Citation:

H. Zwaardemaker, Radium as a Substitute to an equiradio-active amount for Potassium in the so-called physiological fluids; an experimental investigation in collaboration with mr. T.P. Feenstra, assistant at the Utrecht Physiol. Lab, in:
KNAW, Proceedings, 19 I, 1917, Amsterdam, 1917, pp. 633-636

These data appear to us to clearly demonstrate that the inhibition, proceeding from the false recognition in the interval, exerted upon the recognition of the primary stimulus, manifests itself also in the reaction-times. A comparison of the latter in the case of false recognition with those for the figures, the alteration of which was recognized in the interval (I and II) reveals that this inhibition is not insignificant with each observer. This appears still more clearly from a comparison of the times of I and IV, since the figures, shown only at the first sitting, were not under the influence of inhibition in the interval.

The fact that the time, required for recognition, in the case of a recognized alteration in the interval (II) is much shorter than the time needed for a sensation of novel experience (III) evoked for the altered figure, is easily accounted for by the circumstance that, owing to the novel sensation evoked by the figure, the experiencing person could not associate this figure with the primary one, which he could indeed when recognition of the alteration occurred.

Physiology. — *"Radium as a Substitute, to an equiradio-active amount, for Potassium in the so-called physiological fluids; an experimental investigation in collaboration with Mr.* T. P. FEENSTRA, *assistant at the Utrecht Physiol. Lab."* By Prof. H. ZWAARDEMAKER.

(Communicated in the meeting of Sept. 30, 1916).

Considering that potassium is the only radio-active element always present in the animal body, I suggested to Mr. T. P. FEENSTRA, about a year ago, to ascertain whether potassium could be replaced by other radio-active elements in non-toxic doses. It afterwards appeared that similar experiments had been performed on rubidium by S. RINGER, after whom the physiological solutions, in use nowadays, are generally named, when he expressed the relation of all the salts of the MENDELEJEFF-group (to which potassium belongs) to potassium salts, in equimolecular ratios. Mr. FEENSTRA, while abandoning the molecular ratios, followed quite a different method, viz. he measured the doses of his elements upon the basis of radio-activity, being fully alive to the responsibility for the view-point which he thereby assumed.

This bold, at all events extraordinary method of observation led in a few months to the results published in the communications of

April 28 and May 27, 1916[1]), in which the elements K., Rb., U., and Th. have been mutually compared. Their doses in the physiological solutions, used by FEENSTRA are in the ratios of their *total*[2]) radio-activities. The experiments were performed chiefly upon the frog's heart. It kept beating for hours in every one of the solutions, just as with the best prepared RINGER's mixture, in common use.

From the very beginning we have, moreover, proposed detecting at the same time any antagonism for the salts, in which the radioactive elements are used. Antagonism was found indeed and appeared to be primary, i.e. it concerns the system in which the excitability of the heart muscle arises automatically and spreads, for the antagonism affects the electrocardiogram as well as the myogram. Besides all reactions are reversible.

Finally the element Radium has also been examined in the same way.

The apparatus were arranged as before. A frog's heart, removed from the body, was first fed for fifteen minutes by means of a KRONECKER cannula with normal RINGER's mixture (NaCl 0.7 %, KCl 0.01; $CaCl_2$ 0.02; $NaHCO_3$ 0.02, glucose 0.1), to enable it to restore itself. Subsequently Potassium-free RINGER's mixture was given until, after a short retardation and irregularity, a standstill ensued. Only in the third place followed the administration of a potassium-free RINGER's mixture to which radium-bromide had been added to an amount, which, as far as its total radioactivity is concerned, may be considered about equal to the amounts of K., Rb., U., and Th., used in previous experiments.

The radium at the disposal of Mr. FEENSTRA was obtained of the Radiogen-Gesellschaft, branch-office at Amsterdam and was equal to 1000 Mache-units per litre of the original fluid. In the 7 cc. mixed with one litre of potassium-free RINGER's mixture this corresponded with about 3 micromilligrams (3.10^{-9} gram).

The small quantity of the solution supplied by the Company, which was to be one of the constituents of the circulating fluid, was neutralised beforehand and the fluid was used immediately afterwards in order to prevent a slow precipitation of the radium-salt in unacidulated fluids[3]).

Thus we invariably succeeded in 10 + 3 experiments in making

---

1) T. P. FEENSTRA, See these Proceedings Vol. 24 p. 1822; Vol. 25 p. 37 1916.

2) Total radio-activity after RUTHERFORD's data in MARX's Hdb. d. Radiology, Vol. 2 p. 519, 525; the measurement for Potassium and Rubidium was performed according to data found here and there in the book.

3) A. S. EVE, Amer. J. of Science (4) Vol. 22, 1906 p. 4

the heart resume its beats after it had been brought to a standstill by the potassium-free RINGER'S mixture. About 15 minutes after the radium-circulation has commenced maximal contractions occur at irregular intervals at first, but presently they become as rhythmic as previously in the same heart. If the radium-RINGER'S mixture is replaced by potassium-free RINGER'S mixture the radium-pulsations persist another hour or so. Finally the heart stops beating again. By applying radium-containing fluid again the beats recommence deliberately within a few (3—10) minutes. On the other hand, when administering normal RINGER'S mixture a radium-heart's action is arrested abruptly, from which it recovers only after an hour. These results are quite in accordance with those previously obtained with uranium and thorium and which were then considered to be due to the accumulative effect of the hardly diffusible ion and the rapidly incoming potassium-ion. The question of antagonism, being theoretically a matter of great moment, is kept back for a later paper. Thanks to Prof. SCHOORL'S kindness we were also now in a position to determine any accidental amount of potassium both in the radium-fluid and in the reagents. In all cases a Litre of potassium-free, resp. radium-containing circulating fluid contained less than 2.5 mgrms of potassium, an amount which, of itself, is incapable of maintaining the heart-beats, as has been shown in frequently repeated experiments.

In three experiments the emanation was removed from the radium solution used for the preparation of the circulating fluid (first by boiling, then by neutralising)[1]). In these cases also we succeeded in making the heart resume its beats; with a well-measured dose this was even effected perfectly in the normal space of time.

It is evident, therefore, that Potassium, Rubidium, Uranium, Thorium, and Radium can replace each other, as far as the heart is concerned, in the RINGER-circulating fluid, provided that doses are taken in proportion to their total radio-activity. With all of them the recovery of the cardiac action as well as its toxic inhibition occur in the same way. The most normal doses are: (See page 635).

I beg leave for the present to merely make mention of the facts detected. It goes without saying that they give ample scope for far-reaching speculations, but I wish to postpone them, as new experiments are being made, which, I feel confident, will throw more light upon these results.

As observed above, potassium is the only radio-active element that plays a part in ordinary life. It is very likely, however, that an important rôle is played only by the free, mobile potassium, that

1) RUTHERFORD in MARX'S Hdb. d. Radiologie Bnd 2 S. 422.

Metals used	$\frac{\text{litre-dose}}{\text{mol. weight}}$	salt-dose[1]) in mgr. per litre	metal-dose in mgr. per litre	total radio-activity per gramm per secunde	$\frac{\text{metal-dose}}{\text{atom weight met.}} = a$	$a \times$ tot. rad. in mgr. p. sec.
Potassium (as Pot.-chloride)	1.34	100	53	0.3×10^{-1} erg.	1.5	0.000045
Rubidium (as Rubidiumchloride)	1.20	150	105	0.7×10^{-1} erg.	1.2	0.000084
Uranium (mostly as uranylnitrate)	0.063	25	15	0.8 erg.	0.06	0.000048
Thorium (as Thoriumnitrate)	0.10	50	24	0.3 erg.	0.1	0.000030
Radium (as Radiumsalts)	1×10^{-8}	5×10^{-6}	3×10^{-6}	1.38×10^{6} erg.	1×10^{-8}	0.000019

occurs in the animal circulating-fluids and in the tissue-fluids, and that, carried along by ions, may adhere to the cells.

Utrecht, 28 September 1916.

Chemistry. — *"On the Influence of Temperature on Chemical Equilibria"*. By Dr. F. E. C. SCHEFFER. (Communicated by Prof. J. D. VAN DER WAALS).

(Communicated in the meeting of Sept. 30, 1916).

1. *The expression for the influence of temperature on equilibria.* When in a rarefied gas mixture or a diluted solution a chemical reaction is possible, there exists a definite relation between the concentrations of the reacting substances in the state of equilibrium. The "constant of equilibrium", the value of the product of the concentrations of the substances of one member of the reaction equation, divided by that of the concentrations of the substances of the other member, in which every concentration is raised to the power of which the exponent gives the number of molecules taking part in the conversion, is constant at a definite temperature, but

[1]) The salt doses in RINGER's mixture give some scope for variation, also when the Calcium-content is permanent; the values given are those actually used by us.