

A NOMOGRAM FOR THE COMPUTATION OF PLASMA pCO₂ FROM pH AND TOTAL CO₂ CONTENT AT DIFFERENT TEMPERATURES

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A nomogram has been constructed for the computation of plasma pCO₂, once pH and total CO₂ content have been determined experimentally. It has the advantage that it can be used during hypothermia since there is a temperature correction scale operating over the range 25° to 40°C.

The Henderson-Hasselbalch equation has been used extensively to calculate CO₂ tension of plasma, after pH and total CO₂ values have been determined experimentally. More detailed information can be obtained by exposing the plasma to oxygen of known CO₂ tension and re-examining as in the micro Astrup system of Andersen, Engel, Jorgensen and Astrup (1960), but few of these instruments are in use in India and where cardiac surgery is being undertaken the Henderson-Hasselbalch equation is still valuable for indirect evaluation of pCO₂.

Van Slyke, Sendroy, Hastings and Neill (1928) used the value 0.510 for ∞ , the solubility co-efficient of CO₂ in normal plasma at 38° which yielded an 's' value of 0.0301 in the practical equation :

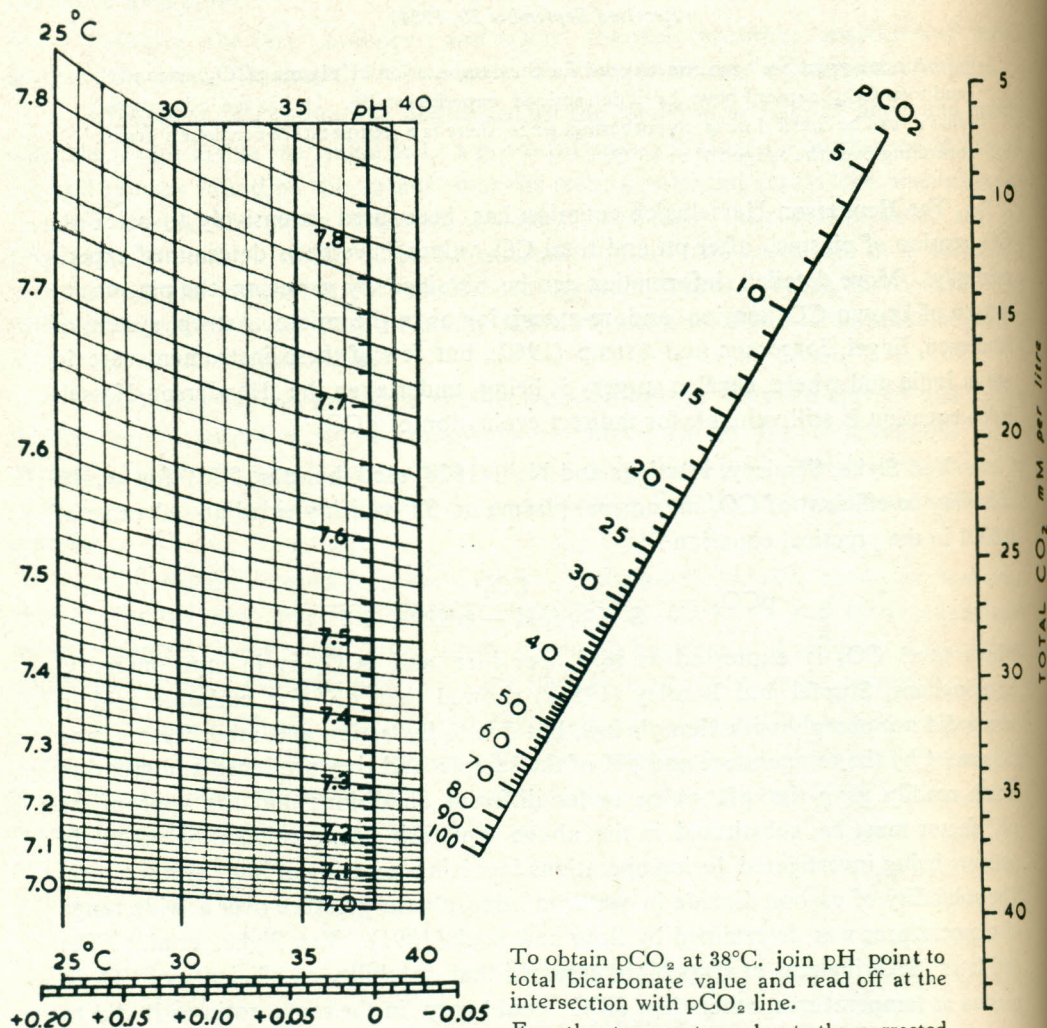
$$pCO_2 = \frac{CO_2}{S [10 (pH - pK') + 1]}$$

where total CO₂ is expressed as mM. per litre and pCO₂ is in mm. mercury. Severinghaus, Stupfel and Bradley (1956a) showed that pK' for carbonic acid in serum did not comply with Henry's law, but due to hydration and other factors, was influenced by the temperature and pH of the sample and they produced a nomogram which readily gave the pK' value under different conditions and the appropriate pK' factor must be substituted in the above equation when calculating pCO₂ in patients being investigated during operations involving lowering of body temperature. The solubility of carbon dioxide in water at atmospheric pressure over a wide range of temperatures was determined by Bohr and Boek (1891). Van Slyke, et al. (1928) and later Severinghaus et al. (1956b) assumed that solubility co-efficients of CO₂ in plasma at temperatures other than 38°C would vary in the same ratio as it did to water at 38°C and the latter authors tabulated values of 's' derived at different temperatures on that basis. The nomogram shown in Fig. 1 has been prepared

using the 's' and pK' data of Severinghaus et al. mentioned above, in such a way that pCO_2 can be readily computed for different body temperatures.

CONSTRUCTION OF NOMOGRAM

NOMOGRAM FOR COMPUTATION OF PLASMA pCO_2 FROM pH AND TOTAL CO_2 AT DIFFERENT TEMPERATURES



CORRECTION FACTOR to be added to pH values determined at 38°C. to give pH at t°C.

To obtain pCO_2 at 38°C. join pH point to total bicarbonate value and read off at the intersection with pCO_2 line.

For other temperatures locate the corrected pH value and the temperature point on the left hand side of the chart and move HORIZONTALLY across to the 38°C. line and continue as above.

Two parallel vertical lines were drawn as shown in figure to represent pH at 38°C and total CO₂ content and the latter was divided into equal steps to represent a scale 0 to 45 m. eq. CO₂ per litre and the divisors in the Henderson-Hasselbalch equation were calculated using 0.0301 for 's' and substituting the appropriate value of pK' at 38° for the pH in question and these 'd' values, from 0.25 to 1.65, were set off in linear divisions and the pH value for each 0.1 pH unit inserted at its own 'd' in order to calibrate the 38° pH scale and cover the range 7.0 to 7.8 as shown.

Tie lines were then drawn between pH 7.8 and total CO₂ of 16.4 and pH 7.6 and 10.3 to locate the point corresponding to 10 mm. Hg. on the pCO₂ line. Similarly by joining pH 7.6 to 41.1 and pH 7.4 to 25.8, the point which would represent 40.0 mm. Hg. was obtained, thus defining the slope of the pCO₂ line which showed only the slightest deviation from linearity. Further calculation around certain fixed points allowed detailed calibration of this scale and thereafter to obtain pCO₂ from experimental pH and total CO₂ it was only necessary to join these two points by a straight edge and read off the required value of pCO₂ at the intersection with the pCO₂ line.

The arrangement is somewhat similar to that of Van Slyke and Sendroy (1928) but was more convenient for the next stage which involved extension of the temperature scale to cover the range 25°C to 40°C.

Combinations of 's' and pK' for different temperatures and pH values which yielded the same divisor 'd' in the equation given above were so arranged that when a pH and temperature point was located on the left-hand side of the chart and a horizontal line was drawn across to meet the 38°C line, the reading from this point to the total CO₂ line again gave the value of pCO₂ under the defined conditions.

Most clinical laboratories maintain the water-jackets of their blood pH meter electrodes at 38°C and although it would have been possible to arrange that the temperature side of the chart should include a correction for blood samples obtained from subjects during hypothermia but on which the pH value had been determined at 38°C, in order to avoid undue complication this has not been done and if the pH of such samples is measured at 38°C the temperature correction of Rosenthal (1948): $pH_{38} = pH_t - 0.0147(38 - t)$, should be applied in order to obtain the pH of the blood at the patient's body temperature before locating pH and temperature on the left-hand side of the chart. The temperature correction factor to be added to the pH as determined at 38°C can be obtained from the separate scale shown on the lower left-hand corner of the nomogram.

Rosenthal gave tentative evidence that total CO₂ content of plasma obtained from normal subjects using the usual precautions for collecting blood for pH determination, and separated at 38°C to give true plasma, differed from that of 'derived' plasma obtained by centrifuging and separating at a lower temperature.

Severinghaus et al. (1956 b) on the other hand, in more detailed experiments were unable to show any difference between total CO_2 content of such samples although the pH and pCO_2 were of course affected.

The nomogram proved useful in this laboratory in expediting the indirect determination of pCO_2 in eliminating mathematical errors and also in illustrating changes which could be postulated by altering one or other of the factor.

It has been shown, however, that differentiation of metabolic and/or respiratory acidosis or alkalosis cannot in certain cases be satisfactorily resolved by a single pH and total CO_2 determination, although the clinical condition of the patient often gives an indication of the type of abnormality involved.

The additional information obtained by exposing the sample to other known CO_2 tensions as the Astrup system, readily gives a full assessment of the patient's acid/base status.

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