Chemistry. — *Osmosis of ternary liquids. General considerations IX.*
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(Communicated at the meeting of February 23, 1929).

The isentonic curves and the membrane.

For an osmotic system, in which the substances X, Y and W diffuse through the membrane, obtains among other things, as we have seen in Gen. VI and VII :

a. Eight D.T.'s (diffusion-types) are possible ; we find them in scheme I.

SCHEME I.

	X	Y	W
1.	←	←	←
2. (r)	←	←	→
3. (t)	←	→	←
4. (s)	←	→	→
5. (p)	→	←	←
6. (q)	→	←	→
7. (u)	→	→	←
8.	→	→	→

b. The composition of the liquids determines which of the D.T.'s is incongruent and, therefore, not possible.

c. The nature of the membrane determines which of the seven other D.T.'s will occur.

Now we shall first consider fig. 2 Gen. VI, in which ab, cd and ef represent isotonic curves ; we shall call the six fields into which these curves divide the triangle, field p, field q etc. in accordance with the letters, put into them.

We now take the osmotic equilibrium

$$1 \mid M(n) \mid L \qquad \text{fig. 2. Gen. VI} \quad \ldots\ldots \quad (1)$$

in which on the left side of the membrane is a liquid, represented in fig. 2 Gen. VI by point 1. From our deductions in Gen. VI we know that for this liquid will obtain, when liquid L is situated within :

field p then is the D.T. N^o. 5 incongruent.
,, q ,, ,, ,, ,, N^o. 6 ,,
,, r ,, ,, ,, ,, N^o. 2 ,,

etc. This has also been indicated in scheme I ; the letter p behind N^o. 5

namely means that the D.T. N°. 5 is incongruent, when the liquid is situated in field p ; etc.

If, therefore, we have a system :

$$1 \mid M(n) \mid L(p) \quad \text{fig. 2. Gen. VI} \quad \ldots \quad (2)$$

in which $L(p)$ is an arbitrary liquid of field p, then the D.T. N°. 5 is incongruent and consequently not possible.

If we have a system :

$$1 \mid M(n) \mid L(q) \quad \text{fig. 2. Gen. VI} \quad \ldots \quad (3)$$

in which $L(q)$ represents an arbitrary liquid of field q, then the D.T. N°. 6 is incongruent and consequently not possible.

So in each of these and the other systems seven D.T.'s are admissible ; the nature of the membrane now will determine which of the seven admissible D.T.'s will occur in each definite case.

We may now illustrate this a little further by the aid of the isentonic curves, which we have discussed already in Gen. VIII ; in order to do this we take an osmotic system :

$$g \mid M(n) \mid L \quad \ldots \quad (4)$$

in which the liquid g has a definite composition and is represented, therefore, by a definite point g of the diagram (figs. 1 and 2).

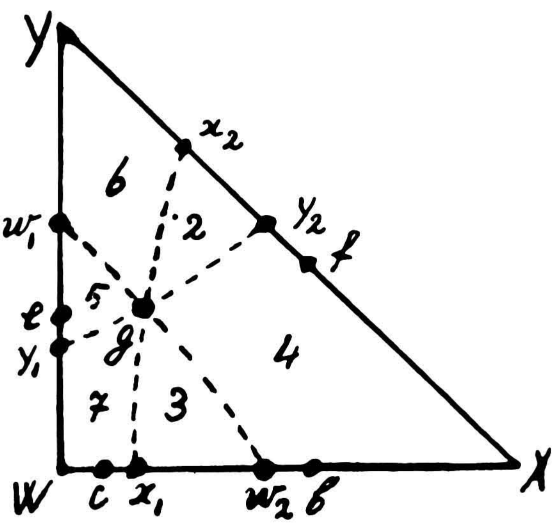

Fig. 1.

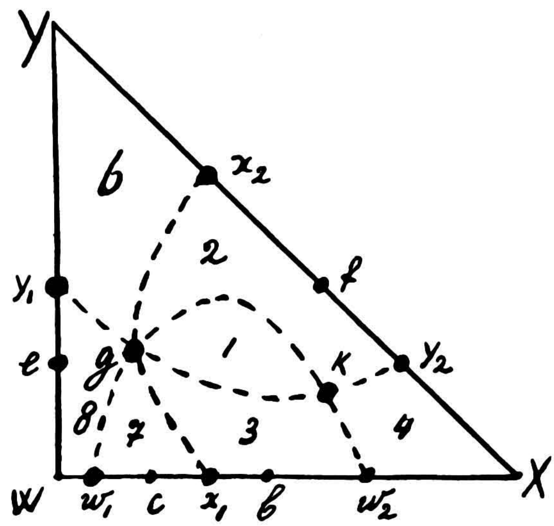

Fig. 2.

Through this point run an isentonic X-curve $x_1 x_2$, an isentonic Y-curve $y_1 y_2$ and an isentonic W-curve $w_1 w_2$. As we have seen in Gen. VIII, these curves may be differently shaped ; for their shape not only depends on the nature of the substances X, Y and W but also on the nature of the membrane.

These isentonic curves divide the triangle into different fields ; in each of those fields we find a figure ; this indicates a D.T. of scheme I, as we shall see below.

We now take a membrane M_1 viz. a membrane, for which the isentonic curves are situated as drawn in fig. 1.

We now imagine liquid L of system (4) somewhere within field 4 ; if we also imagine an isentonic X-curve drawn through this point L, then we see that the liquid g has a greater O.X.n.A. than liquid L ; consequently in system (4) the substance X diffuses towards the left.

If besides we imagine isentonic Y- and W-curves, running through L, then we see that this liquid L has a greater O.Y.n.A. and O.W.n.A. than the liquid g ; so in system (4) the substances Y and W diffuse towards the right. From this appears :

when the liquid L is situated within field 4, then the substances diffuse in system (4) according to :

$$\longleftarrow X \qquad \longrightarrow Y \qquad \longrightarrow W \quad . \quad . \quad . \quad . \quad . \quad (5)$$

viz. according to the D.T. N⁰. 4 of scheme I.

In a corresponding way we are now able to deduce also according to which D.T. the substances will diffuse, when the liquid L is situated in one of the other fields ; this may be found more simply, however, in the following way.

As long as the liquid L is situated in field 4, the D.T. N⁰. 4 obtains and consequently the water diffuses towards the right ; when, however, L is situated somewhere on part $g\ w_2$, of the isentonic W-curve $w_1\ w_2$, then no more water passes through the membrane ; when L now passes into field 3 and, therefore, comes on the other side of $g\ w_2$, then the water will diffuse towards the left.

As the directions in which the substances X and Y pass through the membrane, do not change when liquid L passes from field 4 into 3, it follows, therefore, that the diffusion takes place according to :

$$\longleftarrow X \qquad \longrightarrow Y \qquad \longleftarrow W \quad . \quad . \quad . \quad . \quad . \quad (6)$$

i.e. according to D.T. N⁰. 3. Consequently we may say :

when the liquid L is situated within field 3, then the substances in system (4) diffuse according to the D.T. N⁰. 3.

When the liquid L passes from field 3 into field 7, therefore, running past part $g\ x_1$ of the isentonic X-curve $x_1\ x_2$, only the direction, in which the substance X passes through the membrane, will change ; so the substances diffuse according to :

$$\longrightarrow X \qquad \longrightarrow Y \qquad \longleftarrow W \quad . \quad . \quad . \quad . \quad . \quad (7)$$

i.e. according to the D.T. N⁰. 7. Consequently we find :

when liquid L is situated within field 7, then the substances diffuse in system (4) according the D.T. N⁰. 7.

When the liquid L passes from field 7 into field 5, consequently running past part $g\,y_1$ of the isentonic Y-curve $y_1\,y_2$, then only the direction, in which the substance Y passes through the membrane will change ; the substances then diffuse according to :

$$\longrightarrow X \quad \longleftarrow Y \quad \longleftarrow W \quad . \; . \; . \; . \; . \quad (8)$$

i.e. according to the D.T. N⁰. 5. So we see :

when the liquid L is situated within field 5 the substances in system (4) diffuse according to the D.T. N⁰. 5.

In a corresponding way we find :

when the liquid L is situated within fields 6 or 2, the substances will diffuse in system (4) according to the D.T.'s N⁰. 6 or 2.

From this we see that the figure, placed in a field, indicates the D.T. according to which in system (4) the substances diffuse, when the liquid L is situated within that same field.

Now it appears from fig. 1 :

in system (4) the substances can diffuse through a membrane M according to all D.T.'s except according to N⁰. 1 and N⁰. 8 ; so the three substances cannot at the same time go through the membrane, either towards the left or towards the right.

We now imagine a membrane M_2 viz. a membrane for which the isentonic curves are situated as in fig. 2 ; herein the curves $w_1\,w_2$ and $y_1\,y_2$ intersect not only in g, but also in a point k. The final points w_1 and w_2 of curve $w_1\,w_2$ are in this figure both situated on the side $W\,X$ of the triangle (compare also fig. 2 Gen. VIII).

In a way corresponding to that for fig. 1 we now find that the figure, placed in a field of fig. 2, indicates the D.T. according to which the substances diffuse in system (4), when the liquid L is situated in that same field.

Now it appears from fig. 2 :

in system (4) the substances can diffuse through a membrane M_2 according to all D.T.'s except according to N⁰. 5.

Every change in the membrane involves a change in the form of the isentonic curves. In fig. 2 we have assumed among other things that the curves $w_1\,w_2$ and $y_1\,y_2$ intersect not only in g but also in an other point ; if we take an other membrane, then the other curves may also have two points of intersection. In fig. 2 we have assumed also that the two final points w_1 and w_2 of curve $w_1\,w_2$ are situated on side WX ; when we take an other membrane, however, both these points may also be situated on side WY and it is even possible that curve $w_1\,w_2$ is situated entirely within the triangle and forms, therefore, a closed curve. The same obtains for the curves $x_1\,x_2$ and $y_1\,y_2$.

If, therefore, other membranes are used, diagrams may arise, in which the appearance, the division and the expansion of the fields may differ absolutely from what is seen in figs. 1 and 2 ; it is even possible fields may occur, consisting of two parts, entirely separated from one another.

In further deductions we shall use only the membranes M_1 and M_2 and, therefore, the figs. 1 and 2 ; the reader may apply these considerations also to other cases.

We imagine the figs. 1 and 2 placed upon one another in such a way that the anglepoints W, X and Y coincide ; now we assume that the points g coincide also, so that the liquid g has the same composition in both figures ; of course the isentonic curves and fields of the two figures do not coincide.

Now we take an osmotic system :

$$g \mid M(n) \mid L \quad \ldots\ldots\ldots \quad (9)$$

in which L is a liquid, which in fig. 1 is situated within field 4. In fig. 2 this liquid can be situated also within field 4, but also in an other field. If we assume that field 4 of fig. 1 totally or partly covers the fields 1, 2, 3 and 4 of fig. 2, then the liquid L of system (9) may be, therefore, situated within anyone of the fields 1, 2, 3 or 4 of fig. 2. From this follows :

if in system (9) we bring a membrane M_1 viz. a membrane for which the isentonic curves are situated as in fig. 1, then the substances diffuse according to the D.T. N°. 4, independent of the composition the liquid L has.

if, however, in system (9) we bring a membrane M_2 viz. a membrane, for which the isentonic curves are situated as in fig. 2, then the composition of the liquid L will determine according to which of the D.T.'s Nos 1, 2, 3 or 4 the substances will diffuse.

Besides in system (9) with a membrane M_2 transition-D.T.'s may occur, which are not possible with a membrane M_1.

When the liquid L namely is situated on the line dividing fields 1 and 2 and consequently on the isentonic W-curve, no water will diffuse ; then the diffusion takes place according to :

$$\longleftarrow X \quad \longleftarrow Y \quad —— W \quad \ldots\ldots \quad (10)$$

which represents the transition between the D.T.'s N°. 1 and N°. 2.

When L is situated on the line dividing fields 3 and 4 and consequently also on the isentonic W-curve, the diffusion will take place according to :

$$\longleftarrow X \quad \longrightarrow Y \quad —— W \quad \ldots\ldots \quad (11)$$

When L is situated on the line dividing fields 1 and 3 and, therefore, also on the isentonic Y-curve, the diffusion will take place according to :

$$\longleftarrow X \quad —— Y \quad \longleftarrow W \quad \ldots\ldots \quad (12)$$

When L is situated on the line dividing fields 2 and 4, the diffusion will take place according to :

$$\longleftarrow X \quad —— Y \quad \longrightarrow W \quad \ldots\ldots \quad (13)$$

As a very special case L can be situated also in the point of intersection

K of the isentonic W- and Y-curves ; then the diffusion will take place according to :

$$\longleftarrow X \quad —— Y \quad —— W \quad . \; . \; . \; . \; . \quad (14)$$

From this follows, therefore :

If in system (9) we bring a membrane M_1, then the substances X, Y and W always pass through the membrane according to the D.T. N°. 4 ;

if, however, we take a membrane M_2, then the substances will diffuse according to one of the D.T.'s Nos 1, 2, 3 or 4 ; it is also possible, however, that only the substance X or only $X + Y$ or only $X + W$ pass through the membrane. It depends on the composition of the liquid L which of these cases will occur.

It is clear that the transition-types, discussed above, can exist only during a single moment. If namely an osmotic system is left to itself, both liquids will change their compositions ; they run along their osmosispath, so that they are continually represented by other points of the diagram. If for the sake of simplicity we keep the composition of the liquid g constant during the osmosis in some way or other, then the liquid L passes along a path, which terminates in point g. When this path intersects more fields, then the transition-type occurs in the moment that L passes from one field into an other.

We now take the osmotic system

$$g \mid M(n) \mid water \quad . \; . \; . \; . \; . \; . \; . \; . \quad (15)$$

in which pure water is on the right side of the membrane ; so the substances X and Y can only diffuse towards the right side ; the direction in which the water diffuses depends, however, on the nature of the membrane. If in this system (15) we bring a membrane M_1 then point W is situated in field 7 of fig. 1 ; therefore, the substances diffuse according to D.T. N°. 7 namely :

$$\longrightarrow X \quad \longrightarrow Y \quad \longleftarrow W \quad . \; . \; . \; . \; . \quad (16)$$

Consequently the water diffuses towards the liquid g.

If, however, we bring a membrane M_2 in this system, then point W is situated in field 8 of fig. 2 ; so the substances diffuse according to D.T. N°. 8 viz. :

$$\longrightarrow X \quad \longrightarrow Y \quad \longrightarrow W \quad . \; . \; . \; . \; . \quad (17)$$

We can also imagine a membrane, for which the point w_1 of the isentonic W-curve in fig. 2 coincides with the anglepoint W ; then the diffusion will take place according to the transition-type :

$$\longrightarrow X \quad \longrightarrow Y \quad —— W \quad . \; . \; . \; . \; . \quad (18)$$

so that no water diffuses.

As the substances X and Y diffuse towards the right side, the water in system (15) passes at once into a liquid, which contains all substances.

The curves *ab*, *cd* and *ef*, going through point 1 in fig. 2 Gen. VI are isotonic curves ; we now imagine them drawn also in the figures 1 and 2 of this communication ; we now call them also *ab*, *cd* and *ef* ; in figs. 1 and 2 we only find the points *b*, *c*, *e* and *f* of these curves. The six fields into which these curves divide the triangles are called again, just as before, field *p*, field *q* etc. In order that the diagrams may be more easily compared, we imagine in fig. 2 Gen. VI the point 1 substituted by *g*.

We now imagine the left-side liquid 1 in the osmotic system (2) replaced by *g* ; we then have :

$$\left.\begin{array}{c} g \mid M(n) \mid L(p) \\ 1,\ 2,\ 3,\ 4,\ (5),\ 6,\ 7,\ 8 \end{array}\right\} \quad \ldots\ldots\ldots \quad (19)$$

This means : when the right-side liquid is situated in field *p*, the D.T. N^o. 5 is incongruent and, therefore, not possible ; the seven other D.T.'s are admissible ; the nature of the membrane determines which of these admissible D.T.'s will occur.

We now bring a membrane M_1 in this system. If in fig. 1 we now imagine that part *gb* of curve *ab* has been drawn and part *gf* of curve *ef*, then we see that field *p* (viz. field *gbXf*) is situated within field 4. From this appears : if in system (19) we bring a membrane M_1 then of the seven admissible D.T.'s only the D.T. N°. 4 occurs. We represent this by :

$$\left.\begin{array}{ll} g \mid M_1 \mid L(p) & \text{fig. } 1 \\ 4,\ (5). & \end{array}\right\} \quad \ldots\ldots\ldots \quad (20)$$

If we change the nature of the membrane, the isotonic curves remain unchanged ; their shapes namely only depend on the nature of the substances *X*, *Y* and *W* ; the isentonic curves, however, do change. We can imagine that in fig. 1 point w_2 comes between *b* and *X*, so that field *p* also covers a part of field 3 ; when y_2 comes between *f* and *X*, then field *p* also covers a part of field 2.

If we now take a membrane M_2 so that the isentonic curves are situated as in fig. 2, then field *p* covers the fields 1, 2, 3 and 4 entirely or partly. We then find :

$$\left.\begin{array}{ll} g \mid M_2 \mid L(p) & \text{fig. } 2 \\ 1,\ 2,\ 3,\ 4,\ (5). & \end{array}\right\} \quad \ldots\ldots\ldots \quad (21)$$

This means: if in system (19) we bring a membrane M_2, then four of the seven admissible D.T.'s can occur viz. N°s 1, 2, 3 and 4.

Here it appears, however, that it depends also on the composition of the liquid *L* (*p*) which of those four D.T.'s will occur.

We now take the osmotic system :

$$\left.\begin{array}{c} g \mid M(n) \mid L(q) \\ 1,\ 2,\ 3,\ 4,\ 5,\ (6),\ 7,\ 8 \end{array}\right\} \quad \ldots\ldots\ldots \quad (22)$$

in which, as we have seen in (3), the D.T. N°. 6 is incongruent and, therefore, not possible.

Now we imagine in figs. 1 and 2 that the curves gb and gc have been drawn ; then we see that field q (viz. the field bgc) entirely or partly covers the fields 3, 4 and 7 in fig. 1 and the fields 3 and 7 in fig. 2.

If in system (22) we now bring a membrane M_1 or M_2, we find :

$$\left.\begin{array}{llll} g \mid M_1 \mid L(q) & \text{fig. } 1 & g \mid M_2 \mid L(q) & \text{fig. } 2 \\ 3,\ 4,\ (6),\ 7 & & 3,\ (6),\ 7 & \end{array}\right\} \quad (23)$$

Consequently the substances can diffuse through both membranes according to the D.T.'s N°. 3 and 7 and through the membrane M_1 according to N°. 4 besides.

We now take the osmotic system :

$$\left.\begin{array}{c} g \mid M(n) \mid L(r) \\ 1,\ (2),\ 3,\ 4,\ 5,\ 6,\ 7,\ 8 \end{array}\right\} \quad (24)$$

in which the D.T. N°. 2 is incongruent and, therefore, not possible. We now imagine that in figs. 1 and 2 the curves gc and ge have been drawn ; then we see that field r (viz. the field $gcWe$) partly covers the fields 5 and 7 in fig. 1 and the fields 7 and 8 in fig. 2. If we now bring a membrane M_1 or M_2 in system (24) it follows, therefore :

$$\left.\begin{array}{llll} g \mid M_1 \mid L(r) & \text{fig. } 1 & g \mid M_2 \mid L(r) & \text{fig. } 2 \\ (2),\ 5,\ 7 & & (2),\ 7,\ 8 & \end{array}\right\} \quad (25)$$

Consequently the substances can diffuse through both membranes according to the D.T. N°. 7, besides through M_1 according to N°. 5 and through M_2 also according to N°. 8.

We now take the osmotic system :

$$\left.\begin{array}{ccc} & g \mid L(bg) & \\ O.X.A. & O.Y.A. & O.W.A. \\ \longleftarrow & \longrightarrow & \text{——} \end{array}\right\} \quad (26)$$

in which the right-side liquid is a liquid of the part bg of the isotonic W-curve ab ; so the two liquids of system (26) have the same O.W.A., as in (26) has indeed been indicated by the dash. If we imagine a point on bg (e.g. in fig. 2 Gen. VI) we see, as has already been indicated by the arrows in (26), that this liquid has a smaller O.X.A. but a greater O.Y.A. than the liquid g.

Therefore, the substance X diffuses through a membrane M (X) towards the left ; the substance Y through a membrane M (Y) towards the right ; the water, however, does not diffuse through a membrane M (W).

If we now bring a membrane M_1 in system (26) then bg is situated in field 4 of fig. 1 ; if, however, we take a membrane M_2 then bg is situated in field 3 of fig. 2 ; consequently we find :

$$\left.\begin{array}{llllll} g \mid M_1 \mid L(bg) & & \text{fig. } 1 & g \mid M_2 \mid L(bg) & & \text{fig. } 2 \\ \longleftarrow & \longrightarrow & \longrightarrow 0 & \longleftarrow & \longrightarrow & \longleftarrow 0 \end{array}\right\} \quad (27)$$

in which the letters X, Y and W have been omitted ; the sign o indicates that the water diffuses incongruently. From this appears, therefore :

the substance X diffuses through the membranes M (X), M_1 and M_2 in the same direction, viz. towards the left ;

the substance Y diffuses through the membranes M (Y), M_1 and M_2 in the same direction, viz. towards the right ;

the water does not diffuse through a membrane M (W) ; through the membrane M_1 it goes towards the left and through a membrane M_2 towards the right.

If we take the osmotic system :

$$\left.\begin{array}{ccc} & g \mid L\,(eg) & \\ O.X.A. & O.Y.A. & O.W.A. \\ \longrightarrow & \overline{} & \longleftarrow \end{array}\right\} \quad \ldots\ldots \quad (28)$$

in which on the right side of the membrane is a liquid of part eg of the isotonic Y-curve ef, then both liquids have the same O.Y.A. We see that the arrows point to that side of the membrane where the O.X.A. and the O.Y.A. are greatest.

If we now bring a membrane M_1 in this system (28), then eg is situated in field 5 of fig. 1 ; if, however, we take a membrane M_2 then eg is situated in field 8 of fig. 2 ; so we find :

$$\left.\begin{array}{ccc} g \mid M_1 \mid L\,(eg) & & \text{fig. 1} \\ \longrightarrow & \longleftarrow 0 & \longleftarrow \end{array} \qquad \begin{array}{ccc} g \mid M_2 \mid L\,(eg) & & \text{fig. 2} \\ \longrightarrow & \longrightarrow 0 & \longrightarrow 0 \end{array}\right\} \quad (29)$$

From this appears :

the substance X diffuses through the membranes M (X), M_1 and M_2 in the same direction, namely towards the right ;

the substance Y does not diffuse through a membrane M (Y) ; Y goes through the membrane M_1 towards the left and through a membrane M_2 towards the right ;

the water diffuses through the membranes M (W) and M_1 towards the left ; through the membrane M_2, however, towards the right, therefore incongruently.

In the osmotic system :

$$\left.\begin{array}{ccc} & g \mid L\,(fg) & \\ O.X.A. & O.Y.A. & O.W.A. \\ \longleftarrow & \overline{} & \longrightarrow \end{array}\right\} \quad \ldots\ldots \quad (30)$$

on the right side of the membrane is a liquid of the part fg of the isotonic Y-curve ef. If we bring a membrane M_1 in this system, then fg is situated in field 4 of fig. 1 ; if, however, we take a membrane M_2 then fg intersects the fields 1 and 2, so that the D.T.'s Nos 1 and 2 and their transition-type can occur ; so we have :

$$\begin{array}{ccc} & g \mid M_1 \mid L(fg) & \text{fig. 1} \\ \longleftarrow & \longrightarrow 0 & \longrightarrow \end{array} \qquad \left.\begin{array}{ccc} & g \mid M_2 \mid L(fg) & \text{fig. 2} \\ \longleftarrow & \longleftarrow 0 & \longleftarrow 0 \\ \longleftarrow & \longleftarrow 0 & \text{——} \ 0 \\ \longleftarrow & \longleftarrow 0 & \longrightarrow \end{array}\right\} \quad (31)$$

From this appears :

the substance X diffuses through the membranes $M\ (X)$, M_1 and M_2 towards the left ;

the substance Y does not diffuse through a membrane $M\ (Y)$; through a membrane M_1 the substance Y goes towards the right and through a membrane M_2 towards the left ;

the water diffuses through the membranes $M\ (W)$ and M_1 towards the right ; through a membrane M_2, however, it may diffuse as well towards the right as towards the left and besides it may not diffuse at all ; it depends on the composition of the right-side liquid which of these three cases will occur.

It appears from the cases, discussed above, and the great number of others still to be deduced by the reader, that the composition of the liquids and the nature of the membrane determine the directions, in which the substances diffuse.

(To be continued.)

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