Chemistry. — *Osmosis in systems consisting of water and tartaric acid and containing three liquids, separated by two membranes.* II. By F. A. H. SCHREINEMAKERS and H. H. SCHREINEMACHERS.

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V. *Influence of the position of the two membranes on the stationary state.*

If for the sake of simplicity we substitute the 3.999 % of tartaric acid of system (22) in Comm. I by 4 %, we have the system:

$$\begin{array}{ccccc} & \textit{cell.} & \triangle m > o & \textit{bl.} & \\ \textit{inv.}\ (W) & | & \textit{stat.}\ (\pm 1.958\ ^0/_0) & | & \textit{inv.}\ L'\ (4\ ^0/_0\ \textit{tart. ac.}) \\ & \rightarrow & W & \leftarrow o\ * & \\ & \leftarrow & \textit{tart. ac.} & \leftarrow + & \end{array} \quad . \quad . \quad . \quad (1)$$

in which the membrane on the left consists of cellophane and the membrane on the right of pig's bladder. As appears from the arrows, the water diffuses inwards through both membranes; the tartaric acid diffuses inwards through the bladder and outwards through the cellophane. As has been indicated by the sign + with the corresponding arrow, more tartaric acid diffuses inwards than outwards, however. The quantity of the stat. liquid continuously increases, as has been indicated by the sign $\triangle m > o$.

If we also substitute the 4.005 % of tartaric acid of system (25) in Comm. I by 4 %, we have the system:

$$\begin{array}{ccccc} & \textit{bl.} & \triangle m < o & \textit{cell.} & \\ \textit{inv.}\ (W) & | & \textit{stat.}\ (\pm 1.936\ ^0/_0) & | & \textit{inv.}\ L'\ (4\ ^0/_0\ \textit{tart. ac.}) \\ & \leftarrow o\ * & W & \rightarrow & \\ & \leftarrow + & \textit{tart. ac.} & \leftarrow & \end{array} \quad . \quad . \quad . \quad (2)$$

in which the membrane on the left now consists of a bladder and the membrane on the right of cellophane; the two invariant liquids, however, are the same as in system (1).

The water, however, now diffuses outwards through the two membranes; the tartaric acid, however, still diffuses towards the left through both membranes just as in (1), but now, as has been indicated by the sign +

with the corresponding arrow, more tartaric acid runs outwards than inwards. The quantity of this stationary liquid now decreases continuously, as has been indicated by $\triangle m < o$, whereas in (1) it increased continuously.

In the systems (1) and (2) one of the invariant liquids consisted of pure water; the osmosis (namely the direction of the arrows etc.) will not change, however, when the water contains a little tartaric acid besides, we shall call this liquid "diluted" and we shall represent it by L_d. The same obtains also when the other invariant liquid contains some little quantity of tartaric acid; as we assume, however, that this liquid contains more tart. acid than L_d, we shall call it "concentrated" and we shall represent it by L_c

We now represent these systems by:

$$\begin{array}{c} \textit{cell.} \qquad \textit{bl.} \\ inv.\, L_d \mid \triangle\, m > o \mid inv.\, L_c \\ \rightarrow \quad W \quad \leftarrow o\, * \\ \leftarrow tart\ ac. \leftarrow + \end{array} \qquad \text{(1a)}$$

$$\begin{array}{c} \textit{bl.} \qquad \textit{cell.} \\ inv.\, L_d \mid \triangle\, m < o \mid inv.\, L_c \\ \leftarrow o\, * \quad W \quad \rightarrow \\ \leftarrow + tart.\ ac. \leftarrow \end{array} \qquad \text{(2a)}$$

which we shall call (1*a*) and (2*a*).

From this follows among other things:

1. When the diluted liquid L_d is next to the cellophane (system 1*a*), the quantity of the stationary liquid increases continuously; when the diluted liquid L_d is next to the bladder, the quantity of the stationary liquid decreases continuously (system 2*a*).

2. If we change the places of the two membranes of one of the systems (1*a*) or (2*a*), one system will pass into the other. From this it appears that the interchange of the membranes has a great influence on the progress of the osmosis (comp. 1 and 1*a* with 2 and 2*a*).

3. If in system (1*a*) we add water on the left side and a little tartaric acid on the right side, the left-side liquid will remain diluted and the right-side liquid concentrated; the osmosis will then develop in a similar way.

4. If in system (1*a*) we add a sufficient quantity of tartaric acid on the left side, and on the right side a sufficient quantity of water, so that the left-side liquid now becomes the concentrated- and the right-side liquid the diluted one, (1*a*) will pass into the system:

$$\begin{array}{c} \textit{cell} \qquad \textit{bl.} \\ inv.\, L'_c \mid \triangle\, m < o \mid inv.\, L'_d \end{array} \qquad (3)$$

As the diluted liquid now is next to the bladder, this system now is the same as (2*a*), only the sequence from left to right is different.

From 3 and 4 it now appears that for the progress of the osmosis in system (1*a*) it makes a great difference whether we add water on the left side and tartaric acid on the right side or vice versa. Of course the same also obtains for system (2*a*).

We may suppose the liquids i_1 and i_2 of the stationary system:

$$inv.\, i_1 \mid stat.\, L \mid inv.\, i_2 \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (4)$$

remain invariant, because of a continuous current of i_1 and i_2 flowing along the membranes, or because i_1 and i_2 are a kind of tissues in which the state remains practically invariant. In the space between these two invariant states, a stationary liquid L will then form.

We now imagine the space of the stationary liquid completely closed, but for a tiny opening, and the quantity of this liquid continuously increasing; we may then compare this space with the cavity of a gland and liquid L with the fluid secreted.

This secreted fluid generally has quite an other composition than the currents of tissues i_1 and i_2; nor can it generally be looked upon as a mixture of these liquids.

In this simple example the composition of this glandular secretion depends upon:

1. the state of the two currents or tissues i_1 and i_2.

2. the nature of the two membranes and the ratio of their surfaces.

Every change in one or more of these factors will also cause a smaller or greater change in the composition of the glandular secretion.

We now may suppose also that one or two membranes gradually change in such a way that the quantity of the secretion, instead of increasing continuously, now begins to decrease. The gland will then stop functioning as such, although the two tissues may have remained perfectly unchanged: of course this may also be the case when one or both tissues change gradually [1]).

VI. *A combination of two membranes.*

If we place a piece of cellophane and a piece of a pig's bladder against each other in such a way that they stick closely together and no room is left between them, then we may consider this combination as a single membrane, the one layer consisting of cellophane and the other of a blad-

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[1]) Later on one of us will refer in extenso to stationary states in connection with tissues and glands. Comp. also F. A. H. SCHREINEMAKERS, These Proceedings **35**, p. 1131 (1932).

der. If we now bring this combination-membrane between the two liquids L_d and L_c, we have the osmotic systems:

$$\begin{array}{r|l} \textit{cell.} & \textit{bl.} \\ \textit{inv.}\ L_d & \textit{inv.}\ L_c \end{array} \quad \ldots\ldots\ldots \quad (1b)$$

$$\begin{array}{r|l} \textit{bl.} & \textit{cell.} \\ \textit{inv.}\ L_d & \textit{inv.}\ L_c \end{array} \quad \ldots\ldots\ldots \quad (2b)$$

which we shall call (1*b*) and (2*b*). These systems now consist of the same liquids and the same membrane, which however in (1*b*) turns its cellophane-layer towards the left and in (2*b*) towards the right. We get these systems (1*b*) and (2*b*) by placing the two membranes in (1*a*) and (2*a*) against each other.

As osmosis occurs in these systems (1*b*) and (2*b*), the water and the tartaric acid will diffuse continuously in some direction or other through the two layers and consequently also through the boundary plane they have in common.

We now can imagine that at a certain moment of the osmosis the cellophane and the bladder under some influence or other will get loose from each other in some small spot, so that a small cavity will form between the two layers; this will then be filled with a small quantity of the diffusing substances and will pass into a stationary state. We now distinguish two cases.

1. When this takes place in system (1*b*), it passes into system (1*a*) in which, however, there is only a small quantity of the stationary liquid as yet. As this quantity continuously increases, however, the two layers will get further away from each other. We now represent this system by:

$$\textit{inv.}\ L_d \overset{\textit{cell.}}{\ } \left(+\right) \overset{\textit{bl.}}{\ } \textit{inv.}\ L_c \quad \ldots\ldots\ldots \quad (5)$$

in which for the sake of clearness a biconvex form has been given to the combination.

2. When it takes place in system (2*b*), viz. the cellophane and the bladder getting loose in a small spot, (2*b*) will pass into (2*a*). As the quantity of the stationary liquid now decreases, however, the small quantity of liquid that has penetrated between the two layers, will disappear again; so the membrane will not become biconvex now, but remain unchanged.

To be able to observe these phenomena, we took the system

$$\begin{array}{r|l} \textit{cell.} & \textit{bl.} \\ \textit{Water} & L\ (4\ \%\ \textit{tart. ac.}) \end{array} \quad \ldots\ldots\ldots \quad (6)$$

in which, however, the two liquids were not kept invariant, so that they changed during the osmosis ; this does not influence the occurring or non-occurring of these phenomena, however.

After some hours (6) had passed already into a system

$$\overset{cell.}{L_d}\left(+\right)\overset{bl.}{L_c} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (7)$$

in which the liquid between the two layers could already be seen quite clearly, its quantity increasing continuously.

When this combination-membrane was turned round [1]), and we consequently had the system

$$\overset{bl.}{L_d}\left(-\right)\overset{cell.}{L_c} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (8)$$

we saw the liquid absorbed disappear again and the membrane becoming flat ; this was still the case when we again replaced L_d by pure water and L_c again by a liquid with 4 % of tartaric acid.

It appears from these investigations and theoretical considerations that similar phenomena are to be expected with all membranes, consisting of two or more layers of a different nature ; the turning of the membrane or, what is the same, the interchange of the two liquids may here have a greater or a smaller influence on the progress of the osmosis, depending on the difference in the nature of the layers and the compositions of the liquids.

In order to show the influence of the position of a membrane (or of its turning) in still another way we took the two systems :

$$\begin{array}{r|l} cell. & bl. \\ L\,(2\,\%) & L\,(2\,\%) \end{array} \quad (1c) \quad \text{and} \quad \begin{array}{r|l} bl. & cell. \\ L\,(2\,\%) & L\,(2\,\%) \end{array} \quad . \; . \quad (2c)$$

which we shall call (1*c*) and (2*c*). As the two liquids had the same composition in both systems (namely 2 % of tart. acid) there was no osmosis of course. The two systems differ only in the position of the membrane. We now added in both systems water on the left side and a little tartaric acid on the right side.

Then system (1*c*) passed into a system (7), in which after a few hours a liquid could already clearly be observed between the cellophane and the bladder, its quantity continuously increasing.

In system (2*c*) no liquid formed between the two layers of the combination-membrane.

When we turned the membrane in system (7) which had developed from system (1*c*), we saw, as was indeed to be expected, that the liquid taken in between the two layers, disappeared again.

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[1]) Experimentally it is simpler of course not to turn the membrane, but to interchange the two liquids ; indeed we did it in this way.

If in the osmotic system

$$inv.\,(Water)\,|\,L\,(W + tart.\,ac.) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

we bring a membrane of cellophane, the osmosis proceeds according to the D.T.

$$\rightarrow W \qquad \leftarrow tart.\,ac. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

no matter what concentration the variable liquid L may have at the beginning of the osmosis. (Comm. I, pg. 1243).

If, however, we bring a membrane of pig's bladder in this system, then the osmosis does depend upon the concentration the variable liquid has at the beginning of the osmosis, and no water will diffuse when liquid L has a certain concentration; we have called this liquid the neutral liquid L_n (Comm. I, pg. 1243).

If at the beginning of the osmosis we now take for L in system (9) a liquid with a greater amount of tart. acid than liq. L_n, then the substances will first diffuse for some time according to the first D.T. and afterwards until the end of the osmosis according to the second D.T. of (11) namely:

$$\left.\begin{array}{lll} first & \rightarrow W & \leftarrow tart.\,ac. \\ later\ on & \leftarrow o * \ W & \leftarrow tart.\,ac. \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

The composition of the neutral liquid L_n at which the water-diffusion changes its direction, depends upon the nature of the pig's bladder used; with one of the bladders we found $\pm$ 14 %, with an other $\pm$ 17 % and with a third $\pm$ 21 % of tart. acid.

We now may put the question according to which D.T.'s the osmosis will proceed, when we bring a combination-membrane of cellophane and a pig's bladder in system (9).

In order to examine this we took the system

$$\begin{array}{r|l} bl & cell. \\ inv\ \ (Water) & L\,(beg.\ 28\ 1\ {}^0/_0\ tart.\,ac.) \end{array} \quad . \quad . \quad . \quad . \quad (12)$$

in which the variable liquid contained 28.1 % of tart. acid at the beginning of the osmosis. As the combination-membrane is next to the water with its layer of bladder, it was very probable that the combination would behave during the entire osmosis as a single membrane, namely that no liquid would form between the two layers (comp. 2*b* and 8); the experiment has indeed confirmed this.

The data for this osmosis are found in table 1. In column 1 we find the numbers of the successive determinations, in column 2 the number of hours that passed after the beginning of the osmosis; in column 3 we find the amount of tart. acid of the variable liquid. In columns 4 and 5 we find the number of grams of tart. acid and water, taken in (sign +) or given off

TABLE I

N⁰.	t in hours	°/₀ tart. ac. of the variable liq.	Diffused to the var. liq.		Δm
			gr. tart. ac.	gr. W	
1	0	28.10			
2	24	27.71	− 0.98	+ 2.728	+ 1.748
3	113	26.02	− 4.53	+ 10.456	+ 5.926
4	237	24.35	− 4.29	+ 10.492	+ 6.202
5	424	22.12	− 6.54	+ 12.266	+ 5.726
6	664	20.10	− 5.94	+ 11.038	+ 5.098
7	1024	17.69	− 7.52	+ 12.222	+ 4.702
8	1433	15.55	− 7.03	+ 9.386	+ 2.356
9	1907	13.51	− 6.97	+ 7.042	+ 0.072
10	2431	11.60	− 6.40	+ 5.945	− 0.455
11	3049	9.346	− 7.36	− 1.010	− 8.370
12	3528	7.345	− 6.10	− 1.973	− 8.073
13	4166	4.632	− 7.61	− 5.087	− 12.697

(sign —) by the variable liquid between two successive determinations. From these columns 4 and 5 the last column follows at once, namely the total quantity Δm taken in (sign +) or given off (sign —) by the variable liquid between two successive determinations.

From this it appears that the tartaric acid diffuses ← during the entire osmosis and the water first → and afterwards ← o ⋆ so that the two D.T.'s (11) occur; the neutral liquid contains ± 10 % of tart. acid.

So this combination-membrane of a bladder and cellophane always behave as if it consisted of a bladder only; yet there are differences of course; the velocity of the osmosis namely is much smaller (after 4166 hours or almost 173 days the amount of tartaric acid, which at the beginning of the osmosis was 28.1 %, had decreased to no more than 4.632 %, whereas this amount in a system with a bladder only, had decreased after more than 34 days from 25.768 % to 0.137 % already); the neutral liquid also has a smaller amount of tartaric acid (namely ± 10 %) than when only a bladder was used (namely ± 14, 17 and 21 %).

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