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# A Rapid Determination of the Specific Activity of $^{85}$Krypton in Pressurized Cylinders

**Kenneth D. Williams, M.S.**[1]

*Bethesda, Maryland*

During the past several years, the inhalation of radioactive $^{85}$krypton gas has been utilized as a diagnostic method in the identification of left-to-right circulatory shunts (1,2). The current procedure requires the patient to breathe a mixture of $^{85}$krypton in air directly from a pressurized cylinder. To estimate the radiation exposure to the patient, it is necessary to know the concentration of the inhaled $^{85}$krypton mixture prior to administration (3).

A precise value for the specific activity of $^{85}$krypton in a given cylinder may be obtained by removing a sample of gas and comparing it with a certified $^{85}$krypton gas standard at a known temperature and pressure. $^{85}$Krypton gas standards may be obtained from the National Bureau of Standards. However, since this procedure is time consuming when dealing with a large number of cylinders, a simple, sensitive, and rapid method has been devised to eliminate the need for sampling the gas from all the cylinders (4).

## METHODS AND MATERIALS

Number 4, steel, pressurized cylinders containing approximately 80 mc of $^{85}$krypton in 200 liters of air at a pressure of 1,280 psi were used in this study. The manufacturer has stated that the average volume of these cylinders is 2.31 liters.

To determine the total activity of $^{85}$krypton in a cylinder, the radiation intensity at the surface parallel to the long axis of the cylinder was measured using an end-window Geiger-Mueller tube and a scaler. The Geiger-Mueller tube was placed so that the end-window was as close as possible and normal to the surface of the cylinder. The count-rate (corrected for coincidence and background) for a given cylinder was found to be proportional to the total activity (A) of $^{85}$krypton, thus:

$$cpm = kA \tag{1}$$

where k is the constant of proportionality. The value for k will vary from cylinder to cylinder. Since the activity is the product of the specific activity of a unit volume (SA) and the volume (V) of the gas at some temperature and pressure, an expression for the specific activity at a temperature of 20° C and a pressure of 760 mm of Hg (S.T.P.) is given by

$$SA = Kcpm/P \tag{2}$$

[1]U.S.D.H.E.W., Public Health Service, National Institutes of Health, Clinical Center, Department of Radiation Safety, Bethesda, Maryland 20014.

The constant K expresses the proportionality between the count-rate and the total activity, and the proportionality between the volume of gas at S.T.P. and at the pressure of the gas in the cylinder. (The derivation is given as an appendix).

Several cylinders having the same specific activity as determined by direct measurement were found to have different surface count-rates due to variations in the wall thickness of these cylinders. The difference in wall thickness was demonstrated by measuring the intensity of an external gamma source ($^{60}$cobalt) with and without empty (no $^{85}$Kr gas) cylinders in the radiation beam. It was found that those cylinders having the same gross weight attenuated the beam equally and that there was a variation of attenuation with gross weight. Since the gross weights of the cylinders have varied from 12 to 18 pounds, an attenuation correction factor must be applied to the surface count-rate. Figure 1 is a plot of the count-rate correction factor, f, (constant specific activity) as a function of the gross weight. A value of unity was assigned to f for a cylinder weight of 13 pounds, since this was the weight of the majority of the cylinders. The specific activity (S.T.P.) is now given by

$$SA = Kf\, cpm/P \tag{3}$$

The value of K can be determined if the count-rate, pressure and specific activity of samples from several cylinders are known. Data from 20 cylinders were used to establish the values of K and f. The pressure of the gas in each cylinder was measured with a calibrated pressure gauge and the count-rate was measured at the surface of each cylinder. It was found that the count-rate was independent of the location of the Geiger-Mueller tube along the surface parallel to the long axis of the cylinder. However, the count-rate varied considerably at either end. The specific activity of a small sample was determined at atmospheric pressure using ionization chamber methods.

A vacuum manifold system was used for removing gas samples from a cylinder. Gas was allowed to expand into the evacuated system until a manometer indicated atmospheric pressure. The sample collecting flask was closed and removed so that the system could be reevacuated for the next cylinder. A pre-calibrated gas-tight syringe was used to transfer a small volume of gas from the sample flask (Fig. 2) to an evacuated ionization chamber (Fig. 3). Air was added to the chamber until the gas inside was at atmospheric pressure, then the chamber valve was closed. The sample volumes were corrected from atmospheric temperature and pressure to standard temperature and pressure.

The apparatus used to determine the activity of $^{85}$krypton in the chamber consisted of a vibrating-reed electrometer and a strip chart recorder. The sensitivity (amp/$\mu$c) of the electrometer system (for a one liter chamber) was obtained using a certified $^{85}$krypton gas standard. The ionization current was measured by both the high-resistance-leak method and the rate-of-charge method. The specific activity was then calculated, using the volume (S.T.P.) of the sample transferred into the chamber.

## RESULTS AND APPENDIX

Table I shows the surface count-rate, cylinder pressure and the measured specific activity for seven cylinders, each weighing 13 pounds (f = 1). These

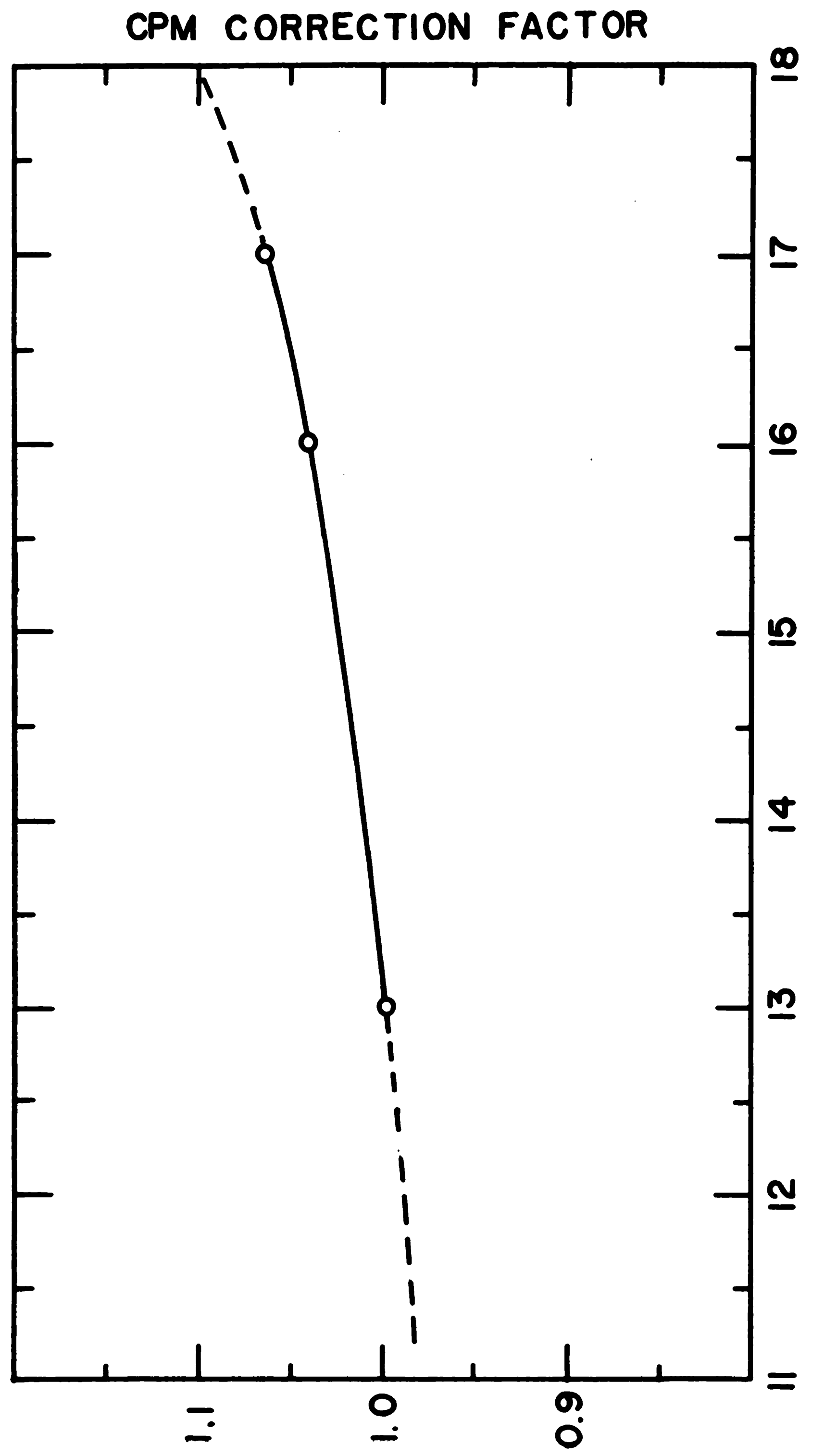


**Fig. 1.** Count-rate corrections for cylinders having different gross weights.

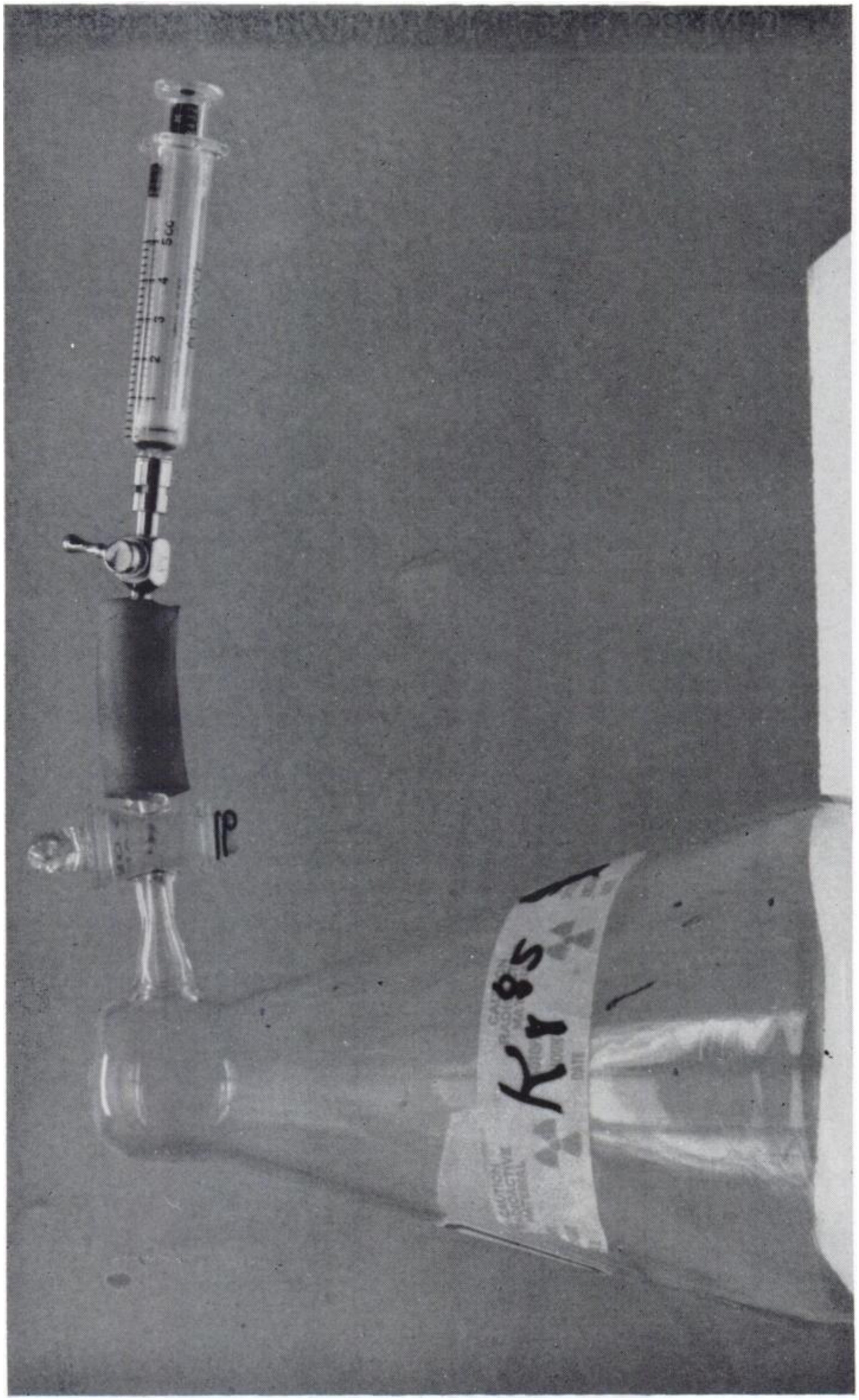


Fig. 2. Sample flask and gas transfer syringe.

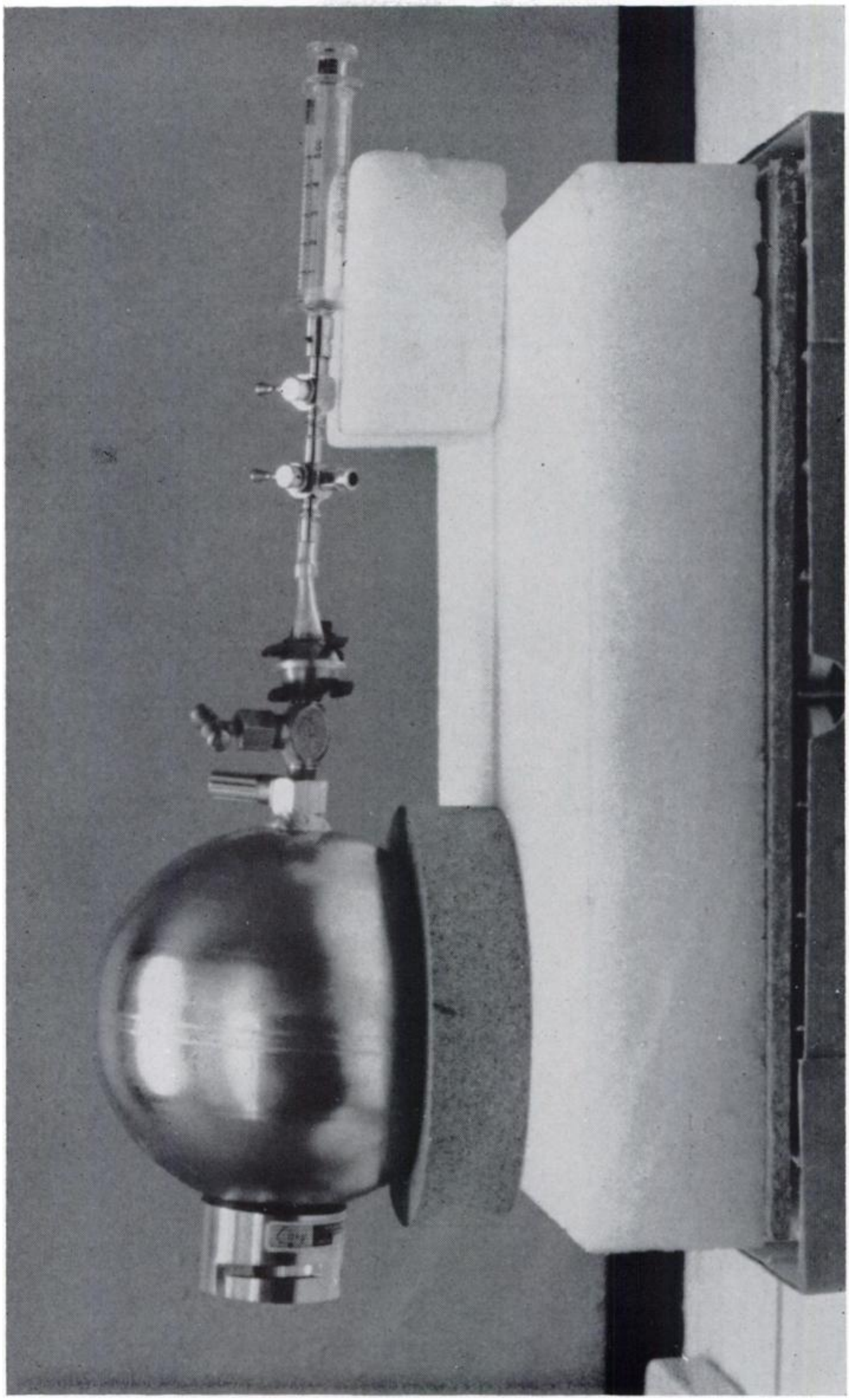

**Fig. 3. Evacuated ionization chamber and gas transfer syringe.**

data along with equation (3) were used to determine the value of K. The average value of K for our system was found to be 0.0348 when P is expressed in psi.

Table II lists the calculated values and the measured values of the specific activity for 12 cylinders. These data show that the difference between the calculated and measured values of specific activity is no greater than 5 per cent. The precision in measuring the specific activity is of the order of 2 percent. Therefore, the overall accuracy of the rapid method is estimated to be within 10 percent.

The following symbols are used to derive the expression for the specific activity at S.T.P.:

S.T.P. = standard temperature and pressure (20° C and 760 mm of Hg)

SA = the specific activity of the $^{85}$Kr gas at S.T.P. (in mc/liters)

TABLE I

CALCULATED VALUES OF K DETERMINED FROM DIRECTLY MEASURED VALUES OF SPECIFIC ACTIVITY FOR KRYPTON$^{85}$ CYLINDERS WEIGHING 13 POUNDS

| *Cylinder Tag No.* | *Net Count-Rate (cpm)* | *Cylinder Pressure (psi)* | *Specific Activity (μc/ml)* | *K* |
|---|---|---|---|---|
| CQ8859 | 16000 | 1150 | 0.510 | 0.0365 |
| DB1744 | 14000 | 1110 | 0.443 | 0.0350 |
| DB1746 | 13500 | 1110 | 0.436 | 0.0357 |
| DB1750 | 8900 | 790 | 0.440 | 0.0353 |
| DB1792 | 14500 | 1070 | 0.437 | 0.0323 |
| DB1793 | 15000 | 1150 | 0.437 | 0.0334 |
| DB6210 | 14200 | 1090 | 0.466 | 0.0357 |

Average Value for K = 0.0348 ± 0.0015.

TABLE II

CALCULATED AND MEASURED VALUES OF SPECIFIC ACTIVITY OF VARIOUS KRYPTON$^{85}$ CYLINDERS

| *Cylinder Tag No.* | *Net Count-Rate (cpm)* | *Gross Cylinder Weight (lbs)* | *Cylinder Pressure (psi)* | *Calculated Specific Activity (μc/ml)* | *Measured Specific Activity (μc/ml)* |
|---|---|---|---|---|---|
| BT7232 | 7300 | 15 | 820 | 0.319 | 0.325 |
| DB6209 | 8900 | 16 | 700 | 0.463 | 0.470 |
| DB6976 | 14500 | 16 | 1200 | 0.438 | 0.437 |
| DB6977 | 14700 | 13 | 1200 | 0.428 | 0.428 |
| DB6979 | 14400 | 13 | 1190 | 0.422 | 0.420 |
| DB6980 | 12400 | 13 | 990 | 0.438 | 0.439 |
| DB6981 | 14600 | 13 | 1190 | 0.428 | 0.442 |
| DB6982 | 13600 | 13 | 1110 | 0.428 | 0.436 |
| DB6984 | 14800 | 13 | 1180 | 0.438 | 0.433 |
| DI2528 | 13400 | 13 | 1200 | 0.390 | 0.383 |
| DI2529 | 11600 | 13 | 1200 | 0.337 | 0.334 |
| DJ8503 | 11700 | 13 | 1210 | 0.335 | 0.330 |

$V_0$ = volume of the $^{85}Kr$ gas at S.T.P. (in liters)
$p_0$ = atmospheric pressure (average = 14.6 psi)
v = internal volume of cylinder (nominal value of 2.31 liters.)[1]
P = gauge pressure of $^{85}Kr$ gas in the cylinder (in psi)
C = compressibility factor for air at 1,200 psi (0.9875)[1]

Since the count-rate (cpm) at the surface of a cylinder is proportional to the activity of $^{85}Kr$ in the cylinder, then:

$$A = SA \times V_0 = k_1\ cpm$$

where $k_1$ is the proportionality constant. An expression for $V_0$ can be obtained from the ideal gas law. Thus:

$$V_0 p_0 = v(p + p_0)/C$$

and

$$V_0 = v(P + p_0)/Cp_0$$

However, since $p_0$ is small compared to P (1,200 psi) and the daily variation in $p_0$ is less than 2 per cent, then

$$V_0 = k_2 P$$

where $k_2 = v/Cp_0 = 2.31/(0.9875 \times 14.6) = 0.16\ \frac{liters}{psi}$

Substituting for $V_0$ in the original equation gives

$$SA = \frac{k_1}{k_2} \times \frac{cpm}{P}$$

If $K = k_1/k_2$, then the specific activity at S.T.P. is given by

$$SA = K\ cpm/P$$

[1]These values obtained from the Matheson Company.

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REFERENCES

1. Sanders, R. J. and Morrow, A. G.: Localization of Circulatory Shunts with Inhaled Krypton-85; *Bulletin of the Johns Hopkins Hospital.* **103**:27 July, 1958.
2. Sanders, R. J. and Morrow, A. G.: Identification and Quantification of Left-to-Right Circulatory Shunts; *Am. J. Med.,* **26**:508 April, 1959.
3. National Institutes of Health, Radiation Safety Committee Communication RAD-1, No. 200.
4. Brown, J. M., Jr. and Williams, K. D.: Monitoring and Assay Procedures for Krypton-85 Used in Circulatory Tests; paper submitted to the International Symposium on Radiation Pollution of the Gaseous Media; November, 1963.