one line. Transitions which are not accompanied by radiation are shown by dotted

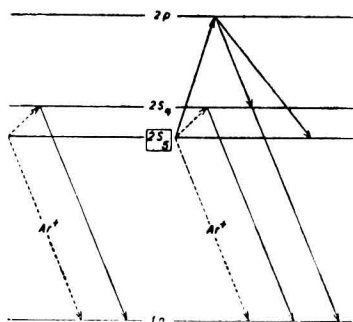


Fig. 1a.

Fig. 1b.

lines ; besides the transition from $2s_5$ to $2s_4$ (which limits probably in pure neon the life time of the $2s_5$ -atoms) we have in the case of an argon admixture the transition from $2s_5$ to the normal state by the way of the ionisation of an argon atom. Fig 1b and 1a show the transitions in case irradiation when a neon column is applied (fig. 1b) or not (fig. 1a).

Indeed, this effect of irradiation could be demonstrated. As an example the following experiment may be mentioned.

A discharge tube contained 20 mm neon with about 0.001 % argon, the electrodes were planè, parallel iron plates of $2\frac{1}{2}$ cm diameter, the distance between them was 1 cm. The discharge space was surrounded by a positive column tube, filled with 10 mm neon. This tube had been bent into a circle of about 3 cm internal diameter. A current of 15 mA through this latter tube gave rise to an increase of the sparking potential of 28 V ; for 100 mA the increase was 50 V¹⁾.

It should be remarked that a considerable increase of the sparking potential can be obtained only if not more than a very small amount of admixture is present. Indeed, with a large amount of admixture a metastable atom will ionise already after a small fraction of its natural lifetime. As a consequence of this the probability that a metastable atom is reduced to the normal state by irradiation becomes much less. So a discharge tube of the type already described, but filled with 25 mm neon and a drop of mercury (at room temperature 0.004 % Hg) showed no increase of the sparking potential when it was exposed to irradiation in the way as mentioned above. If however the vapour pressure of the mercury was lowered by cooling, then the effect showed itself again.

In the second place the pressure of the main gas should not be too high. As was stated higher up the destruction of the metastable atoms by irradiation is caused by the transition of the atoms from the $2p$ -states via the $2s_2$ - and $2s_4$ -state to the normal state. If the pressure becomes too high, the time t_1 between two collisions with gasatoms will become smaller than the natural life time t_2 of the s_2 - and s_4 -states (for neon at a pressure of 20 mm t_1 is already ²⁾ 10^{-8} sec., while t_2 is about 10^{-8} or 10^{-7} sec. ³⁾.) Now at a collision an atom in the s_2 - or s_4 -state has a considerable chance

¹⁾ See for these experiments also Physica 8, 137, 1928.

²⁾ For a normal neon atom t_1 is about 10^{-8} sec., therefore for an excited atom probably considerably lower.

³⁾ Cf. the experimental values of W. WIEN: Ann. d. Phys. 73, 483, 1924.

to pass into a metastable state of lower energy ¹⁾. It is clear that this effect diminishes the influence of the irradiation. The experiments point into the same direction. In the first efforts to detect the effect, the electrodes were very small and very near to each other (about 1 mm). In this way we were able to obtain a large radiation density by concentrating the light of the neon tube between the electrodes with a lense. In order to have appropriate values of pd , the pressure had to be made much higher, so it was taken 600 mm. Although in this experiment the decrease of the sparking potential by small amounts of argon showed itself in the usual way, an intense irradiation had no effect, in agreement with the remarks made above.

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¹⁾ Cf. J. FRANCK and P. JORDAN, *Anregung von Quantensprüngen durch Stösse*, Berlin 1926, p. 232 etc., P. D. FOOTE, *Phys. Rev.* **30**, 288, 1927; W. ORTHMANN and P. PRINGSHEIM, *Zts. f. Phys.* **46**, 160, 1927
