for circulating gases, only minor changes are necessary to render the apparatus described by them efficient for circulating liquids, as was pointed out by Funnel and Hoover. A single valve, probably less efficient, electromagnetic all-glass pump for circulating liquids was described by Smith and Wood in 1923.[5]

ROBERT LIVINGSTON

SCHOOL OF CHEMISTRY,
UNIVERSITY OF MINNESOTA

SPECIAL ARTICLES

ON THE CRITICAL TEMPERATURE OF SERUM: DEPOLARIZATION FACTOR AND HYDRATION OF SERUM MOLECULES

IN a series of papers published recently[1] we have shown, successively, first, that the curve representing the viscosity of serum as a function of temperature presented an absolute minimum around 56° C.; second, that the curve expressing the rotatory power of serum, unaffected by heat up to 54°, suddenly showed an increase around that temperature, and that the subsequent increases were nearly proportional to the temperature; third, that the amount of light scattered at right angles by the serum also began to increase after 55° had been reached.

By application of Lord Rayleigh's formula connecting the amount of scattered light to the volume of the scattering particles, this last value was computed and was shown to increase almost linearly with the temperature, above 57° C. The purpose of this paper is to summarize the results obtained by measuring the depolarization factor of the scattered light. It is known that this light is almost completely polarized vertically in colloidal solutions and that the amount of depolarized light depends on the size, the shape and the anisotropy of the molecules or particles. It is difficult to estimate the part played by the shape, when dealing with particles which are not opaque; Cabannes has shown that, in the case of open chain hydrocarbides, the depolarization factor was independent of the length of the chain.[2] It is therefore probable that the main factors are the size and the optical anisotropy.

It was found that the depolarization factor ϱ begins to increase, just as do the physical properties quoted above, after a certain temperature is reached, namely, 57° C. Its increase is slow at first, then very rapid, and its value may reach 0,50 for pure serum heated for ten minutes at 68°. The increase is continuous, and shows no jump when the sol becomes a gel. After the gel state is attained, the increase goes on, regularly, just as the increase in volume of the molecules, computed from Lord Rayleigh's formula. Table I gives the figures for a normal horse serum, heated ten minutes in sealed tubes.

TABLE I

Temperature	Norm.	55°	58°	60°	62°	64°	66°	68°
ϱ	0,0175	0,0170	0,0191	0,0282	0,0490	0,0725	0,0832	0,467
								coagulated

When the serum is diluted with saline solution (0,9 per cent. NaCl) the depolarization factor may reach, for ten minutes heating at 76°, the extremely high value $\varrho = 0{,}810$. In this case the amount of polarized light amounts to less than 20 per cent. of the scattered light.

If an attempt is made to explain the behavior of serum proteins in the aforesaid experiments (viscosity, polarized light, scattered light) it becomes soon obvious that hydration is the main factor. But in order to account for the quantitative side of the phenomena, it is necessary to resort to a new hypothesis concerning the mechanism of hydration. We have shown previously that, after a certain temperature was reached, the rotatory power and the volume of the molecules increased very nearly proportionally to the temperature, and that below a certain temperature nothing happened. We find now that the optical anisotropy of the molecules, expressed by ϱ, increases very rapidly also. If the water molecules were adsorbed at the surface of the protein molecules, these facts would not be comprehensible. If on the contrary we assume that the water molecules can penetrate inside the huge molecular structure of the protein, and in doing so, change the relative position of the groups, the optical phenomena become quite clear. This hypothesis has the further advantage of

[1] P. L. du Noüy, *Ann. Inst. Pasteur*, 42: 742, 1928; 43: 749, 1929; 44: 109, 1930; *J. Gen. Phys.*, 12: 363, 1929.

[2] J. Cabannes, "La diffusion moléculaire de la lumière," p. 135, Paris, 1929.

[5] Smith and Wood, *Journ. Am. Chem. Soc.*, 45: 2632, 1923.

explaining the reason of a threshold, around 55° C., and the proportionality to temperature of the phenomena: as long as the kinetic energy of the water molecules does not reach a certain value, the forces binding the external groups of the protein together will not let them in. When the critical temperature is reached, it simply means that the kinetic energy of the water molecules is of the same order of magnitude, and that they can force their way through. From that moment on, the amount of molecules which will penetrate is directly proportional to their energy, that is to say, to the temperature. The volume of the protein molecules will then increase until they occupy the whole volume of the solution: the sol becomes a gel. As the concentration of proteins in horse serum, for instance, is high (about 7 per cent.), and as the volume occupied by these molecules, expressed in per cent. of the total volume, is roughly equal to 11, it means that if the molecules of protein increase their volume nine times, they will be in contact with no free solvent between them; in this case, their mean diameter is only increased about twofold. Such an amount of hydration (900 per cent.) is not at all in contradiction with what is known concerning the capacity of hydration of proteins. Marinesco[3] has found for egg-albumin values as high as 1.300 per cent.

A detailed paper will appear shortly and bring forth a few more facts in favor of this hypothesis.

P. LECOMTE DU NOÜY

INSTITUT PASTEUR, PARIS

ELECTROMAGNETIC RADIATION AND THE PROPERTIES OF THE ELECTRON

THERE is weighty evidence, I have shown,[1] that the link between electromagnetic radiation and the electron, which engages the attention of physicists very much at present, is represented by certain properties of the electron. I would like to point out here additional evidence. Consider an electron gas kept at constant temperature, through which two beams of *continuous* electromagnetic radiation of equal intensities parallel to each other are passed in opposite directions. Suppose that the electrons consist of perfectly reflecting particles. On account of their motion the radiation will exert a pressure tending to decrease their velocities continually. But on the average this can not happen. The electrons therefore regain their velocities during the collisions, which can happen only through an increase of their fields during the process; and hence their fields decrease during the intervals between collisions. The increase in electric potential energy during the collisions can be derived only from the internal energy of the electrons, which can be replenished only through an absorption of radiation, into which the kinetic energy lost was initially converted. The electrons thus absorb radiant energy during their motion which is stored up as internal energy and which is attended by a decrease in their electrical fields.

Now suppose that the intensities of the two beams are varied in such a manner that the velocity of a selected electron of the gas is not influenced through the change of the distribution of the pressure of the beams and surrounding radiation acting upon the electron. If further we suppose that the absorption of radiation takes place in such a manner that no force is exerted upon the electron, it would proceed indefinitely with a constant velocity while absorbing radiation, whose total amount may become infinitely large. But this is impossible. Hence the absorption of radiation takes place asymmetrically and in such a way that a force is introduced acting contrary to the motion of the electron, and in a degree that when the motion is reduced to zero the absorption ceases. Hence if v_0 denote the velocity of the electron at the beginning and v that at the end of a free path, the change in momentum under these conditions is given by

$$m\,(v_0 - v) = k_1 h \Sigma\ k_2 \nu / c$$

where m denotes the mass of the electron, h Planck's constant, c the velocity of light, ν the frequency of radiation, and k_1 and k_2 denote constants. The amount of internal energy converted during the collision at the end of the path into kinetic energy and radiation by acceleration will be less than twice the change in kinetic energy, since the acceleration is produced by a recovery of the field. The difference

$$k_3 h \Sigma k_2 \nu - m\cdot(v_0{}^2 - v^2)$$

is therefore the minimum amount of internal energy that at some part of the path (probably where collision occurs) is reconverted *directly* into radiation, where $k_3\ h\ \Sigma\ k_2\ \nu$ denotes the energy absorbed over the path, k_3 being a constant equal to or greater than k_1. This expression may be written

$$\left(k_3 c - k_1\,(v_0 + v)\right)\frac{h\,\Sigma\,k_2\,\nu}{c}$$

by means of the above equation. It is evidently a positive quantity, and electronic internal energy is thus converted *directly* into radiant energy under these conditions. They will, no doubt, occasionally be satisfied by the radiation surrounding an electron without any external assistance. Internal energy will also obviously be directly converted into radiation

[3] N. Marinesco, *C. R. ac. Sc.*, 189: 1274, 1929; 187: 718, 1929.

[1] *Phil. Mag.*, 7: 493, 1929; SCIENCE, 70: 478, 1929; 61: 340, 1930; *Nature*, 124: 728, 1929.