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Experiment 6

Radon Testing

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Notes for Instructors

Purpose

To measure the integrated radon concentration over a 30-day period at a location of your choice; to pool class data and construct a map of estimated radon concentrations.

Method

Radon is measured in this experiment by the alpha-track method. The detector is a small piece of plastic. Air being tested diffuses through a filter to the detector. When alpha particles from radon and its decay products strike the detector, they cause damage tracks or defects. At the end of the test, the sample is returned to the laboratory. The plastic is etched in strong base. Etching occurs preferentially at defect sites and thus enlarges the damage tracks. The damage tracks over a given area are counted using a microscope. The number of tracks per area is used to calculate the radon concentration at the site tested.

The detector can be distributed and collected by mail. The method yields an integrated average radon concentration over the 30-day period, and could be used to measure even longer term average concentrations to correct for seasonal variations. The accuracy of the method depends on the area density of tracks counted.

Concentrations greater than 4 pCi/L indicate the need for a follow-up test. If parents or students are concerned about the results, they should be

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referred to the local health department where they can learn how to obtain an approved radon monitoring test. We recommend that copies of *A Citizen's Guide to Radon* (ISBN 0–16–036222–9, U.S. Government Printing Office, Superintendent of Documents, Mail Stop: SSOP, Washington, DC 20402–9328) be available for reference. This document also contains the telephone numbers of places to call for information in each state.

Materials

Samples of CR-39 polymer with a polyethylene film covering both sides. *See* Supplier Information.

Use a small piece of double stick tape to fasten the plastic with its protective covering to an index card. Tape a tissue to one end of the card.

It is possible that no radon will be found, so it is useful to have some CR-39 samples that have been exposed to alpha radiation to give positive results. Exposed and etched samples are also helpful for practice in counting. Direct exposure of the plastic for 24 hours to a lantern mantle containing thorium will result in a sufficient number of alpha tracks after etching. ^{232}Th is a weak alpha emitter with a half-life of 14 billion years. (A nonradioactive lantern mantle based on yttrium rather than thorium recently was introduced, so be sure to read the label when purchasing. When used as a lantern mantle, thorium oxide or yttrium oxide provides a catalytic surface with a high melting point for the combustion reaction. For more information, see Breedlove, C. H. *J. Chem. Educ.* **1992**, *69*, 621.)

Sample holder (small key ring) and paper clip

6 M NaOH (240 g NaOH or 312 mL 50% NaOH, diluted to 1 L).

Test tube (16 × 125 mm)

Boiling water

Microscope with 10× objective (100× total magnification)

Sample Results

See the experiment for discussion of the calculations. Counting the tracks in 10 different fields of view gave 3, 4, 4, 5, 9, 7, 4, 3, 8, and 6 for an average of 5.3 tracks.

Area of view at 10×: $A = \pi(\text{diameter}/2)^2 = \pi(0.17 \text{ cm}/2)^2 = 0.023 \text{ cm}^2$

Days exposed: 24.19 days

Tracks/cm^2/day: 5.3 tracks/0.023 cm^2/24.19 days = 9.5 tracks/cm^2/day

Activity: $$\frac{370 \text{ pCi/L}}{2373 \text{ tracks/cm}^2\text{/day}} = \frac{x \text{ pCi/L}}{9.5 \text{ tracks/cm}^2\text{/day}}; \; x = 1.5 \text{ pCi/L}$$

Radon Testing

Indoor radon gas is a national health problem. Radon causes thousands of deaths each year. Millions of homes have elevated radon levels. Homes should be tested for radon. When elevated levels are confirmed, the problem should be corrected.

Surgeon General Health Advisory, 1987

Purpose

To measure the integrated radon concentration over a 30-day period at a location of your choice; to pool class data and construct a map of estimated radon concentrations.

Introduction

Radon-222 is a naturally occurring, radioactive gas, with a half-life of 3.824 days. Radon comes from the natural radioactive breakdown of uranium-238, which has a half-life of 4.47 billion years; uranium is found in nearly all soils (20–30 ppb average earth abundance). Radon enters homes through cracks or other holes in the foundation.

The small plastic disk that you will use to detect radon is a high-clarity polymer that is often used in eyeglasses, poly[ethylene glycol bis(allyl carbonate)], called CR-39. The chemical formula of the monomer is $C_{12}H_{18}O_7$. Solid CR-39 is sensitive to penetration by alpha particles, but is insensitive to beta and gamma radiation. Alpha particles cause damage in the plastic, probably due to disruption of the polymer linkage along the path of penetration. Although the damage is not visible to the eye, chemical etching of the sample by NaOH occurs preferentially in the damaged regions. The etched samples then exhibit damage "tracks" when viewed under a microscope. The number of tracks in a given area of the plastic disk can be used to estimate the radon level at the sampled location.

Procedure

Exposing the Detector

The detector should remain undisturbed at the sampling location for at least 3 weeks. Take or mail the detector to your home or other location. Include with the detector these instructions:

NOTE: This experiment was written by Craig Gabler, Centralia High School, Centralia, WA 98531; and Laura E. Parmentier and George C. Lisensky, Beloit College, Beloit, WI 53511.

Radon Detection

1. A small, plastic disk that is sensitive to the presence of radon gas is taped to the middle of the enclosed index card. Please peel off the thin plastic film covering the disk (there really is a film there!) and very loosely tuck the tissue over the card and disk. The disk needs to be protected from dust and particles, but air needs to be able to flow freely over the disk.
2. Place the card with the disk in a location where it can remain undisturbed for 3 weeks. The best location to test for radon is a basement or any room or garage that is close to the ground.
3. Please record the following information about this experiment:

   Date detector was put in place ______ Time detector was put in place __________

   Location of detector ________________ Floor level of location __________________

   Date detector was removed _________ Time detector was removed _____________
4. At the end of the 3-week period, please fold this paper over the index card and disk (to protect the disk) and mail back. We will analyze the disk on ____________. **Please mail this back so that it is received by ____________.**

Etching the Disk

After 3 or more weeks of exposure, remove the disk from the index card and peel off the polyethylene film from the back. Slip the ring of an “etch clamp” over the top of the disk and fasten onto a paper clip that has been bent so there is a hook at each end (see Figure 1A). Hook the disk inside a test tube, and add enough 6 M NaOH solution to cover the disk in the tube. **CAUTION: Hot 6 M NaOH is extremely corrosive. Wear goggles at all times. Rubber gloves are strongly recommended.**

Heat the test tube containing the disk and NaOH solution in a boiling water bath for 40 minutes. At the end of the 40 minutes, remove the disk and rinse thoroughly with lots of water.

Counting the Alpha Tracks

Determine the area (in square centimeters) of the field of view of your microscope at low power (10×) by looking through the microscope at a ruler.

Practice looking at alpha tracks on a previously exposed and etched disk. (This disk was exposed to a camping lantern mantle which contains thorium!) Your disk will likely have fewer tracks. Note the various shapes of the tracks, which depend on how the alpha particles entered the solid (see Figure 1B): The circular-shaped tracks are due to alpha particles that entered straight in (perpendicular to the disk), and the more tear-drop shapes are due to alpha particles that entered at an angle.

Place your disk on a microscope slide and count the number of tracks *in 10 different fields of view.*

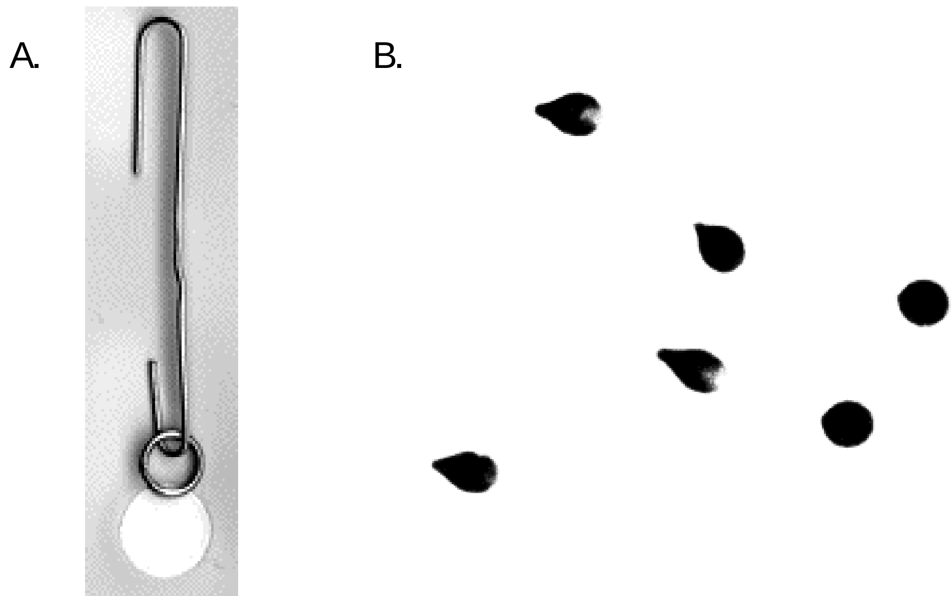

Figure 1. A. Disk ready for etching. The disk is pinched between the rings of the "etch clamp." B. Alpha tracks after etching, viewed through microscope.

Calculations

Experiments have shown that tracks due to background alpha radiation are negligible. Determine the average number of tracks in a field of view for your disk, and then determine the average number of tracks per square centimeter per day (including any fraction of a day). Control plastic disks that were sent to a radon facility in which the radon level was known to be 370 picocuries per liter were found to exhibit 2370 tracks/cm^2/day by this etching and counting technique. Given this relationship between picocuries per liter and tracks per square centimeter per day, calculate the radon level in picocuries per liter of air for your sample. How does your sample compare with the 4-pCi/L guidelines set by the Environmental Protection Agency? Concentrations greater than 4 pCi/L indicate the need for a follow-up test using an EPA-approved radon monitoring service.

The precision of this experiment is not good because of day-to-day and seasonal variations in radon levels (longer exposure times give better average results), and because of lack of operator experience in counting alpha tracks. Commercially available alpha-track detectors give results that vary by about 25% for a 30-day exposure at a 4-pCi/L radon level.