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ORIGINAL PAPER

Strange behaviour of our brain

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We are used to the experience that new thoughts must usually be worked for and do not appear all by themselves. This makes our mental work often very cumbersome and time-consuming and does not offer itself just by chance. This short paper, however, presents two examples, which prove—or at least seem to prove—that this statement is not rigorously correct or can even be questioned.

One of these examples was personally experienced and reported by Kekulé in about 1862 [1]. This scientist was deeply involved in the structure of organic molecules, and especially in that of benzene, whose structure containing six CH groups, i.e. (C_6H_6), could not be explained on the basis of Kekulé's knowledge about any known structural entities. Kekulé reported that in his mind, he saw very different parts and pieces of CH chains which danced around but did not come to a rest while he was watching the molecular theatre [2]. But look!! He was extremely alerted when he suddenly detected one chain—he calls it a snake—consisting of six CH entities that behaved in a hitherto unseen way in that its one end grabbed and attached itself to the other end and thus formed a ring-like kind of molecule. This ring consisting of six CH groups was stable and joined in the movements of all the other parts and pieces of the molecular dance. Kekulé concentrated on this special molecule, investigated its behaviour rather thoroughly and came to the conclusion that this six-CH ring was exactly the kind of molecule he had been looking for during the last weeks. Strange enough, his brain had thus found the basis of all six-CH ring (or $(CH)_6$) molecules just by itself.

The second and main example of this short text is concerned with a similar but, nevertheless, basically different story. The subject is the functioning of glass electrodes. pH and pM glass electrodes exhibit a sub-Nernstian response at medium pH and pM values outside the acid and sodium error range [3]. This effect is normally not noticed because it is hidden within the slope factor when glass electrode-containing electromotive cells with transference are standardized. However, it can be measured when glass electrode potentials are directly compared with that of the platinum hydrogen electrode, which exhibits the theoretical slope, $k=(RT\ln 10)/F$, and when glass and platium/hydrogen electrode potentials are indirectly compared in cells with a common reference electrode. The practical slope k_{gl} is referred to the theoretical slope by the 'electromotive efficiency' $\alpha=k_{gl}/k$ introduced by Bates [4].

The sub-Nernstian response was detected rather early. For instance, Kratz in 1951 cited several papers from which $\alpha \geq 0.996$ could be estimated [5]. Bates reported that electromotive efficiencies could be as small as $\alpha=0.995$ in the intermediate pH range [5], and Covington published

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EMFs which yielded $\alpha \geq 0.997$ [6]. Also, our own measurements resulted in $\alpha=0.997$ to 0.998 for a glass electrode with lithium silicate-based membrane glass. Surprisingly, all of these glasses and several others exhibit a comparable sub-Nernstian reponse of a magnitude around $\alpha=0.997$, independent of the membrane glass composition. Obviously, this is not just caused by chance, but must be the consequence of some kind of law, whose origin seems to be connected with the membrane glass or the electrode. The cause, however, remained unknown for a long time.

These problems kept me extremely active. What was the cause of the effect that was so reproducible? All possible reasons were thought but did not even hint to a reasonable answer. For nights I did not really sleep but was kept awake by the problem and the connected questions, and this went on for quite some time until one night when I had finally fallen asleep but had not really found a dreamless rest. My brain had kept working; it was a kind of half-sleep, and near midnight, I suddenly had a strange feeling: I awoke and at once I literally saw the solution of the problem, a faulty equation that had kept me from many nights of relaxing sleep. I saw a basic error I had made during all of this time: The glass electrode function is not just the consequence of a number, the pH (or pM), which is put into the Nernst equation, as I had erroneously assumed, but constitutes one of the numbers of the equilibrium between the participants in the equilibrium between the solution and the glass surface. The change of the pH (or pM) thus changes also the activities (or concentrations) of all members of the equilibrium, which means that the applied pH (or pM) also changes the slope of the electrode function, and I saw also at once that the resulting slope was necessarily slightly smaller than the slope assumed as the consequence of the constant members of the Nernst equation. Surprisingly, my brain had solved the problem that had kept me so busy for weeks, and it had done so all by itself.

The two examples given seem to be rather similar but are nevertheless basically different. The one concerned with the organic molecules and the six-ring is a qualitative example, whereas the (second) glass electrode example rests on a quantitative equation, and the corrections are quantitatively mathematical expressions given by the numbers of the equilibrium. Nevertheless, also this solution appeared within a dream. Of course, one can speculate about a possible remembrance of a similar equation. But such cause is expected with much less probability for the equation than for the qualitative appearance of a ring-shaped molecule. Thus, it seems that both appearances should be taken as what they represent—the results of the quiet work of our sleeping brain

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