IN THE LABORATORY

Time-saving Apparatus for Respiratory Exchange Measurements[1]

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The apparatus here reported was designed originally to provide light-weight equipment for measuring the respiratory exchange of large farm animals, especially horses and mules. However, certain features of the design may be of general use in respiratory studies.

The major modification in this open-circuit apparatus is the use of a "flowrater"[3] instead of the usual displacement meter to measure pulmonary ventilation rate.[4] As pulmonary ventilation rate is affected by nervousness, the accuracy with which the resting or basal rate is measured depends not only on the mechanical precision of the meter but also on the relative level or changing rate during the period of measurement. With the displacement type meter, an interval of several minutes must be allowed between the initial and final readings of the meter; but animals, as a rule, are not quiet for several minutes at a time, and changes in rate escape detection since the rate cannot be calculated until after the final meter reading is made. The flowrater as here used, however, indicates visually at all times the state of constancy or change in the pulmonary ventilation rate, and so permits rapid measurements to be made during brief quiet periods.

Constancy of the pulmonary ventilation rate during the measurements is of considerable physiologic importance, since the composition of the expired air, the respiratory quotient (hence, the calorific values of oxygen and carbon dioxide), and the pulmonary vaporization rate are all affected by changes in the pulmonary ventilation rate.

Since the float in the flowrater tended to rise and fall with each exhalation, it was necessary to design auxiliary equipment to maintain a constant rate of flow through the flowrater. A diagram of the apparatus is shown in Fig. 1. The subject draws fresh air through the inspiration check valve (one-way valve) into the mask. Exhaled air passes from the mask through the expiration check valve and into the large expansible mixing (Douglas) bag. When the blower is running at the proper speed to draw air from the mixing bag at the same average rate at which the exhaled air enters the bag, the electrical contact, attached to the movable side of the bag, fluctuates only a small distance with each exhalation and remains on the middle post of the three stationary contacts. However, if the pulmonary ventilation rate changes sufficiently to cause an appreciable change in the volume of air in the bag, and consequently to swing the movable contact over to one of the side stationary posts, the electrical resistance in the blower motor circuit will vary in such a direction as to cause an overcompensation in the adjustment of flow into and out of the mixing bag. The movable contact will then oscillate between the center stationary post and one of the outer stationary posts, the condition of disequilibrium being signaled by the rise and fall of the float in the flowrater. Equilibrium can then be restored by adjustment of the hand rheostat.

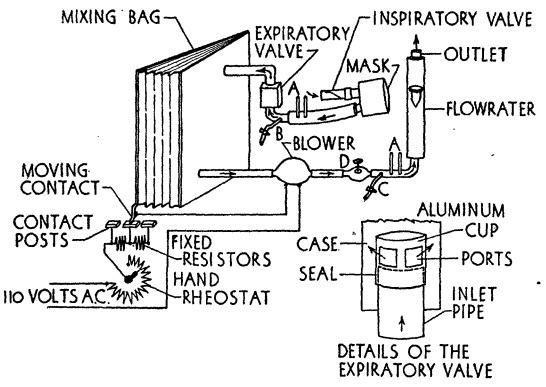

FIG. 1. Diagram of respiratory exchange apparatus. The parts designated by letters are as follows: A, wet and dry bulb thermometers; B, connection for use in recording respiration rate; C, connection for collecting samples of expired air; D, auxiliary regulating valve.

A sample of expired air is collected at C (Fig. 1) when the animal is quiet and the pulmonary ventilation rate is constant. The composition of the sample is then determined by means of laboratory gas analysis apparatus.

Various types of check valves may be used to govern the direction of flow. Since light-weight rubber valves deteriorate rapidly when exposed to expired air, we have constructed an aluminum expiratory valve (see detail,

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[3] The flowrater (formerly called "rotameter") is a flow rate metering instrument in which the medium being measured flows between the periphery of the head of a float and the inside wall of the tapered tube in which it travels. The float remains at a constant elevation for a given rate of flow and changes elevation when the rate of flow is changed. Our instrument was manufactured by Fischer & Porter Company, Hatboro, Pennsylvania; for technical information see their catalog 98-Y, "Theory of the Rotometer."

[4] Pulmonary ventilation rate is a measure of the volume of air inspired or expired per minute.

Fig. 1) consisting of an aluminum cup inverted over the end of the pipe that transports expired air to the valve. With each exhalation the cup rises until the ports in its sides open above the end of the pipe. The succeeding inhalation pulls the valve closed. The rubbing surfaces are machined to a close fit; a film of oil between the cup and the pipe insures a tight air seal. The valve is encased in an air-tight box.

A flap-type valve with aluminum frame and rubber diaphragm is used for the inspired air. Silverman and Lee (*1*) have recently described a similar valve and have given the reference sources.

Reference

1. Silverman, L., and Lee, R. C. *Science*, 1946, **103**, 537.

Comparison of the Determination of the Disintegration Rate of Radiophosphorus by Absolute Beta Counting and Calorimetric Measurement[1]

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The quantitative measurement of radiophosphorus, P^{32} (14.3 days), is important in connection with clinical treatment and in connection with medical and biological research where the absolute quantity of beta radiation emitted by P^{32} must be known. Accordingly, it is desirable to be able to make quantitative measurements which are reasonably accurate. Up to the present, however, there has often been a great deal of uncertainty in the measurement of this material and, for that matter, in the measurement of many other radioisotopes. Curtiss (*1*) has recently pointed out that, in an interlaboratory comparison of measurements of I^{131}, deviations from the average by as much as 40–80% occurred.

We have had occasion to make a comparison of the determination of the disintegration rate of P^{32} by calorimetric measurement and by absolute beta counting and believe it is worth while to report these results in order to give an idea of the accuracy with which radiophosphorus can be measured.

The calorimeter used for the determination of the rate of heat evolution of radiophosphorus was of an isothermal type operating at the temperature of liquid nitrogen and using the rate of evaporation of nitrogen at constant pressure as the measure of the rate of heat input. A calibration of the calorimeter was made with a resistance heater at 5 points between the energy inputs of 0.2×10^{-4} and 2.5×10^{-4} watts. Mean deviation from the root mean square best straight line of rate of energy input versus nitrogen evolution was ± 0.8%. Time of equilibration in passing from one heat input to another was less than 30 min.

Absolute beta counting was done with an end-window G-M counter which was calibrated using several different isotopes (Co^{60}, I^{131}, Au^{198}, RaE, Na^{24}, and UX_2) of known disintegration rate to determine the counter efficiency.[2] The disintegration rate of RaE was determined by making an absolute alpha count of RaF, which grows in as RaE decays. The disintegration rate of an equilibrium UX_1–UX_2 mixture carried from a solution of aged uranium was calculated from the known disintegration rate of the uranium. Disintegration rates of Co^{60}, I^{131}, Au^{198}, and Na^{24} were determined using coincidence counting technique.

A carrier-free sample of P^{32} prepared by the (n,p) reaction with S^{32} of an activity of approximately 25 mc was placed in the calorimeter and the energy output determined. Making a 1.3% correction for loss of beta-particle energy, which escaped the calorimeter as Bremsstrahlung, the sample measured $8.58 \pm 0.11 \times 10^{-5}$ watts at a given reference time.

A similar P^{32} sample was analyzed in a thin lens-type beta-ray spectrometer using a 50-μg/cm² source mounting. Under these conditions the Kurie plot was straight from the maximum energy to ca. 100 kv, where the absorption in the counter window could no longer be neglected. Assuming the Kurie plot to be straight below this energy, P^{32} was found to have an average energy of 0.700 Mev. This value of the average energy combined with the wattage determined calorimetrically gave a disintegration rate of $7.73 \pm 0.10 \times 10^8$ d/s at the reference time.

Absolute beta counts were made of 8 different aliquots of the P^{32} solution. A 1.3% correction for backscattering from the 2.5 mg/cm² polystyrene film on which the P^{32} aliquots were mounted for beta counting was made. The determinations showed a standard deviation of 2.1% with a value of $7.90 \pm 0.17 \times 10^8$ d/s at the reference time.

The rates of disintegration of two aliquots of the P^{32} solution were also determined by beta counting, using a National Bureau of Standards RaD + E beta-ray standard and following the procedure recommended by the Bureau. The two determinations gave disintegration rates of 7.64×10^8 and 7.83×10^8 d/s, respectively, at the reference time.

The disintegration rates determined by the calorimetric method, the use of a calibrated G-M tube, and the use of a National Bureau of Standards RaD + E beta-ray standard all agree within experimental uncertainty. The results indicate that, using thin, end-window G-M counter tubes with proper technique, the disintegration rate of P^{32} may be determined with a probable error of no more than 2 or 3%.

Reference

1. Curtiss, L. F. *Science*, 1947, **106**, 302.

[1] This document is based on work performed under Contract No. W-35-058-eng-71 for the Atomic Energy Project at the Clinton Laboratories.

[2] Reported in a paper, "Absolute Beta Counting Using End-Window Geiger-Müller Counter Tubes," by L. R. Zumwalt, presented at the September 1947 meeting of the American Chemical Society, New York City.