saturated solution of boric acid in the receiver while in the case of inorganic salts 5 % sulphuric acid was used as a rule. The receiver was usually heated during the process in a water bath at 38°–45°.

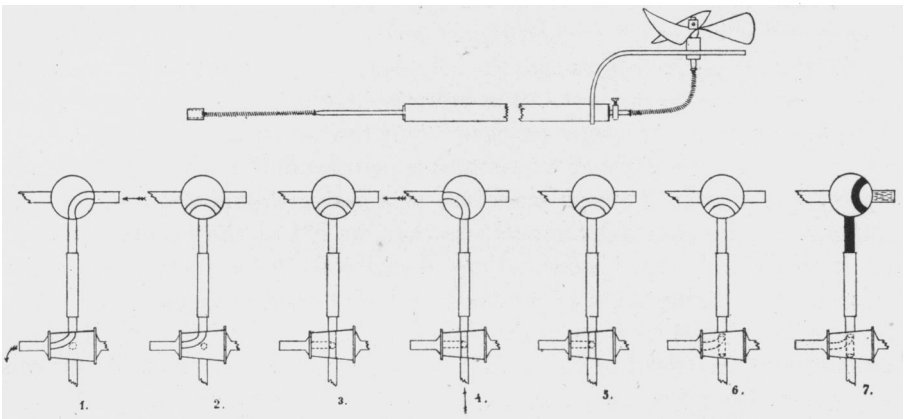


Fig. 5. Below is the small (liquid) receiver in connection with the inlet tap of the evacuation receiver. In the first position (from the left) the dead space is filled with distilled water, in the fourth position the liquid is led into the pump and in the last position the tap of the evacuation receiver is closed and the small receiver can be removed and pumping begun. Above is the stirrrer for the thermostat.

## CHAPTER V

### THE DIRECT EMPIRICAL DETERMINATION OF $\Lambda_{(s)}$ IN THE MODIFIED HENDERSON-HASSELBALCH EQUATION IN ITS APPLICATION TO BLOOD.

The values obtained in the present chapter are calculated from experiments in which the apparent hydrogen ion activity ($H_2$–Pt electrode) and the combined carbonic acid were estimated on the same sample of blood, and in which the $CO_2$ tension with which the blood was in equilibrium was known. In the literature similar estimations by K. A. Hasselbalch [1916, 2], T. R. Parsons [1917] and J. F. Donegan and T. R. Parsons [1919] will be found.

Hasselbalch's measurements were made with a small hook-shaped wire electrode. The volume of the hydrogen was about half that of the liquid in the electrode vessel used. Hasselbalch reckoned his constants from these experiments but did not correct for depression of hydrogen pressure. The constants have been recalculated by means of the equations given in chapter III, and the values obtained by correcting for decreased hydrogen pressure are given on the assumption that the $CO_2$ tension in the electrode vessel was the same as that in the saturation mixture and that $CO_2$ and $H_2$ alone were present in the electrode vessel. This proviso as we have seen in a previous chapter is

only approximately true as the liquid is usually not renewed in Hasselbalch's measurements in this electrode but it will be observed from the table that the correction is only small. Parsons' and Donegan and Parsons' measurements were done on Höber's principle with Walpole's electrode vessel and are already corrected for diminished $H_2$ tension.

There is reason to believe that the electrical measurements of Parsons and his collaborators are the best in the literature because they replatinised their electrodes each day and only let them come in contact with the blood when the measurement was about to commence, saturation being accomplished in a special saturator. Parsons made use of a water thermostat and possibly obtained a more constant temperature than we did at the Finsen Institute. But it seems likely that his estimations of combined $CO_2$ are a little uncertain. This assertion is supported by an examination of his experiments by plotting them as curves, and the view is also shared by E. Jarlöv [1919]. The electrical measurements recorded in Table VIII were carried out on serum which was centrifuged from blood saturated with $CO_2$, at the saturation temperature, saturation being maintained throughout. In experiments with reduced blood the saturation was carried out with $H_2$–$CO_2$ mixture and the serum was resaturated with the same mixture. In experiments with oxygenated blood saturation with $CO_2$–air mixture was performed and the serum separated by the centrifuge was resaturated with $H_2$–$CO_2$ mixture with the same content of $CO_2$ as in the mixture used for the blood. The measurements given in Table IX were made directly on $H_2$–$CO_2$ saturated blood. All Parsons' figures for combined $CO_2$ refer to blood.

I have myself performed a number of similar experiments most of which were carried out with the small saturation electrode, but some with low $CO_2$ tension with the large saturation electrode L I. The platinum electrodes were platinised before each measurement, which was found to be necessary (cf. Hasselbalch and Gammeltoft [1915]) otherwise the potential was lower than with freshly platinised ones. It was found unnecessary after a few experiments to heat the electrode to redness before platinising, but later on measuring strong haemoglobin solutions this was found to be essential, for which reason it would be advisable in future to avoid all trouble by always heating the electrode to redness first.

The potential always became constant a few minutes after the electrode was ready for an estimation (except at 38° when the air in the thermostat got cool on account of the unavoidable manipulations connected with the taking of samples etc.), and this was taken as one of the indications that everything was in order.

The relative absorption coefficient in Hasselbalch's, Parsons', Donegan and Parsons' and the author's blood experiments was always taken as 0·92, while in measurements of serum-rich and serum-poor mixtures of blood I have used 0·95 and 0·855 respectively.

When not otherwise stated the blood used in the present experiments

came from the cattle market and was not used before the day after the animal was slaughtered (so that "1st day" signifies the first day after slaughter). All the experiments with blood at room temperature are marked series A (and also a series with serum). They were all carried out in the autumn of 1918 and I have reason to believe all the potentials were too low without however being able definitely to state the cause. The mutual agreement within a series of experiments was however sufficiently good and therefore I have considered the experiments should be published; the course of the curve for the combination of carbonic acid is also of some interest.

The experiments marked B are subject to no such uncertainty.

Certain points about the value of $\Lambda_{(s)}$ can be surmised in advance. From the very considerable experience accumulated in different quarters on the reaction of the blood (serum) with various $CO_2$ tensions it can be concluded that the activity of the bicarbonate ion in serum cannot be greatly different from its mean concentration in the corresponding blood, from which it follows that $\Lambda_{(s)}$ must be of the same order of magnitude as $K_1$. Hasselbalch considered that $K_I$ (Hasselbalch) varied with the mean concentration of bicarbonate in the same way as it varied in sodium bicarbonate solutions while Milroy [1917], Parsons [1919] and Michaelis [1920] on theoretical grounds thought the value ought not to vary in blood. I can support the opinion of these authors in so far as I have grounds for believing $\lambda_{(s)}$ does not vary but one cannot predict to what extent the variations of the volume of the blood corpuscles ($Q$ in the equation (123)) react upon $\Lambda_{(s)}$ or whether the partition of the bicarbonate ion ($D$) between serum and blood corpuscles is variable. These conditions will be thoroughly investigated in a subsequent chapter. Haggard and Y. Henderson in 1919 calculated this constant from a number of Hasselbalch's and Parsons' experiments. The results differ somewhat from those about to be given chiefly because Haggard and Henderson have dealt with "hydrogen ion concentration" while I have dealt with "apparent activity" (Bjerrum), but furthermore these two authors have not realised that a number of Hasselbalch's experiments which they used in their calculations are really not valid for this purpose because the "hydrogen ion concentration" was not determined electrically, but reckoned from Henderson and Hasselbalch's equation.

In calculating the mean figures of the experiments I have felt justified in neglecting the values in brackets. This applies to the experiments of Parsons [1917] and Donegan and Parsons [1919] which refer to very low tensions of $CO_2$ because a small error in the determination of the combined $CO_2$ will produce a large error in $p\Lambda'_{(s)}$ in these cases. Further I have excluded all the exepriments of Donegan and Parsons where $p\Lambda'_{(s)}$ is under 6·10, since as a matter of experience too low values are much commoner than too high ones with the electrode cells employed, and the low values will therefore not be balanced in the mean value without the adjustment alluded to.

The correction for the temperature in my experiments at room temperature is effected in such a way that 0·005 was subtracted from $p\Lambda'_{(s)}$ at the

temperature of the experiment for each degree below 18° and added for each degree above 18°.

The mean of Hasselbalch's 24 determinations at 38° was

$$p\Lambda'_{(s)} = 6{\cdot}139 \pm 0{\cdot}0039^{1}.$$

From Parsons' and Donegan and Parsons' 48 determinations at 37°

$$p\Lambda'_{(s)} = 6{\cdot}178 \pm 0{\cdot}0039.$$

From my own 15 determinations at 38°

$$p\Lambda'_{(s)} = 6{\cdot}147 \pm 0{\cdot}0079.$$

Parsons [1917] and Donegan and Parsons [1919] have remarked that there is a difference between their $p_H$· values and those calculated according to Hasselbalch's method. They write:

"It will be seen that the general direction of the curve ($p_H$·–$P_{CO_2}$ curve) is the same but that Hasselbalch's blood appears to be more acid than mine at each $CO_2$ pressure. The reason for this may be to a certain extent in an individual variation, and without more data of this kind for the blood of a number of individuals the extent to which this factor operates must remain undecided. But the divergence may possibly be partly explained by differences in our experimental procedure. It is a significant fact that practically all errors which are likely to occur in electrometric determinations on blood (with the exception of loss of $CO_2$, which is out of the question in the experiments here described) tend to produce a reduction in the value of the E.M.F. with a consequent shift of the results to the acid side. The particular points in which Hasselbalch's procedure differs from ours is that he runs oxygenated blood into the electrode vessel, and so his results are liable to be affected by an error due to depolarisation of the electrode."

Parsons has repeatedly emphasised that blood is a heterogeneous system and he also realises that Hasselbalch's constant is a total constant, but in the article written in conjunction with Donegan they draw some conclusions which will not bear criticism. They write:

"There is no doubt of the applicability of Hasselbalch's calculations in homogeneous systems containing $CO_2$ and sodium bicarbonate in equilibrium. But while aqueous solutions of sodium bicarbonate and also blood plasma[2] represent such systems, the same is not true of whole blood. Here we have a two-phase system, composed of corpuscles and plasma in which the differences of composition of the two phases lead to marked differences of their combining powers for $CO_2$. Therefore the relation between $CO_2$-tension and $CO_2$-content in the whole blood will be different from that in plasma. Now it has been shown previously that it is the relation between free and combined $CO_2$ in the plasma, which determines the value obtained in an electrometric determination of $p_H$· of the whole blood, while it is from the different relation

[1] The "mean error" of the mean determination.

[2] It follows from what was said in chapter III, that I am unable to support Donegan and Parsons on this point.

between free and combined $CO_2$ in the whole blood we shall obtain the calculated value of its $p_H$·. In other words the difference between the observed and the calculated $p_H$·'s of blood is simply an expression of the difference in behaviour of corpuscles and plasma towards $CO_2$."

Although I am in agreement with Parsons [1917] that the oxygen error may have caused Hasselbalch's measurements to be too low, he overlooks the fact that the $CO_2$ tension has not been properly appreciated in Hasselbalch's electrode (no renewal) which will militate against the $O_2$ error so that it is impossible to predict which factor will be paramount.

Donegan and Parsons also overlook the fact that Hasselbalch's constant was determined by measurements on whole blood so that the constant contains a correction for the different bicarbonate contents of serum and blood corpuscles, and that the calculated and measured $p_H$· must be the same if Hasselbalch's and Parsons' techniques give concordant results.

That the $p\Lambda'_{(s)}$ value of Parsons and Donegan and Parsons is 0·023[1] greater than mine can only be due to lack of uniformity in the technique of the electrical measurements and as they are all carried out on the Höber principle it seems to me that provided the difference is a real one there can only be two possibilities:

(1) either our calomel electrodes are different,

(2) or my lower value depends upon my not having glowed my platinum electrode before each platinising.

The difference between our constants is really very small, although it seems to be real judging from the mean error, and it would mean a considerable number of new experiments to determine what the true value ought to be.

If the tables are examined more carefully it will appear that $p\Lambda'_{(s)}$ from Donegan and Parsons' measurements seems to increase greatly with reactions more alkaline than $p_H$· 8·0. This is however doubtful and my own measurements with a marked alkaline reaction though few in number do not show this.

On the face of it there appears to be no certain variation of $p\Lambda'_{(s)}$ caused by change of reaction but a more careful investigation of the question might be useful.

If we divide Parsons' and Donegan and Parsons' measurements in such a way that all the experiments in which $p_H$· was equal to or over 7·46 are placed in one group, and all those in which $p_H$· was equal to or below 7·45 are placed in a second group, we get 21 experiments

$$p_H \geqq 7{\cdot}46 \quad p\Lambda'_{(s)} = 6{\cdot}188 \pm 0{\cdot}0063$$

with a standard deviation of 0·029; and 27 experiments

$$7{\cdot}45 \geqq p_H \quad p\Lambda'_{(s)} = 6{\cdot}170 \pm 0{\cdot}0049$$

with a standard deviation of 0·023. The difference between the constants is $0{\cdot}018 \pm 0{\cdot}008$.

[1] Corrected for the influence of the temperature.

It seems from the above as if $p\Lambda'_{(s)}$ increases a little with the $p_{H'}$ value. The standard deviation in the two series is of the same order so that we are justified in assuming there is a real deviation of the "constant," and the results group themselves about the mean in the same way in the two groups so that we can compare the mean values.

Dealing with my own experiments at 38° in a similar way, we have 8 experiments $p_{H'} \leqslant 7{\cdot}39 \quad p\Lambda'_{(s)} = 6{\cdot}161 \pm 0{\cdot}0099$ with a standard deviation of 0·028; and 9 experiments

$$7{\cdot}38 \leqslant p_{H'} \quad p\Lambda'_{(s)} = 6{\cdot}133 \pm 0{\cdot}012$$

with a standard deviation of 0·036. The difference between the constants is $0{\cdot}028 \pm 0{\cdot}0155$; $p\Lambda'_{(s)}$ seems therefore to increase a little with the $p_{H'}$. It is clear however from the calculations that the change in $p\Lambda'_{(s)}$ is small in all cases and a large number of experiments would still be necessary to accurately determine its magnitude.

At 38° the following is the mean of Parsons' [1917], Donegan and Parsons' [1919] and my own measurements:

$p\Lambda'_{(s)} = 6{\cdot}159$, from which $p\Lambda_{(s)} = 6{\cdot}193$

and $\Lambda_{(s)} = 6{\cdot}41 \times 10^{-7}$.

At 18° I found $p\Lambda'_{(s)} = 6{\cdot}24$, from which $p\Lambda_{(s)} = 6{\cdot}27$

and $\Lambda_{(s)} = 5{\cdot}4 \times 10^{-7}$.

## Résumé.

I. The constant $\Lambda_{(s)}$ has been calculated at body temperature and room temperature from all the suitable experiments to be found in the literature.

II. A considerable number of new experiments for the determination of the constant have been performed.

III. A small discrepancy has been shown to exist between the constant reckoned from Parsons' and Donegan and Parsons' experiments and my own, and the possible causes of the disagreement are discussed.

IV. It has been shown to be probable that the constant increases a little with increasing hydrogen ion activity.

Table VII. Calculated after K. A. Hasselbalch, *Biochem. Zeitsch.* **78**, p. 123.

| | mm. Hg $CO_2$ | Vols. % $CO_2$ (combined) | $p_{H'(s)}$ | $pA'_{(s)}$ | Corrected $p_{H'}$ | Corrected $pA'_{(s)}$ |
|---|---|---|---|---|---|---|
| 38°. Ox blood I | 39·3 | 42·6 | 7·31 | 6·11 | 7·32 | 6·12 |
| | 28·1 | 37·2 | 7·43 | 6·14 | 7·44 | 6·15 |
| | 63·1 | 47·9 | 7·19 | 6·14 | 7·21 | 6·15 |
| | 95·6 | 62·7 | 7·09 | 6·10 | 7·12 | 6·13 |
| 38°. Ox blood II | 10·7 | 31·6 | 7·77 | 6·13 | 7·77 | 6·13 |
| | 33·6 | 47·8 | 7·47 | 6·15 | 7·48 | 6·16 |
| | 96·7 | 65·0 | 7·11 | 6·11 | 7·14 | 6·14 |
| | 61·2 | 58·7 | 7·27 | 6·10 | 7·29 | 6·12 |
| | 20·1 | 39·8 | 7·62 | 6·15 | 7·63 | 6·16 |
| | 43·7 | 51·8 | 7·36 | 6·11 | 7·37 | 6·12 |
| | 74·0 | 64·7 | 7·22 | 6·11 | 7·24 | 6·13 |
| 38°. Ox blood III | 41·1 | 48·8 | 7·37 | 6·12 | 7·38 | 6·13 |
| | 41·0 | 48·5 | 7·37 | 6·13 | 7·38 | 6·14 |
| 38°. Ox blood V | 42·7 | 44·3 | 7·31 | 6·13 | 7·32 | 6·14 |
| | 39·3 | 44·5 | 7·33 | 6·10 | 7·34 | 6·11 |
| | 40·9 | 42·2 | 7·29 | 6·12 | 7·30 | 6·13 |
| 38°. Ox blood VI | 36·3 | 45·2 | 7·39 | 6·12 | 7·40 | 6·13 |
| | 54·4 | 52·0 | 7·32 | 6·17 | 7·34 | 6·19 |
| | | | | | | Mean 6·14 |
| 38°. Human blood (K.A.H.) | 50·8 | 57·1 | 7·31 | 6·09 | 7·33 | 6·11 |
| | 45·7 | 52·9 | 7·37 | 6·13 | 7·39 | 6·15 |
| | 32·7 | 45·1 | 7·43 | 6·12 | 7·44 | 6·14 |
| | 18·5 | 35·1 | 7·60 | 6·15 | 7·61 | 6·16 |
| | 22·4 | 36·7 | 7·54 | 6·15 | 7·55 | 6·16 |
| | 80·7 | 61·3 | 7·17 | 6·12 | 7·20 | 6·15 |
| | | | | | | Mean 6·145 |
| 18°. Human blood (K.A.H.) | 44·8 | 54·3 | 7·23 | 6·20 | 7·24 | 6·21 |
| | 22·3 | 44·3 | 7·47 | 6·22 | 7·48 | 6·23 |
| | | | | | | Mean 6·22 |

Table VIII. T. R. Parsons, *J. Physiol.* **51**, p. 448.

| No. | mm. Hg $CO_2$ | Vols. % $CO_2$ (combined) Oxygenated blood | Vols. % $CO_2$ (combined) Reduced blood | $p_{H'}$ Oxygenated blood | $p_{H'}$ Reduced blood | $pA'_{(s)}$ 37° Oxygenated blood | $pA'_{(s)}$ 37° Reduced blood |
|---|---|---|---|---|---|---|---|
| 1 | 37·4 | 43·4 | 47·3 | 7·37 | 7·45 | 6·13 | 6·18 |
| 2 | 0·79 | — | 12·4 | — | 8·55 | — | (6·19) |
| 3 | 19·6 | 34·4 | 39·9 | 7·62 | 7·69 | 6·20 | 6·22 |
| 4 | 72·1 | 59·9 | 64·4 | 7·25 | 7·28 | 6·17 | 6·17 |
| 5 | 10·1 | 30·0 | 31·5 | 7·79 | 7·86 | 6·16 | 6·21 |
| 6 | 8·1 | — | 27·4 | — | 7·91 | — | 6·22 |
| 7 | 55·3 | — | 55·1 | — | 7·35 | — | 6·19 |
| 8 | 33·4 | 41·5 | 47·6 | 7·48 | 7·53 | 6·13 | 6·21 |
| 9 | 5·7 | 21·3 | 23·8 | 7·96 | 8·01 | 6·22 | 6·22 |
| | | | | | | Mean 6·17 | 6·20 |
| | | | | | | 6·19 | |

Table IX. Calculated after Donegan and Parsons, *J. Physiol.* **52**, pp. 317–318.

| mm. Hg $CO_2$ | Vols. % $CO_2$ (combined) | $p_H$. | $p\Lambda'_{(s)}$ 37° |
|---|---|---|---|
| 0·7 | 4·5 | 8·29 | (6·32) |
| 9·7 | 33·1 | 7·78 | (6·08) |
| 29·6 | 44·3 | 7·51 | 6·17 |
| 44·0 | 53·1 | 7·39 | 6·14 |
| 65·7 | 60·7 | 7·30 | 6·17 |
| 1·3 | 6·4 | 8·26 | (6·30) |
| 12·7 | 30·5 | 7·75 | 6·20 |
| 37·0 | 45·0 | 7·45 | 6·20 |
| 67·6 | 52·6 | 7·24 | 6·18 |
| 2·1 | 8·4 | 8·26 | (6·29) |
| 18·8 | 36·3 | 7·67 | 6·22 |
| 31·5 | 48·2 | 7·49 | 6·14 |
| 2·2 | 10·4 | 8·30 | (6·36) |
| 18·1 | 39·4 | 7·68 | 6·16 |
| 38·9 | 43·8 | 7·44 | 6·22 |
| 59·3 | 53·9 | 7·30 | 6·18 |
| 1·3 | 7·7 | 8·19 | (6·25) |
| 20·0 | 35·5 | 7·59 | 6·18 |
| 42·7 | 45·1 | 7·36 | 6·17 |
| 65·9 | 53·0 | 7·24 | 6·17 |
| 1·3 | 10·0 | 8·27 | (6·22) |
| 15·9 | 35·6 | 7·66 | 6·15 |
| 38·2 | 46·9 | 7·41 | 6·16 |
| 51·5 | 50·7 | 7·31 | 6·14 |
| 1·0 | 12·4 | 8·28 | (6·01) |
| 21·3 | 38·5 | 7·58 | 6·16 |
| 40·5 | 46·8 | 7·37 | 6·14 |
| 60·0 | 50·8 | 7·26 | 6·17 |
| 2·0 | 8·9 | 8·15 | (6·34) |
| 14·2 | 29·3 | 7·67 | 6·19 |
| 30·8 | 38·9 | 7·43 | 6·17 |
| 45·9 | 45·0 | 7·34 | 6·18 |
| 2·0 | 8·5 | 8·23 | (6·32) |
| 19·1 | 33·5 | 7·61 | 6·20 |
| 40·8 | 44·6 | 7·39 | 6·19 |
| 60·7 | 54·9 | 7·27 | 6·15 |
| 10·9 | 26·0 | 7·74 | 6·20 |
| 29·3 | 37·8 | 7·47 | 6·20 |
| 45·3 | 46·2 | 7·32 | 6·20 |
| 0·7 | 8·8 | 8·02 | (6·75) |
| 11·6 | 27·4 | 7·58 | (6·03) |
| 31·3 | 37·0 | 7·37 | 6·13 |
| 46·1 | 41·3 | 7·27 | 6·15 |
| 12·5 | 23·0 | 7·61 | 6·18 |
| 25·6 | 30·3 | 7·42 | 6·18 |
| 40·9 | 36·9 | 7·28 | 6·16 |
| | | | Mean 6·18 |

Table X. Determination of $p\Lambda'_{(s)}$ in blood at 38° with the small saturator electrode, Series B.

| mm. Hg $CO_2$ | mm. Hg $O_2$ | Vols. % combined $CO_2$ | Vols. % combined $O_2$ | $p_H$. | $p\Lambda'_{(s)}$ | |
|---|---|---|---|---|---|---|
| 13·6 | 0·4 | 27·7 | 0·2 | 7·65 | 6·18 | |
| 74·6 | 0·5 | 26·5 | 0·6 | — | — | Human blood (E.J.W. 31. i. 19). Placed |
| 39·5 | 0·4 | 42·8 | 0·6 | 7·39 | 6·20 | on ice immediately |
| 109·2 | 0·5 | 64·7 | 0·2 | 7·10 | 6·15 | |
| 544·5 | 0·5 | 99·5 | 0·1 | 6·60 | 6·17 | In the ice safe overnight |
| | | Ordinary air | 24·8 | Mean | 6·18 | |
| 501·9 | 0·4 | 84·2 | 0·0 | 6·53 | 6·13 | |
| 83·5 | 0·2 | 55·7 | 0·1 | 7·07 | 6·08 | |
| 36·0 | 0·5 | 44·1 | 0·3 | 7·34 | 6·10 | Ox blood |
| 8·4 | 0·3 | 24·2 | — | 7·75 | 6·11 | |
| 108·7 | 0·2 | 60·5 | 0·4 | 7·07 | 6·15 | |
| 39·6 + ord. air | | 39·6 | 20·1 | Mean | 6·10 | |
| 33·4 | 0·3 | 44·3 | 0·2 | 7·43 | 6 14 | Rabbit blood from four animals (quite |
| 120·9 | 0·4 | 65·4 | 0·2 | 7·04 | 6·14 | fresh, placed on ice immediately) |
| 39·4 | 0·3 | 45·5 | 0·7 | 7·38 | 6·15 | |
| 37·8 | 140·0 | 41·2 | 13·2 | Mean | 6·14 | |
| 518·1 | 0·7 | 99·4 | 0·0 | 6·55 | 6·10 | |
| 39·6 | 0·3 | 49·8 | 0·7 | 7·45 | 6·18 | Horse blood |
| 97·3 | 0·5 | 65·7 | 0·5 | 7·16 | 6·19 | |
| 31·9 | 0·5 | 47·0 | 0·6 | 7·51 | 6·17 | In the ice safe overnight |
| 34·1 | 137·5 | 40·0 | 20·0 | Mean | 6·16 | |
| 26·0 | 1·0 | 36·3 | 0·1 | 7·48 | 6·16 | Human blood, fresh (chronic nephritis) |
| 19·9 | 0·2 | — | 0·1 | 7·59 | — | |
| 96·6 | 0·4 | — | — | 7·10 | — | |
| 36·4 | 136·8 | 34·7 | 20·8 | — | — | |

Mean of all the determinations 6·15.

Table XI. Determination of $p\Lambda'_{(s)}$ in blood at 18° with the small and large (L I) saturator electrodes, Series A.

| Temp. | mm. Hg $CO_2$ | mm. Hg $O_2$ | Vols. % combined $CO_2$ | Vols. % combined $O_2$ | $p_H$ | $p\Lambda'_{(s)}$ | |
|---|---|---|---|---|---|---|---|
| 17·5 | 250·4 | 0·8 | 112·1 | 0·1 | 6·85 | 6·23 | Human blood (E.J.W. 3. x. 18), |
| 18·5 | 91·8 | 0·6 | 89·2 | 0·4 | 7·17 | 6·23 | fresh, placed on ice |
| 18 | 24·1 | 0·8 | 59·4 | — | 7·62 | 6·28 | |
| 18 | 26·3 | 0·8 | 56·5 | — | 7·60 | 6·32 | 2nd day |
| 18 | 37·7 | 0·3 | — | — | 7·50 | — | |
| 18 | 16·6 | 0·8 | 48·9 | 0·2 | — | — | |
| 18 | 73·1 | 0·7 | 78·6 | 0·5 | 7·23 | 6·25 | |
| 18 | 58·0 | 143·8 | 65·6 | 22·7 | — | — | |
| 18 | 58·0 | 143·8 | 65·9 | 23·1 | — | — | |
| 18 | 4·2 | 0·8 | 26·3 | 0·8 | 8·02 | 6·29 | 3rd day. Large saturator elect. (L I) |
| | | | | | Mean | 6·27 | |
| 16·5 | 147·1 | 0·8 | 74·0 | 0·2 | 6·84 | 6·21 | Ox blood |
| 17 | 80·2 | 0·6 | 65·3 | 0·4 | 6·07 | 6·22 | |
| 17 | 58·8 | 0·8 | 59·8 | 0·5 | 6·19 | 6·24 | |
| 17 | 58·8 | 0·8 | 59·6 | 0·0 | 6·19 | 6·24 | $CO_2$ preliminary treatment |
| 16·5 | 419·6 | 1·1 | 85·8 | 0·4 | 6·43 | 6·19 | Next day. $CO_2$ preliminary |
| 17 | 51·7 | 1·2 | 58·4 | 0·0 | 7·26 | 6·27 | treatment |
| 17 | 16·2 | 0·6 | 42·3 | 0·0 | 7·57? | (6·22)? | „ „ |
| 17 | 22·3 | 1·0 | 48·4 | 0·2 | 7·50 | 6·23 | „ „ |
| 16·5 | 5·3 | 0·6 | 29·1 | 0·0 | 7·92 | 6·24 | 3rd day. Large saturator elect. (L I) |
| | Air from water blower | | | 14·9 | Mean | 6·24 | |
| | „ | | „ | 15·1 | | | |
| 19 | 77·1 | 0·8 | 68·5 | — | 7·15 | 6·25 | Dog blood (0·1 % oxalate) |
| 19 | 29·3 | 0·3 | 53·5 | — | 7·47 | 6·26 | |
| 19 | 56·4 | 0·3 | 62·4 | 0·4 | 7·29 | 6·29 | |
| 19 | 127·5 | 0·2 | 76·0 | 0·2 | 6·97 | 6·24 | |
| 19 | 337·6 | 0·5 | 88·8 | 0·2 | 6·65 | 6·26 | |
| 19 | 2·2 | 0·7 | 21·8 | 0·4 | 8·15 | (6·38) | Large saturator elect. (L I) |
| | Air from water blower | | | 19·2 | Mean | 6·26 | |
| | „ | | „ | 19·2 | | | |
| 18·5 | 41·5 | 0·3 | 63·0 | 0·4 | 7·38 | 6·25 | 60′ after blood Rabbit blood |
| 18·5 | 24·2 | 0·3 | 53·1 | 0·0 | — | — | 90′ was taken. (on ice) |
| 18·5 | 83·1 | 0·5 | 76·5 | 0·2 | 7·14 | 6·23 | 150′ „ |
| 18·5 | 368·0 | 0·2 | 107·0 | 0·4 | 6·61 | 6·20 | 195′ „ |
| 18·5 | 44·2 | 0·5 | 64·1 | 0·4 | 7·35 | 6·24 | 240′ „ Vol. % $O_2$ |
| 18·5 | 16·0 | 0·3 | 48·6 | 0·5 | 7·64 | 6·21 | 300′ „ (combined) |
| 18·5 | 81·7 | 0·4 | 73·8 | 0·1 | 7·16 | 6·25 | 390′ „ 16·6 |
| | | | | | Mean | 6·23 | |
| 19 | 91·5 | 0·6 | 83·5 | 0·7 | — | — | 1st day. Horse blood |
| 19 | 22·0 | 0·3 | 56·2 | 0·7 | 7·62 | 6·26 | |
| 19 | 48·7 | 0·3 | 69·9 | 0·7 | 7·39 | 6·28 | |
| 18·5 | 3·0 | 0·4 | 25·2 | 0·4 | 8·14 | 6·26 | L I |
| 19 | 39·6 | 0·2 | 66·3 | 0·5 | 7·43 | 6·25 | |
| 18·5 | 484·7 | 0·2 | 112·2 | 0·9 | 6·54 | 6·25 | 2nd day |
| 19 | 80·2 | 0·2 | 78·2 | — | 7·20 | 6·24 | 3rd day |
| | Air from water blower | | | 22·3 | Mean | 6·26 | |
| | „ | | „ | 22·9 | | | |
| 18·5 | 128·6 | 0·6 | 82·0 | 0·6 | 6·99 | 6·23 | 2nd day. Equal parts of horse |
| 19 | 58·5 | 0·6 | 71·9 | 0·5 | — | — | blood and serum. $\Psi = 5$ |
| 19 | 38·8 | 0·3 | 66·6 | 0·4 | 7·42 | 6·24 | |
| 21 | 269·8 | 0·4 | 90·3 | — | 6·72 | 6·24 | 3rd day |
| | | | | | Mean | 6·24 | |
| 20 | 126·9 | 0·4 | 90·3 | — | — | — | 3rd day. Horse blood cell sus- |
| 20 | 42·6 | 0·4 | 59·6 | — | 7·42 | 6·27 | pension |
| 20 | 72·1 | 0·2 | 74·3 | — | 7·26 | 6·25 | |
| | | | | | Mean | 6·26 | |

Table XI (*continued*)

| Temp. | mm. Hg $CO_2$ | mm. Hg $O_2$ | Vols. % combined $CO_2$ | Vols. % combined $O_2$ | $p_{H'}$ | $p\Lambda'_{(s)}$ | | |
|---|---|---|---|---|---|---|---|---|
| 19·5 | 536·4 | 0·4 | 102·2 | — | 6·45 | 6·22 | 2nd day | Ox blood |
| 21 | 91·9 | 0·3 | 75·5 | — | 7·13 | 6·25 | 3rd day | |
| 19·5 | 24·3 | 0·2 | 53·3 | — | 7·52 | 6·23 | 4th day | |
| — | — | 156·0 | — | 18·96 | Mean | 6·23 | | |
| — | — | 156·0 | — | 18·97 | | | | |
| 19 | 510·5 | 0·5 | 89·6 | — | 6·44 | 6·25 | 2nd day | Equal parts of ox |
| 21 | 91·9 | 0·3 | 72·5 | — | 7·08 | 6·23 | 3rd day | blood and serum. |
| 20 | 34·3 | 0·4 | 60·7 | — | 7·45 | 6·25 | | $\Psi=5$ |
| 20 | 24·3 | 0·2 | 57·8 | — | 7·53 | 6·23 | 4th day | |
| — | — | 156·6 | — | 8·5 | Mean | 6·24 | | |
| 19 | 508·0 | — | 115·8 | — | 6·59 | 6·24 | 1st day | Ox blood cell sus- |
| 20 | 65·7 | 0·3 | 70·3 | — | 7·24 | 6·23 | 3rd day | pension. $\Psi=14·5$ |
| 20 | 34·3 | 0·4 | 57·1 | — | 7·42 | 6·26 | | |
| 20 | 2·8 | 1·1 | 34·4 | — | 7·80 | 6·25 | 5th day | L I |
| — | — | 156·6 | — | 33·8 | Mean | 6·25 | | |
| 18 | 65·3 | 0·5 | 73·0 | 0·1 | — | — | 1st day | Ox blood |
| 19 | 51·0 | 1·2 | 66·6 | 0·2 | 7·29 | 6·21 | 2nd day | |
| 19 | 6·0 | — | 36·5 | 0·3 | 7·96 | 6·22 | 3rd day | L I |
| 18 | 58·0 | 140·7 | — | 16·5 | Mean | 6·215 | | |
| 18 | 58·0 | 140·7 | — | 16·6 | | | | |
| 19 | 38·6 | 0·8 | 64·0 | 0·5 | 7·42 | 6·28 | 1st day | Blood and serum, |
| 19 | 51·0 | 1·2 | 66·7 | 0·4 | 7·29 | 6·23 | 2nd day | equal parts. $\Psi=5$ |
| 18 | 144·5 | 0·6 | 81·6 | — | 6·91 | 6·22 | 3rd day | |
| — | — | 146·3 | — | 6·9 | Mean | 6·24 | | |
| 18 | 53·7 | 1·0 | 71·0 | 0·9 | 7·33 | 6·23 | 2nd day | Ox blood cell sus- |
| 18 | 64·9 | 1·3 | 76·7 | 0·1 | 7·24 | 6·19 | 3rd day | pension |
| 18 | 64·9 | 1·3 | 75·4 | 0·6 | 7·24 | 6·20 | | |
| — | — | 146·3 | — | 32·3 | Mean | 6·20 | | |

## CHAPTER VI

### THE DETERMINATION OF THE $p\Lambda'_{(s)}$ VARIATION.

From equation (127) and (123) in logarithmic form we get

$$p\Lambda'_{(s)} = p\lambda_{(s)} - \log \frac{100 - Q(1-D)}{100} - \log \Phi_a\,(CO_2). \quad \ldots\ldots\ldots(129)$$

If we now calculate $p_{H'(s)}$ for blood by using the following equation

$$p_{H'(s)}\,(\text{uncorrected}) = p\lambda_{(s)} + \log B - \log \int_0 = p\lambda_{(s)} + \log \Phi_a\,(CO_2) + \log B - \log \frac{P_{CO_2 a}}{7·60} \ldots\ldots(130)$$

instead of (126) $\qquad p_{H'(s)} = p\Lambda'_{(s)} + \log B - \log \int_0$,