Radon

Environmental Measurements Laboratory
U.S. Department of Energy

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RADON-222 IN AIR AND BREATH SAMPLES

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APPLICATION

Procedures are presented which describe EML's method of sampling, counting, and calculating ^{222}Rn concentration in air and breath samples. When radium is present in the body, the gaseous progeny, ^{222}Rn ($t_{1/2}$ = 3.825 d), will collect in the lungs and will be eliminated with exhaled breath.

One liter glass sampling flasks are provided to field personnel by EML for collecting breath or atmospheric ^{222}Rn samples. The ^{222}Rn sample is transferred to a pulse type ionization chamber, and after it is allowed to come into equilibrium with its progeny products, the sample is α counted. Two of the progeny, ^{218}Po and ^{214}Po, are α emitters and contribute to the total count.

SPECIAL APPARATUS

A. Sampling.

1. 1-L glass flasks with two large bore stopcocks per flask.

2. Tank of compressed, aged air with two-stage regulator.

3. Face mask - No. CS-6772 inhalator, modified to block the emergency intake and with the outlet modified to accept 9.5 mm ID rubber tubing (Mine Safety Appliance Co., Pittsburgh, PA).

4. Demand regulator - No. CS-46516 single stage or equivalent (Mine Safety Appliance Co., Pittsburgh, PA).

B. Analysis.

1. Platinum black catalyst (Baker and Co., Deoxo Units).

2. Drying tube with Drierite.

3. Flame arresters.

4. Capillary orifice.

5. Vacuum pump.

6. Tank of H_2 with two-stage regulator.

7. Tank of forming gas (85% N_2, 15% H_2) with two-stage regulator.

8. Sample introduction system including valves and piping.

9. Pulse type ionization chamber and associated electronic equipment.

SAMPLE COLLECTION

A. Radon in breath[*]

1. Set up the equipment as described in the above reference using 9.5 mm (3/8 in) rubber tubing on the inhalator outlet. Do not attach to sampling flask.

2. Clean facepiece with cotton and alcohol.

3. Set air pressure on two-stage regulator to 4.5 kg (10 lb).

[*] *Taken from Harley et al., 1951.*

4. Have the subject hold the face piece in place while you check for leaks, particularly around the bridge of the nose.

5. Have the subject breathe with the respirator for 5 min to flush the environmental air from his or her lungs. (This should be regular breathing. Do not ask for deep breaths.)

6. While the subject continues regular breathing, attach the sampling flask (with both stopcocks open) for a 1-min period, remove, and close stopcocks.

7. Repeat Step 6 for a duplicate sample.

B. Radon in the atmosphere.

1. Open both flask stopcocks.

2. Connect about 0.6 m of 9.5 mm (3/8 in) rubber tubing to one stopcock.

3. Inhale through the tubing and flask 20 times. Do not exhale through the flask. If convenient, a suction pump may be used.

4. Close both stopcocks.

MEASUREMENT EQUIPMENT PREPARATION

A. Sample oxidation.

Before transfer to the counting system, enough H_2 is added to the sample flask to completely remove O_2 (as H_2O) in the platinum catalyst. Because O_2 acts to quench the ionization produced by each α disintegration, even small amounts of it in the chamber will seriously affect the counting rate of a sample. Environmental air contains about 20% O_2 and the addition of 40 kPa (6 psi) of H_2 is theoretically sufficient for all samples. It has been our practice to add an excess of H_2 and therefore 70 kPa (10 psi) is usually added to each sample.

B. Flame arresters.

The removal of O_2 from the sample takes place in the platinum black catalyst where O_2 and H_2 combine to form H_2O. This combustion reaction generates a considerable amount of heat, and if allowed to strike back, the sample flask may explode. To prevent such explosions, flame arresters are placed between the catalyst and the sample. The flame arresters consist of a fine mesh copper wire screen and act to dissipate the heat of the reaction.

C. Capillary orifice.

A capillary orifice is placed in the line after the catalyst. This slows the passage of gas through the catalyst and insures complete combustion.

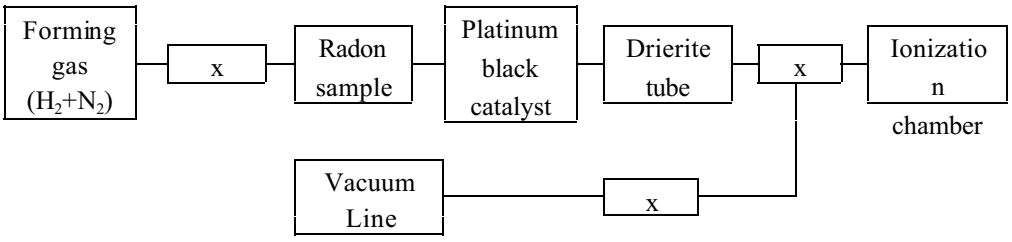
D. Drierite tube.

Water formed in the O_2 removal is collected in a Drierite tube. The Drierite is kept free of H_2O by evacuating the external piping of the system continuously when not transferring the samples.

E. Counting apparatus.

The ^{222}Rn counting apparatus consists of a sample introduction system, ionization chamber, preamplifier, amplifier, and count registering device. The ionization chamber counts almost 100% of the α disintegrations of ^{222}Rn and about 50% of the disintegrations of its progeny. Each chamber plus its sample introduction system has a capacity of 2 L and the chamber is operated at a potential of 1000 V. A mixture of H_2 (15%) and N_2 (85%) is used as a counting gas. The chambers are constructed of a specially selected, electropolished stainless steel and have a background count of about 10 counts h^{-1} and an efficiency of about 6215 counts h^{-1} for 1 Bq of ^{222}Rn.

A block diagram of the counting system and external apparatus is shown below.



x indicates valve or stopcock.

The pulses from the ionization chamber are fed to an EML-built preamplifier, amplifier, and control unit. Two Tattletale Clever counters are interfaced to a PC.

DETERMINATION

1. Connect sample flask to H_2 tank with 9.5 mm (3/8 in) rubber tubing.

2. Raise gauge pressure to 70 kPa (10 psi) gauge.

3. Open flask stopcock to tank to admit H_2 to the flask.

4. Close stopcock and tank valve.

5. Raise the forming gas line pressure to 70 kPa (10 psi) gauge and bleed the line and rubber tubing leading to sample inlet.

6. Connect one flask stopcock to the forming gas line with the above rubber tubing, the other to the counting system with another section of 9.5 mm (3/8 in) rubber tubing.

7. Open the ionization chamber and the vacuum line valve to evacuate the counting chamber, external piping, and the rubber tubing between the counting system and the flask.

8. Close the vacuum line valve when system reaches minus 10.1 kPa of Hg gauge pressure.

9. Open the flask stopcock to allow the sample to enter the counting system. Allow pressure equilibration (indicated by pressure gauge).

10. Check platinum catalyst by touch to assure that combination of H_2 and O_2 has occurred.

11. Close the flask stopcock to the counting system.

12. Open the stopcock to the forming gas line. Allow forming gas to come to pressure in the flask.

13. Repeat Steps 5 and 7 until the gauge indicates atmospheric pressure.

14. Open the stopcock to the forming gas line, then attach the stopcock to the counting system. Allow forming gas to flow until the gauge pressure reaches 35 kPa (5 psi).

15. Close all valves and remove flask and tubing from system.

16. Turn on ionization chamber high voltage.

17. Count the sample for at least 14 h.

DATA PROCESSING AND ANALYSES

1. Discard the first 5 h of counting data (equilibration period for ^{222}Rn and progeny).

2. Determine the gross count over the remaining counting period.

3. Calculate net counts per hour per sample by determining gross sample counts per hour and subtracting background counts per hour.

4. Divide net counts per hour by the chamber standardization value of net counts per hour per Bq of ^{222}Rn.

5. Using the midpoint of the counting interval as the time of counting, extrapolate the value obtained to the time of sampling. Figure 1 may be used for this calculation.

STANDARDIZATION

Each unit is standardized several times a year with ^{222}Rn from a radium solution obtained from the National Institute of Standard and Technology (NIST). This solution is diluted and split into aliquots which are placed in ^{222}Rn bubblers (see Specification 7.8). The ^{222}Rn is allowed to build up for a known period before the standard is used.

The ^{222}Rn standard is transferred to the chamber by emanation. The bubbler is first attached to the external feed system. When the ionization chamber and external system are evacuated, the vacuum line is shut off from the system and the bubbler outlet stopcock opened. The inlet stopcock is then opened and forming gas flushes the ^{222}Rn into the chamber until the system is brought to atmospheric pressure.

At equilibrium, there are three α disintegrations per ^{222}Rn disintegration, however, two of these are from the particulate α-emitting progeny. Since these α disintegrations deposit on the walls of the ionization chamber, they are counted with a maximum efficiency of 50%. One becquerel of ^{222}Rn in the ionization chamber thus has a theoretical counting rate of 7190 counts h^{-1}. Actually, the ionization chambers in this Laboratory yield a counting rate of 6215 counts h^{-1} Bq^{-1} of ^{222}Rn in equilibrium with its progeny or an overall efficiency of 86%.

LOWER LIMIT OF DETECTION (LLD)

Counter Efficiency	(%)	57.5
Counter Background	(cps)	0.0028
Yield	(%)	-
Blank	(cps)	-
LLD (400 min)	(Bq)	0.01
LLD (1000 min)	(Bq)	0.07

REFERENCE

Harley, J. H., E. Jetter and M. Eisenbud
"A Method of Obtaining Reproducible Breath Radon Samples"
Arch. Ind. Hyg. Occ. Med., 4, 1-9 (1951)

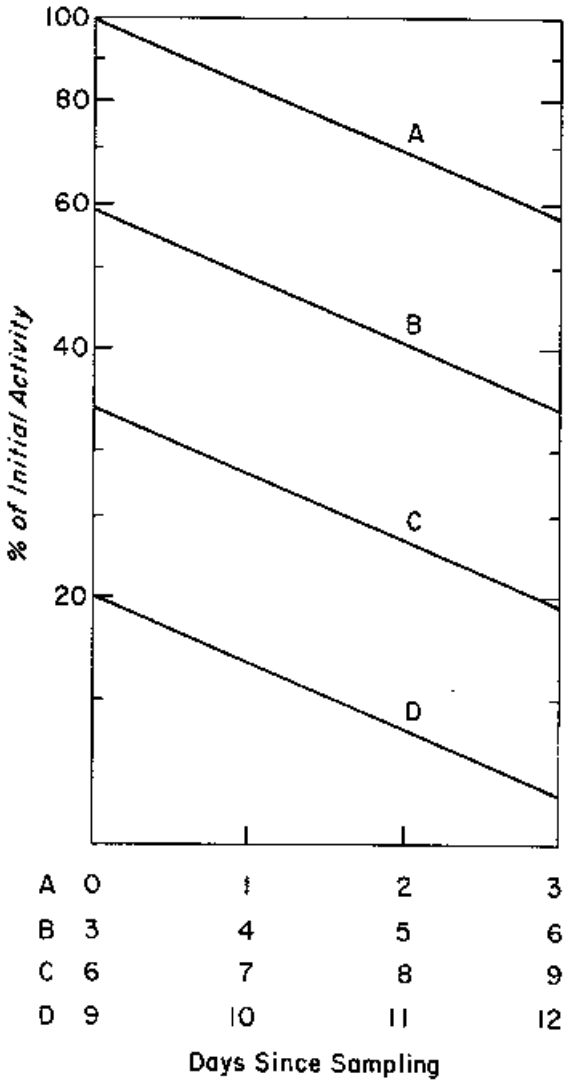


Figure 1. Decay correction for radon from the midpoint of the counting interval to collection time.