A QUANTITATIVE STUDY OF THE EFFECT OF ANIONS ON THE PERMEABILITY OF PLANT CELLS.

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Although the effects of cations on the permeability of plant cells have frequently been studied, comparatively little attention has been paid to the action of anions.

The writer has investigated the effects of a series of anions on the permeability of Laminaria agardhii Kjellm. Measurements were made of the electrical conductivity by the method described by Osterhout.¹

The salts were the purest obtainable and the distilled water was not toxic to delicate test objects. The salt solutions were neutral to phenolsulfonephthalein (pH 7 ± 0.5). The temperature during the course of the experiments was 19 ± 2°C.

Sodium sulfocyanide, iodide, nitrate, bromide, chloride, acetate, sulfate, tartrate, phosphate, and citrate were selected for study.

Solutions of these salts were made of the same conductivity as a slightly diluted sea water solution; viz., a solution having the same conductivity as a 0.51 M solution of sodium iodide. (Normal sea water has the same conductivity as a 0.57 M solution of sodium iodide.) As is well known, various samples of sea water differ slightly in their conductivity and hence no absolute concentration can be given for each salt. The following table shows the approximate concentrations used.

<table>
<thead>
<tr>
<th>Salt</th>
<th>SCN</th>
<th>I</th>
<th>NO₃</th>
<th>Br</th>
<th>Cl</th>
<th>Acetate</th>
<th>SO₄</th>
<th>Tartrate</th>
<th>PO₄*</th>
<th>Citrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>0.62</td>
<td>0.51</td>
<td>0.59</td>
<td>0.51</td>
<td>0.45</td>
<td>1.1</td>
<td>0.36</td>
<td>0.59</td>
<td>0.35</td>
<td>0.43</td>
</tr>
</tbody>
</table>


*The phosphate is a mixture of 0.23 M disodium phosphate and 0.12 M monosodium phosphate.
FIG. 1. Curves showing the resistance of Laminaria in solutions of various sodium salts: A in iodide; B in bromide; C in sulfocyanide; D in chloride; E in nitrate; F in acetate; G in sulfate; H in tartrate; I in phosphate; J in citrate. Ordinates represent resistances (expressed as per cent of the resistance in sea water, which is taken as 100 per cent). Each point represents the average of ten experiments. Probable error less than 10 per cent of the mean.
Measurements of the conductivity (permeability) were taken at the end of 5, 25, 45, 65, 85, and 105 minutes in the salt solution except in certain solutions (citrate, phosphate, and tartrate) where the resistance diminished very rapidly.

The results are shown in Fig. 1, the curve for each salt representing an average of ten experiments. The probable error of the mean (as based on Peter's formula) is always under 10 per cent, and for 75 per cent of the points is under 5 per cent.

It will be noted that the effect of these anions upon the increase in permeability as seen at the end of the experiment is in the series I, Br, SCN, Cl, NO₃, acetate, SO₄, tartrate, PO₄, citrate.

This differs from the Hofmeister series in that the effect of SCN is noticeably more than that of the iodide while the two effects were indistinguishable by Hofmeister, and also in that the relative positions of chloride and nitrate are reversed in this work from that found by both Pauli and Hofmeister. That these positions, however, are not invariable has been shown by Höber who obtained so called “transition series” by varying the hydrogen ion concentration and the concentration of the salt. It may be noted, however, that at the end of the 25, 45, and 65 minute periods, when the disturbance affecting the experiment at the start has subsided and before possible disturbing factors due to the purely mechanical deterioration of the tissue have appeared, the position of the nitrate is above that of the chloride.

It is also seen that there is a distinct grouping into two or three groups. The iodide, bromide, sulfocyanide, chloride, and nitrate behave very similarly, while the acetate, sulfate, tartrate, phosphate, and citrate have a much more striking effect. In order to have solutions of the same conductivity as the sea water used, it was found necessary, as already mentioned, to employ different concentrations. But it is also desirable to make a comparison on the basis of the same molecular concentration. Since the concentration of two of the salts was close to 0.52 m and since this is the concentration of sodium

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Fig. 2. Curves showing the resistance of *Laminaria* in solutions of various sodium salts: A in sulfocyanide; B in iodide; C in bromide; D in nitrate; E in chloride; F in acetate; G in sulfate; H in tartrate; I in phosphate; J in citrate. Ordinates represent resistance (expressed as per cent of the resistance in sea water, which is taken as 100 per cent). Each point represents the average of ten experiments. Probable error less than 10 per cent of the mean.
chloride required to produce a solution of the same average conductivity as undiluted sea water, this was the molecular strength decided upon.

Sea water was concentrated (or diluted) in each case until it possessed the same conductivity as the solution to be tested. After the tissue had been placed in the concentrated (or diluted) sea water long enough to come to equilibrium (20 to 30 minutes) a measurement of the resistance was taken and the material then placed in the salt solution after which the procedure was the same as in the previous experiments.

Fig. 2 shows the results of these experiments. The results for each concentration of each salt are the average of ten experiments as before, all the concentrations being 0.52 M, with the exception of that of the phosphate. In this case the solubility of the disodium salt prohibits a concentration higher than 0.26 M; enough of the monosodium salt was added to produce neutrality and the total molecular concentration reckoned on this basis was about 0.39 M.

In this series the sulfocyanide takes its place at the top along with the iodide, and at the end of the experiment the two were identical. The nitrate curve is raised a trifle so that it now comes between the bromide and the chloride. The chloride, phosphate, and citrate drop slightly and the tartrate rises slightly, all of which changes are to be expected.

The greatest changes occur in the sulfate and acetate, which were farthest from 0.52 M in the first set of experiments. The acetate rises and takes its place among the other monovalent salts and the sulfate drops towards the tartrate and the trivalent salts, thus forming two distinct groups. It should be noted that the acetate comes from Group II up to Group I, but that its rate of fall at the end of the experiment was greater than for the others.

Several explanations for these phenomena may be given, but it does not seem worth while to enter upon a discussion of them at present. The recent work of Loeb on the relation between gelatin and electrolytes may furnish a clue to the ultimate explanation.