ON THE DANYSZ EFFECT WITH REFERENCE TO THE TOXIN-ANTITOXIN REACTION.

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One Figure.

Svante Arrhenius (1908) has taken exception to my criticism (1907) of his interpretation of the Danysz Effect with reference to the Toxin-Antitoxin reaction. In this paper he has given an interesting but rather far-fetched analogy to the Danysz Effect, which is, according to him, purely chemical in character and subject to the laws of chemical mass action, and here marks in italics that "*the opponents of the use of these laws have still given no explanation at all of the Danysz Effect, especially of the experiments cited in our memoir.*"

In this communication I shall, after replying to the objections advanced by Arrhenius, endeavour to give the missing explanation based on the phenomena of adsorption and determine in how far this more physical view is compatible with my own experimental work and with that of Madsen and Walbum in Madsen and Arrhenius's Memoir (1906). In the first place it is necessary to indicate the fundamental significance of the Danysz Effect in the interpretation of the nature of the toxin-antitoxin reaction.

At present the interaction of bacterial toxins with their specific antitoxins is regarded as being practically independent of biological influences and either of a chemical or a physical nature. Of the many views advanced the most definitely crystallised are the purely chemical conceptions of Ehrlich and of Arrhenius and Madsen.

Ehrlich considers the toxic fluids to be mixtures of several toxic chemical substances having different degrees of affinity for the corresponding antitoxins, and he regards the reaction of toxin and antitoxin

as the successive neutralisation in steplike manner of the different toxic constituents, analogous to the neutralisation of a mixture of acids by a base.

Arrhenius and Madsen agree with Ehrlich in regarding the toxins as possibly complex in nature and their neutralisation by antitoxin as similar to the known reactions of acids on bases, but differ from him in the interpretation of the data bearing on the course of the neutralisation. They consider that experimental work so far shows only the neutralisation of one toxic substance, viz. that toxic constituent of the toxic fluid with the greatest affinity for the antitoxin, and that the course of this neutralisation with varying masses of toxic and antitoxic fluids is similar to that obtaining in the neutralisation of a single weak acid by a weak base, *e.g.* the interaction of boracic acid and ammonia in aqueous solution.

They find that the law of chemical mass action enunciated by Guldberg and Waage holds for the reaction between this most toxic constituent and antitoxin, and, further, that similar application of this fundamental relation between chemically active masses is justifiable in numerous reactions in Immunity. Arrhenius and Madsen do not hesitate to push the analogy to its limit and conclude that the stochiometric relations existing between the ultimate particles or "molecules" of toxin and of antitoxin are disclosed by their experiments. Likewise the absorption relations of agglutinin reveal, according to Arrhenius, the dissociation of the agglutinin "molecule" within the absorbent micro-organisms. Arrhenius has found that a certain formula which he maintains is based on the law of chemical mass action expresses with close approximation the quantitative mass relations in thirty-five different cases taken from different departments of Immunity (*Immuno-chemistry* by S. Arrhenius (1907), The Macmillan Co., New York) and considers his fundamental assumptions and methods of calculation to be entirely justified by this general agreement.

The experiments of Danysz (1902) on the neutralisation of ricin and of diphtheria toxin by their corresponding antibodies introduce, however, a new factor necessitating considerable modification of both the theory of Ehrlich and that of Arrhenius. Danysz found that when the toxin was added to the antitoxin in two fractions, a considerable time being allowed to elapse between the additions, the resultant mixture contained a much larger amount of free toxin than in the case when the total quantity of toxin was added to the antitoxin at once. This abnormally high toxicity of a toxin on its fractional addition to

an antitoxin is known as the "Danysz Effect." The "Effect" was explained by von Dungern (1904) as due to the neutralising effect of a new constituent of the toxin, viz. "epitoxonoid," a view subsequently endorsed by Sachs (1904) and Ehrlich.

Arrhenius (1908) attributes the Danysz Effect to a secondary neutralisation process similar in some respects to hydrolysis which proceeds at a lower rate than the primary neutralisation of toxin by antitoxin corresponding to the single acid-alkali relation.

Thus the toxin may be regarded as behaving similarly to chloracetic acid when the latter is added to sodium hydrate, and the antitoxin acts in an analogous manner to the alkali. In experiments of the Danysz Effect type the *first fraction of toxin* or acid is rapidly neutralised by the antitoxin or alkali which is present in excess. If this mixture be allowed to stand a secondary reaction takes place between the excess of antitoxin and the neutralised toxin which becomes more complete with increasing time of contact and corresponds to the pseudo-hydrolytic action studied by Schwab (1883) of the excess of sodium hydrate on the product of the primary neutralisation, viz. the reaction of sodium chloracetate with the alkali to produce sodium glycollate and sodium chloride. During this secondary pseudo-hydrolytic process the excess of antitoxin or of alkali, respectively, decreases considerably and, consequently, on the addition of the second fraction of toxin or acid the antitoxin or alkali is no longer present in sufficient quantity to neutralise the toxin or acid and the resultant mixtures are toxic and acid respectively. When the *total quantities of toxin* or acid respectively are added at once to the antitoxin or alkali the secondary hydrolytic process is negligible and all the antitoxin or alkali is available for the primary neutralisation which is consequently more complete.

On the other hand Nernst (1904) and Craw (1905, I), (1905, III), (1907, VI) have pointed out many difficulties in the application of the laws of chemical mass action to the reactions in Immunity in the manner adopted by Arrhenius; and Bordet (1903), Laudsteiner (1903), Craw (13, II, 1904), Biltz (1904), etc. have indicated that similar quantitative relations hold for the staining act. Thus in the toxin-antitoxin reaction the toxin corresponds to the dye and the antitoxin to the fabric or tissue stained. The free toxin in equilibrium with the bound toxin is found to obey roughly the same general law as holds for the free dye and dye fixed by the tissue, a law closely allied to, if not identical with, that holding for the extraction of substances

from solution by porous bodies such as charcoal and classed under the general heading of adsorption.

Further I found (1905, 1) that the Danysz Effect has its counterpart in the phenomena of staining, a result which has since been confirmed by Bayliss (1906). The general formula hitherto used to express adsorption relations, viz. $C_2 = KC_1^n$, where C_2 is the concentration of adsorbed substance in the adsorbent material, C_1 the concentration of the same substance existing in aqueous solution, and K and n constants dependent upon the nature of the aqueous solvent, the adsorbed material and the temperature, is admittedly an empirical relation and no satisfactory chemical or physical explanation of the meaning of these constants has hitherto been advanced. There being no physical reason why such a relation should hold for adsorption in general I can only attribute the prominence given to the formula as due to the impression that most curves roughly resembling hyperbolas obey the law $Yx^m = \text{constant}$. This however is not necessarily so and the simplest test of the formula by plotting $\log C_2$ against $\log C_1$ shows that in *purely adsorption phenomena* the straight line relationship is but a rough approximation.

I have verified this in the cases of the adsorption of iodine by charcoal and of congo red by filter paper from aqueous solutions. To obtain constancy of the ratio $\frac{C_2}{C_1^n}$ a tendency of n to approach unity as the concentration of free iodine or congo red increases must be assumed. This tendency seems in fact to be the general rule in adsorption phenomena as the work of Hoitsema (1895), Ramsay, Mond and Shields, and Travers (1906) on the adsorption of hydrogen by palladium, of oxygen by palladium, of hydrogen by platinum and of hydrogen and carbon dioxide by carbon definitely shows. Here also the general adsorption formula given above holds throughout a certain range of gas pressures but the value of n is variable with the temperature, approaching more towards unity at the higher temperatures and particularly so for the higher pressures at these higher temperatures.

If the value of n in the adsorption formula be similarly modified for systems containing toxin and antitoxin, especially for the higher concentration of toxin, we obtain an empirical formula which reproduces the experimental data exactly, and the same holds for all of the cases examined by Arrhenius and Madsen which show approximation to their general formula. The latter general formula however does not exactly reproduce the observations and can most easily be brought into con-

sonance with the experimental data by assuming that the power to which the fixed or bound toxin is raised is not constant and that the formula giving the exact reproduction of the observed data is not

$$\begin{matrix}\text{Free Toxin}\\ \text{Concentration}\end{matrix} \times \begin{matrix}\text{Free Antitoxin}\\ \text{Concentration}\end{matrix} = K \left\{ \begin{matrix}\text{Bound}\\ \text{Antitoxin}\end{matrix} \right\}^2,$$

but

$$\begin{matrix}\text{Free Toxin}\\ \text{Concentration}\end{matrix} \times \begin{matrix}\text{Free Antitoxin}\\ \text{Concentration}\end{matrix} = K \left\{ \begin{matrix}\text{Bound}\\ \text{Antitoxin}\end{matrix} \right\}^n,$$

where n is *nearly* equal to 2.

As formerly pointed out the antitoxin concentration is determined empirically and introduces a constant p indicating its equivalence to toxin. We have thus two constants p and K and a variable n by means of which an exact reproduction of the data may be obtained.

Since both the adsorption formula and the chemical mass action formula of Arrhenius do not exactly agree with the observation, but can both be modified by a slight change of the power to which the fixed toxin is raised in such a manner as to give in each case perfect agreement with the experimental data, they are of equal value as empirical formulae. The whole problem resolves itself into the interpretation of the physical and chemical meaning of the power n in the two equations and of p and K of the chemical mass action and K of the adsorption views.

It is therefore necessary to trace as far as possible (i) the significance of the adsorption formula regarded from a purely chemical standpoint and likewise (ii) the meaning of the chemical mass action law from an adsorption point of view.

1. *On the meaning of the adsorption formula from a purely chemical standpoint.*

This problem will be pursued further on a future occasion but a preliminary view can be advanced giving the chief features. The adsorbing substance, *e.g.* amorphous carbon, spongy platinum, palladium, and colloidal "gels" including living organisms, etc., behave as, in the simplest case, a single phase. The medium containing the substance about to undergo adsorption is in general either gaseous or aqueous, and forms a second phase. The substance to be adsorbed, which may be gaseous, crystalloidal, or colloidal, forms part of the second phase and is, it is presumed, subject to the laws of partition holding for the distribution of gas or crystalloidal substance between two phases. A

few examples of this fundamental law, in its simplest form, are the partition of oxygen, nitrogen and hydrogen between gaseous medium and water. The partition law is here known as Henry's law and states that the pressure p_1 of free gas at constant temperature is proportional to the gas-like or osmotic pressure p_2 of the dissolved gas, so that $P_1 = KP_2$, where K is the proportionality constant.

Now the gaseous and osmotic pressures are inversely as the gaseous concentration C_1 or osmotic concentration C_2 of the molecules of the substance present in the two phases, from which we obtain $C_2 = KC_1$. More easily condensable gases do not however obey this simple law exactly, but a very close approximation is obtained to constancy when the ratio $\frac{C_2}{C_1^n}$ is calculated where n is a second constant. This is, in fact, the formula used in tracing adsorption relations, and to obtain perfect agreement with the observed data, n has to be slightly modified when the range of concentration C_1 is great, in a similar manner to the modification required to give exact agreement with adsorption data.

But, in this case, a definite significance can be given to the value of n, for it represents the ratio existing between the number of molecules in the gaseous state and the number in the dissolved state to which the former give rise on solution, thus $n = \frac{2}{3}$ means that two gaseous molecules on solution give rise to three. The variability of n which occurs with variation of concentration seems to me to be a necessary consequence of the molecular view. When it is considered that Boyle's law does not hold exactly for the relations between pressure and volume with easily condensable gases and as a similar deviation from the analogous osmotic pressure and volume relations exists which is not of the same magnitude as the gaseous deviation, the ratio n for high concentrations in both phases must differ from the ratio n at low concentrations.

The value of n in many cases of solution, of occlusion and of adsorption seems to me however to be scarcely compatible with the purely chemical view that we are dealing with relations existing between molecules in two phases, *e.g.* Hoitsema (1895) from his experiments on the solution of hydrogen gas in palladium is forced to conclude that the gas molecule H_2 on solution is dissociated into H atoms but that with increasing concentration of hydrogen the dissolved matter associates more and more and the solution contains more and more complexes H_2, *i.e.* of the same molecular magnitude as the gaseous molecule. This is however more clearly shown by the very exact figures of Travers (*loc. cit.* 1906)

who shows that hydrogen dissolved in amorphous carbon at – 190 deg. C. must be dissociated into fragments of an atom. Ramsay previously had shown that sodium partitioned itself between the gaseous phase and a mercury phase in such a manner that the dissolved sodium ought to be in a subatomic state. Travers has further indicated that carbon dioxide in solution in carbon at 0 deg. C. behaves like hydrogen at – 190 deg. C.—the carbon dioxide must therefore be dissociated into a submolecular state.

Similar relations hold for the partition law when a substance is distributed between two solvents. Thus Nernst (1891) found that when benzoic acid was partitioned between water and benzene the value of n indicated that in benzene the molecules were double the magnitude of those dissolved in water. But when we attempt to interpret the value of n for adsorption when the adsorbing substance is placed in an aqueous solution of the substance to be adsorbed, we are met with similar difficulties to those mentioned above for occlusion. Thus the partitioning of iodine between an aqueous solution and amorphous carbon gives the general relation $C_2 = KC_1^n$, where n is nearly $= \frac{1}{4}$. This indicates that one molecule of the iodine dissolved in water dissociates into four parts in the carbon—or that it exists in the subatomic state. Similarly in washing potassium iodide out of charcoal I find n less than unity. But the potassium iodine, KI in aqueous solution is fully dissociated into the ions $\overset{+}{\mathrm{K}}$ and $\overset{-}{\mathrm{I}}$, consequently in carbon the $\overset{+}{\mathrm{K}}$ ion must have dissociated and likewise the $\overset{-}{\mathrm{I}}$ ion. Similar conclusions must be drawn for the equilibria between salt solutions and paper, and dissociations of simple substances must be assumed where no such dissociation appears to be possible from the present standpoint of physical chemistry. It seems to me therefore that the interpretation of the adsorption formula as showing the relations existing between chemical molecules in the free and adsorbed states leads to highly improbable views of the structure of the substances adsorbed. This being so for substances of known molecular weight it seems to me to be still more doubtful to interpret the partition law as showing molecular relations in the case of substances of the nature of colloids etc., the molecular weights of which are unknown and the degree and nature of the aqueous solutions of which are certainly to a great extent different from crystalloidal solution. Amongst these substances of unknown state of solution or of colloidal nature we must include the great majority of the substances dealt with in Immunity and particularly the toxins,

antitoxins, agglutinins and agglutinable substances. Thus Arrhenius's statement that agglutinin on being partitioned between a saline medium and bacteria undergoes dissociation, two molecules of free agglutinin giving rise to three molecules of adsorbed agglutinin for $n = \frac{2}{3}$, rests on the slenderest of bases, viz. on the chemical interpretation of the value of n.

2. *The meaning of the chemical mass action law from an adsorption point of view.*

Arrhenius's general law for toxin and antitoxin interaction mentioned above is that first found by Arrhenius and Madsen (1902) for tetanolysin and its antilysin.

With a constant quantity of toxin and different quantities of antitoxin the equilibria attained were well represented by an equation showing that one molecule of toxin reacted with one molecule of antitoxin to produce two molecules of the compound toxin-antitoxin. The chemical mass law representing this interaction is

$$\frac{\text{Free Toxin}}{\text{vol.}} \times \frac{\text{Free Antitoxin}}{\text{vol.}} = \frac{K\ (\text{Combined Toxin-Antitoxin})^2}{\text{vol.}},$$

or the concentration of free toxin multiplied by the concentration of free antitoxin is proportional to the square of the toxin-antitoxin compound concentration. This formula is however only apparently simple. Let us inquire how the various factors are determined. The total toxin and total antitoxin are directly measured in cubic centimetres of fluid containing constant quantities of the reacting substances (of unknown molecular concentration). The third experimental datum is the determination of the toxin left free in each mixture. We now proceed to deductions: (1) the concentration of the bound toxin is assumed to be equal to the difference between the concentration of the added toxin and the toxin left free. This, however, entirely overlooks the probability that the antitoxin is either a colloid or bound to a colloid and that *the bound toxin would be concentrated in the antitoxin and not distributed throughout the whole aqueous medium* in the same way as the free toxin.

(2) The concentration of bound antitoxin is arbitrarily made equal to the bound toxin. But all evidence tends to show that no such simple stochiometric relation *persists* even in the case of molecular compounds when the components are *varied in relative concentration.*

(3) The free antitoxin concentration is then taken as the difference

https://doi.org/10.1017/S0022172400016120 Published online by Cambridge University Press

between the concentration of antitoxin added and the bound antitoxin calculated.

(4) The total antitoxin is further not taken as the number of cubic centimetres of antitoxic fluid added in the experiments but is only assumed to be proportional to the latter and the proportionality factor p is interpolated from the whole series of equations corresponding to different amounts of antitoxin. From these we find that N c.cs. of antitoxic fluid correspond to Np c.cs. of toxin. The equation of Arrhenius thus gives only the relation

$$\text{Free toxin} \times (\text{Toxic capacity of antitoxin} - \text{Bound toxin}) = K\ (\text{Bound toxin})^2,$$

or $$\text{Free toxin} \times \text{Toxic capacity of free antitoxin} = K\ (\text{Bound toxin})^2.$$

This we may transpose into

$$\frac{\text{Free toxin}}{\text{Bound toxin}} = K\,\frac{\text{Bound toxin}}{\text{Toxic capacity of free antitoxin}},$$

or in other words the ratio between free and bound toxin is proportional to the ratio between the bound toxin and the amount of toxin which the antitoxin is still capable of taking up. But the bound toxin is the amount that could be taken up by the aqueous fluid to give the original concentration of free toxin. Further the toxic capacity of the free antitoxin is the amount of toxin which could be taken up by the antitoxin to give the original concentration of bound toxin when a very small amount of antitoxin was added to the original concentration of toxin.

So that we obtain

$$\frac{\text{Free toxin}}{\text{Bound toxin}} = K\,\frac{\text{Toxic capacity of the free water}}{\text{Toxic capacity of the free antitoxin}}.$$

This may be made clear by a diagram based on Arrhenius's and Madsen's figures (see p. 55).

By mere inspection it is evident that at A the ratio

$$\frac{\text{Free toxin}}{\text{Bound toxin}} = \text{about } \frac{1}{3},$$

whereas the ratio between the toxic capacity of the free water and the toxic capacity of the free antitoxin is of course $\frac{3}{1}$, we have then $\frac{1}{3} = K\,\frac{3}{1}$ or $K = \frac{1}{9} = 0{\cdot}11$. At B $\frac{\text{Free toxin}}{\text{Bound toxin}} = \frac{1}{11}$, the other ratio is $\frac{1}{1{\cdot}1}$, hence $\frac{1}{11} = K\,\frac{1}{1{\cdot}1}$ or $K = 0{\cdot}1$.

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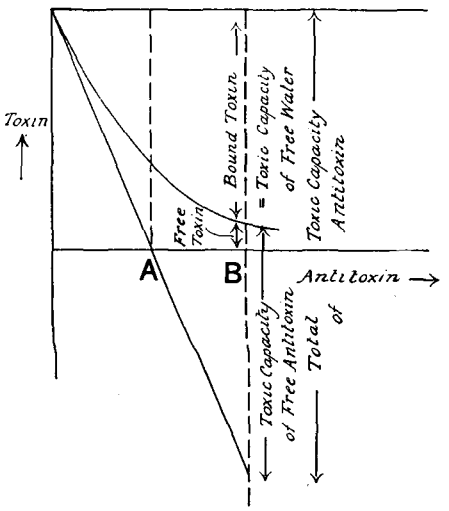
What then is the meaning of this simplified view of Arrhenius and Madsen's highly prized formula? In order to elucidate this important matter we must inquire into the significance of the ratio

$$\frac{\text{Toxic capacity of free water}}{\text{Toxic capacity of free antitoxin}}.$$



Both the numerator and the denominator are dependent upon the initial concentration of toxin in the toxic fluid or, more correctly, upon the absolute amount of toxin, which was the same throughout the series. Had the total quantity of toxin in the toxic fluid used in each individual case throughout the series been greater the saturation of the lower quantities of antitoxin would have been greater and the maximal capacity of the antitoxin for toxin would also have been greater. As a consequence of this the "toxic capacity of free water" would have been greater and likewise the toxic capacity of free antitoxin.

It follows from this that the maximum toxic capacity of an indefinitely small quantity of added antitoxin is equal to the total quantity of toxin used in the experiments in question. Likewise the maximum toxic capacity of the constant quantity of water is equal to the same total quantity of toxin.

The above relationship seems to me to be merely another form of the partition law and would hold equally well for a gas in a closed space to which water was added in small quantities. Thus for ammonia gas and

https://doi.org/10.1017/S0022172400016120 Published online by Cambridge University Press

water in a closed space the relation probably holds that the ratio of free ammonia gas to dissolved ammonia NH_3, Aq is proportional to the ratio of the free space and the free water. Here equally the free space represents the difference between the initial concentration of ammonia gas and the concentration after adding a definite small quantity of water. Likewise the free water is merely a term for the difference between the concentration of ammonia in the first exceedingly small fraction of added water and the concentration in any subsequent fraction. Arbitrary constants being used in a similar manner to that adopted by Arrhenius we should arrive at the conclusion that one molecule of ammonia gas combines with one molecule of water to give two molecules of ammonia-water compounds. So far as I have investigated the figures especially for chlorine and water, there seem to be grounds for thinking that some general relation of the type assumed by Arrhenius holds in the majority of solution and adsorption phenomena as a mere corollary of the partition law and without significance as regards the interaction of molecules. In other words Arrhenius's equation may well be regarded as an adsorption interpolation formula once it has been deprived of its *molecular* significance.

Physical interpretation of the Danysz Effect.

Although the above seems to me to rob Arrhenius's criticism of my objections to his view of the Danysz Effect of its foundations, I hope to furnish shortly a detailed criticism of many minor points he has raised.

I have been led to a more physical explanation of the Danysz Effect as the result of my work during the past year. The study of all kinds of adsorption phenomena seems to me to be most likely to throw light on the subject. With this object in view I have investigated the Danysz Effect in the process of staining, I found that using congo red as the analogue of toxin and filter paper as that of antitoxin, the amount of dye removed from the solution depended upon the manner of addition to, and the distribution of, the paper throughout the dye fluid. The nature of the filter paper influenced to a great extent the amount of dye removed from a given solution and filter papers with a high ash in general removed more congo red than low ash papers. Further, filter paper from which the ash had been removed to a considerable extent showed a decreasing power of adsorbing congo red with decreasing ash content. With papers of low ash slight quantities of sodium and calcium chlorides which had no

precipitating action on the dye greatly increased the adsorption. These facts lead me to the view that the adsorptive power of colloidal substances such as cellulose, globulin, etc. and possibly antitoxins (by analogy) is largely conditioned by their salt content and probably by the specific nature of the adsorbed salts. It is at present too early to do more than indicate that the specificity and high adsorbing power of antitoxin and

Adsorption of Congo Red by Paper.

P	·014	·012	·010	·008	·006	·004	·002
A	30	20	7·5	3	2	2	2
B	21	17·5	10	4·5	3	1·75	1·5
C	20	17·5	14	10	3·5	2	2
D	15	13	10	4·5	4	1·75	1·5

P, represents the absolute percentage of Congo Red in the seven solutions used.

A, gives the relative percentage of Congo Red left free with paper moistened by 10 % alcohol.

B, with unwetted paper.

C, with paper wetted with absolute alcohol.

D, with paper moistened with distilled water.

bacteria for certain toxins and agglutinins may depend to a very great extent upon the nature and ratio of the concentrations of the salts contained. The relation existing between free dye and adsorbed dye when dye fluids of different concentrations are brought into contact with moist filter paper is expressed approximately by the formula $C_2 = KC_1^n$ mentioned above and the deviations are in the sense there indicated. Hitherto these adsorption relations have been studied by adding dry paper to the staining fluids—Bayliss (1906). This latter method does not give an adsorption comparable with the adsorption of toxin by antitoxin, for the latter is already in the moist condition. If dry paper be added a capillary convection of fluid takes place, likewise an imbibition of the solvent and rapid precipitation of the congo red in the paper. It is important that the nature of the fluid moistening the paper be as nearly the same as that containing the dye. Thus when moistened with fluids containing more or less alcohol than that present in the congo red solution (10 %) convection currents are produced which lead to quite other general laws of staining. That the influence of capillary phenomena should be eliminated in the study of adsorption is well shown by experiments with methylene blue = eosin in methyl alcohol and water, or neutral red = "Licht" green in methyl alcohol and water. A strip of dry filter paper shows differentiation of solvent and the individual

stains; *e.g.* "Licht" green rises in the wetted paper to a much greater height than the neutral red. Paper moistened with the solvent is more uniformly stained and any difference between the rates of adsorption of the two stains is due to their different rates of diffusion.

The filter paper being regarded as the analogue of the antitoxin and the dye congo red as corresponding to the toxin the Danysz Effect was determined for the staining of the paper by experiments analogous to those of Madsen and Walbum on tetanolysin and its antilysin. The "Effect" for the staining of paper by congo red is expressible by formulae of the same form as those used by Arrhenius for the Danysz Effect in the toxin-antitoxin reaction. It was however found to diminish with diminishing ash content in the filter paper stained, and also with diminishing salt content in the solvent fluid.

The Danysz Effect is explicable from the point of view of adsorption as due to a condensation of the systems consequent on the fixation of the dye in staining paper or of the toxin-antitoxin system after union has taken place and bears a relation to the second phase of agglutination and of precipitation. The first phase of staining is the adsorption of dye, the second a contraction of the stained material which becomes much less fragile, *i.e.* less easily separated into parts—as can be easily demonstrated. The first phases of the toxin-antitoxin reactions and of agglutination are adsorptions, the second phase of the toxin-antitoxin reaction a withdrawal from the medium by contraction of particles by agglutination or coalescence.

The Danysz Effect is then viewed as a physical condensation of the reacting system, having an intimate connection with other phenomena in Immunity.

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