Chemistry. — *Membrane and Osmosis.* III. By F. A. H. SCHREINEMAKERS.

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Osmosis through a membrane $M(W)$.

We now take the osmotic system (1) in which between the liquids L and L' a membrane $p\,q\,q'\,p'$ is found, absorbing water only. It now depends upon the W-amount of this membrane what will take place at

$$L \quad \begin{array}{r|c|l} p & - & p' \\ & & \\ q & - & q' \end{array} \quad L' \quad \ldots\ldots\ldots \quad (1)$$

the beginning. When, namely, the membrane does not yet contain water, it will first absorb it from both liquids; if the membrane already contains water, then several cases may occur; it may for instance give a part of its water to both liquids; etc.

We now imagine, however, that in some way or other we keep the composition of both liquids constant, so that a stationary state will set in after some time; then the membrane will every moment absorb as much water from the one liquid as it gives out to the other liquid.

We now assume that the boundary plane $p\,q$ of the membrane is practically in equilibrium with the liquid L and $p'q'$ with the liquid L'; the boundary plane $p\,q$ then gets a W-amount $= w_0$ and the boundary plane $p'q'$ a W-amount $= w'_0$. As we have seen in the communications [1]) M. O. I and M. O. II, these W-amounts w_0 and w'_0 differ of course from the W-amount of the liquids L and L'.

For the sake of concentration we now take $w_0 > w'_0$; it is natural to assume that the water will now diffuse from $p\,q$ towards $p'q'$ and, therefore, also from the liquid L towards L'.

We can prove that this is indeed what happens; in connection with further considerations (namely when more substances diffuse) we shall deduce this in the following way.

If in system (1) we bring still a second membrane $r\,s\,s'\,r'$, then we get a system such as has been represented in (2). We imagine this membrane $r\,s\,s'\,r'$ resembles the first in every respect. Then the boundary plane $r\,s$ will also get a W-amount $= w_0$ and the boundary plane $r'\,s'$ a W-amount $= w'_0$.

1) F. A. H. SCHREINEMAKERS. These Proceedings 32. 837, 1024 (1929)

We now begin by supposing the four boundary planes enclosed by an impermeable wall. If we now open the boundary plane *r s*, then the

	p	—	p'	
	q	—	q'	
L				L' . . . . (2)
	r	—	r'	
	s	—	s'	

membrane $r\,s\,s'\,r'$ will after some time be practically in equilibrium with the liquid L and will then have a W-amount $= w_0$. Now we close $r\,s$ and open $r'\,s'$; the membrane will come into equilibrium with the liquid L' and get a W-amount $= w'_0$. As, according to what we have assumed, $w_0 > w'_0$, water will now have passed from the liquid L towards the liquid L'.

So by successively opening and closing $r\,s$ and $r'\,s'$ we can get a "periodical" current of water, going from L towards L'.

We now open the planes $p\,q$ and $p'\,q'$ simultaneously; a "stationary" current of water will now run through the membrane $p\,q\,q'\,p'$. We now are able to prove:

A. the "stationary" and the "periodical" current of water run in the same direction.

For if both currents did not run through the membrane in the same direction, we could with the necessary precautions, regulation of the surfaces of the membranes etc. obtain that the two liquids L and L' did not change their compositions; then we might get an eternal current of water. As we assume that this is not possible, the two currents cannot run through the membrane in opposite direction; consequently they run in the same direction. From this it now follows:

B_1. when two liquids give a different W-amount to a membrane, the water will diffuse from the liquid, giving the greater W-amount to the membrane towards the liquid, giving the smaller W-amount to the membrane.

B_2. when two liquids give the same W-amount to a membrane, no water will diffuse.

In order that we may express this result in still an other way, we shall say:

when two liquids give an equal W-amount to a membrane, they will have the same M.W.F. (Membrane-Water-Force);

when two liquids give a different W-amount to a membrane, the liquid, giving the greater W-amount, will also have the greater M.W.F.

Instead of B_1 and B_2 we now may say also:

C_1. when two liquids have a different M.W. F., the water will diffuse from the liquid with the greater-towards that with the smaller M.W. F.

C_2. when two liquids have the same M.W. F., then no water will diffuse through the membrane.

In a preceding communication we have deduced:

D_1. when two liquids have a different O. W. A. (Osmotic-Water-Attraction) then the water will diffuse from the liquid with the smaller-towards the liquid with the greater O. W. A.

D_2 when two liquids have the same O. W. A., then no water will diffuse through the membrane.

If we compare C_1 and C_2 with D_1 and D_2, we see that with the osmosis of the water the M. W. F. of a liquid plays a part, corresponding to that of its O. W. A.; from this it appears besides what may also be deduced in an other way:

E_1. when two liquids have the same O. W. A., they will also have the same M. W. F.;

E_2 when two liquids have a different O. W. A., they will also have a different M. W. F.; the liquid with the greater O. W. A. has the smaller M. W. F.

All we have found previously with the aid of the O. W. A., now can be found also with the aid of the M. W. F. We found with the aid of the O. W. A. among other things;

F. when two liquids contain only a single other substance besides water, the water will always diffuse through a membrane M (W) from the liquid with the greater-towards the liquid with the smaller *W*-amount.

In order now to deduce this also with the aid of the *W*-amount of the membrane, we take the osmotic system:

$$L\,(a_1) \mid M(W) \mid L\,(a_2) \quad . \; . \; . \; . \; . \; . \; . \; . \quad (3)$$

in which a liquid a_1 is on the left side of the membrane and on the right side a liquid a_2. In fig. 1 of Comm. M. O. I we imagine them represented by the points a_1 and a_2; then the left side liquid has a greater *W*-amount than the right side liquid.

In Comm. M. O. I we have seen that the *W*-amount, a membrane $M(W)$ gets in liquids consisting of $W+X$, may be represented by the *W*-curve of this membrane; we imagine it to be represented in fig. 1 of Comm. M. O. I by the curve $W' w_1 w_2 X$; from W' till in X this curve falls monotonously.

The liquid a_1 gives a *W*-amount $= a_1 w_1$ to the membrane; the liquid a_2 gives a *W*-amount $= a_2 w_2$ to this same membrane. As the left side liquid now gives a greater *W*-amount to the membrane than the right side liquid, the water must, therefore, (comp. B_1) diffuse towards the right.

As the left side liquid also has a greater W-amount than the right side liquid, the symbol:

$$\underset{\rightarrow}{\geq} W \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (4)$$

must obtain for the osmosis in system (3), so that the water diffuses positively. Instead of F we now may say:

G. when two liquids contain only one single other substance besides water, the water will always diffuse positively through a membrane $M(W)$.

If instead of a membrane $M(W)$ we have a membrane $M(X)$, then of course F and G will also obtain for the substance X; so in generally we may say:

H. in a binary osmotic system a substance will always diffuse through a membrane, permeable for this substance only, positively and never negatively.

Of course, what has been said in H, only obtains for binary osmotic systems, and does so no longer when the systems' contain three or more substances. When namely the liquids of the osmotic system:

$$L \mid M(W) \mid L' \quad . \ . \ . \ . \ . \ . \ . \ . \ . \quad (5)$$

contain not only water, but two or more other substances besides, then the nine cases of scheme I are possible.

SCHEME I.

1. $\underset{\rightarrow}{\geq}$	2. $\underset{\leftarrow}{\geq}*$	3. $\underset{—}{\geq}*$
4. $\underset{\rightarrow}{\leq}*$	5. $\underset{\leftarrow}{\leq}$	6. $\underset{—}{\leq}*$
7. $\underset{\rightarrow}{=}*$	8. $\underset{\leftarrow}{=}*$	9. $\underset{—}{=}$

In 1, 2 and 3 the left side liquid has a greater-, in 4, 5 and 6 a smaller W-amount than the right side liquid; in 7, 8 and 9 both liquids have the same W-amount.

In 1 and 5 the water diffuses from the liquid with the greater-towards that with the smaller W-amount; so here we have a positive osmosis.

In 2 and 4 the water diffuses from the liquid with the smaller-towards that with the greater W-amount; so here we have a negative osmosis.

In 3 and 6 no water diffuses, although both liquids have a different W-amount; in 7 and 8, however, water does diffuse indeed, although both liquids have the same W-amount; we may call this also a negative osmosis.

In 9 both liquids have the same W-amount and no water diffuses.

In order to illustrate this with an example, we take for L and L' ternary liquids, which we suppose to be represented in fig. 1.

Through point e we draw a line di, parallel to side XY of triangle WXY, which has not been drawn; we then have:

all liquids of the line di have the same W-amount as liquid e; so the liquids *f*, *g* and *h* have the same *W*-amount as *e*. (comp. 7, 8 and 9 of scheme II).

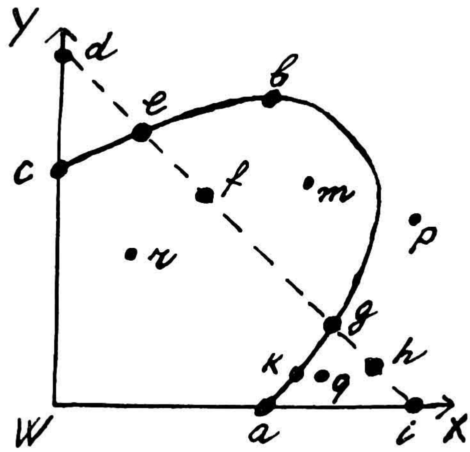

Fig. 1.

all liquids within field *W i d* have a greater *W*-amount than liquid *e*. so the liquids *q*, *k* and *r* have a greater *W*-amount than *e*. (comp. 4, 5 and 6 of scheme II).

all liquids outside field *W i d* have a smaller *W*-amount than liquid *e*; therefore, the liquids *m*, *b* and *p* have a smaller *W*-amount than *e* (comp. 1, 2 and 3 of scheme II).

We now imagine that curve *a b c*, running through point *e* is an isotonic *W*-curve. We then have, as was already deduced before:

all liquids of curve *a b c* have the same O. W. A. as liquid *e*. As the liquids *b*, *g* and *k* are situated on this curve, no water will consequently pass through the membrane in the systems 3, 6 and 9 of scheme II.

all liquids within field *W a b c* have a smaller O. W. A. than liquid *e*. As the liquids *r*, *m* and *f* are situated within this field and consequently have a smaller O. W. A. than liquid *e*, water must diffuse from these liquids towards *e* (comp. 2, 5 and 8 in scheme II).

all liquids outside field *W a b c* have a greater O. W. A. than liquid *e*; as the liquids *p*, *h* and *q* are situated outside this field and have, therefore, a greater O. W. A. than liquid *e*, water must diffuse from *e* towards these liquids. (comp. 1, 4 and 7 of scheme II).

SCHEME II.

1. $\underrightarrow{e > p}$	2. $\underleftarrow{e > m}$ *	3. $\underline{e > b}$ *
4. $\underrightarrow{e < q}$ *	5. $\underleftarrow{e < r}$	6. $\underline{e < k}$ *
7. $\underrightarrow{e = h}$ *	8. $\underleftarrow{e = f}$ *	9. $\underline{e = g}$

We see that the direction in which the water diffuses through a membrane, is not determined by the *W*-amount of the liquids; for as we have seen previously the O. W. A. of a liquid depends not only on its W-amount, but also on the nature and the concentration of the other substances.

All we have deduced above with the aid of the O. W. A. of the liquids, we can now find also with the aid of their M. W. F. with the aid of the W-amount, these liquids give to the membrane.

We now imagine that fig. 1 (Comm. M. O. II) represents the W-plane of a membrane $M(W)$; curve $a\,b\,c$, viz. the projection of the horizontal section $a'\,b'\,c'$ will then represent the liquids, giving an equal W-amount to the membrane; we have called this curve an iso $W.M(W)$-curve.

If we bring a membrane $M(W)$ between two liquids of this curve $a\,b\,c$, it follows B_2 (present communication) that no water will diffuse. From this follows the property we have mentioned already in M. O. II, viz:

an iso $W.M(W)$-curve is also an isotonic W-curve; and the converse: an isotonic W-curve is also an iso $W.M(W)$-curve.

So we may now assume also that in fig. 1 of this communication curve $a\,b\,c$, running through point e is an iso $W.M(W)$-curve; we then have:

all liquids of curve $a\,b\,c$ give the same W-amount to the membrane as liquid e. As the liquids b, g and k are situated on this curve, no water will consequently pass through the membrane in the systems 3, 6 and 9 of scheme II.

It appears from fig. 1 (Comm. M. O. II) that all liquids within the field $W\,a\,b\,c$ give a greater W-amount to the membrane than the liquids of curve $a\,b\,c$; from this follows for fig. 1 of this communication:

all liquids within field $W\,a\,b\,c$ give a greater W-amount to the membrane than liquid e. As the liquids m, r and f are situated within this field, it follows with the aid of B_1, that the water must diffuse from m, r and f towards e (comp. 2, 5 and 8 of scheme II).

It also appears from fig. 1 (Comm. M. O. II) that all liquids outside field $W\,a\,b\,c$ give a smaller W-amount to the membrane than the liquids of curve $a\,b\,c$; from this follows for fig. 1 of this communication:

all liquids outside field $W\,a\,b\,c$ give a smaller W-amount to the membrane than liquid e. As the liquids p, q and h are situated outside this field, it follows with the aid of B_1, that the water must diffuse from the liquid e towards p, q and h (comp. 1, 4 and 7 of scheme II).

From this we see that with the aid of the W-amount the liquids give to a membrane, the same result is obtained as with the aid of the O. W. A. of the liquids.

The direction in which the water diffuses is determined by the W-amount, the liquids give to the membrane; it is clear that not only the W-amount of these liquids plays a part here, but also the nature and the concentration of the other substances.

We may summarise some of the preceding results as follows:

I. in general the water can diffuse through a membrane $M(W)$ as well positively as negatively; when, however, both liquids are binary, it will diffuse positively only and never negatively.

As the same obtains for any other substance S and a membrane $M(S)$ we can say, therefore:

K. in general a substance S can diffuse through a membrane $M(S)$ as well positively as negatively; when, however, both liquids are binary, the substance S will diffuse only positively and never negatively.

It will not be necessary here to dwell on the fact, that all that has been deduced above, only obtains for a membrane, permeable for one single substance only. For a membrane $M(n)$ namely obtains, as we have already deduced previously:

L. through a membrane $M(n)$ a substance can always diffuse as well positively as negatively; here namely it does not matter whether the liquids are binary or not.

So we may say also:

M_1. positive osmosis can occur with all membranes and in all systems.

M_2. with a membrane $M(n)$ negative osmosis can occur in all systems; with a membrane, permeable for one substance only, however it can occur only in systems, containing three or more substances.

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