Rules of Thumb*

***With permission from the Manual of Policies and Procedures for Radiation Protection, for the University of Minnesota, Department of Environmental Health and Safety, Radiation Protection Program, January 2000**

A. Alpha Particles

1. Alpha particles emitting radioisotopes (^{226}Ra, ^{241}Am, ^{210}Po) are highly radiotoxic because alpha radiation presents a significant internal hazard.

2. Most alpha particles present no external radiation hazard because they cannot penetrate the protective layer of the skin covering the body surface. An alpha particle of at least 7.5 MeV is required to penetrate a tissue thickness of 0.07 mm, which is the thickness of the dead layer of skin covering the body.

B. Beta Particles

1. A beta particle of a least 0.07 MeV is required to penetrate the protective layer of skin (0.07 mm).

2. The range of a beta particle in air is approximately 12 feet/MeV. The range of the maximum energy beta from ^{32}P would be 1.71 MeV X 12 ft/MeV = 20 ft.

3. The range of beta particles in gram/cm^2 (density thickness = thickness in centimeters X density in gm/cm^3 is approximately equal to the maximum energy (MeV) divided by 2 (R = E/2). The range of the maximum energy ^{32}P beta particle in lucite is approximately ¼ inch.

4. The average energy of a beta particle spectrum for a particular radioisotope in approximately 1/3 the maximum beta energy.

5. The dose rate in rads per hour in a solution of a beta emitting radioisotope is 1.12 EC/p, where “E” is the average energy per radioisotopes energy per disintegration (MeV), “C” is the concentration (microcuries per cubic centimeter), and “p” is the density of the solution (gm/cm^3). The surface dose rate is about ½ that of the solution.

6. The skin surface dose rate through the protective layer of skin ($7mg/cm^2$) from a uniform thin deposition of 1 $microcurie/cm^2$ is about 9 rads/hour for the beta energies of about 0.6 MeV.
7. For a point source of beta radiation (neglecting air and self-absorption), the dose rate at 1 cm is approximately equal to 200 x number of millicuries = rads/hour. This varies only slightly with beta energy. Dose rate at 1 cm for 1 mCi of ^{32}P is about 200 rads/hour.

8. Bremsstrahlung (breaking radiation) or x-rays produced as a result of beta particles being slowed down increases approximately with the square of the maximum beta energy, and approximately as the square of the atomic number of the absorbing material. For this reason, low Z materials are recommended for shielding beta emitters.

9. When beta particles of 1 to 2 MeV pass through low Z materials such as water, aluminum, lucite, or glass less than 1% of the energy is converted to bremsstrahlung. ^{32}P beta particles will convert approximately 5% of their energy to bremsstrahlung when absorbed in lead.

C. Gamma Rays

1. The exposure rate (mR/hour) at 1 foot from a point source of gamma radiation emitter between 0.07 and 4.0 MeV is approximately equal to 6 x mCi x E x n, where E = energy per disintegration in MeV, and n = number of gamma rays per disintegration.

2. The dose rate in rads/hour in an infinate medium contaminated with a gamma emitter is 2.12 EC/p, where E = average gamma energy per disintegration in MeV, C = number of microcuries per cubic centimeter, and p = density in grams per cm^3. Surface dose rate is about ½ this dose rate.

D. X-Rays

1. The exposure rate at 2 feet from a diagnostic x-ray tube operated at 100 kVp and 100 mA is about 2.3 R/second in the primary beam.

2. The exposure rate in the primary beam of a fluoroscopic x-ray unit operated at 80 kVp and 1 mA is approximately 2.1 R/minute.

3. X-ray diffraction units can have primary beam intensities as high as 400,000 R/minute. Scattered radiation at approximately 1 foot from the point of scatter can be on the order of 150 R/hour.

4. The threshold dose for skin erythema from x-rays is about 300 to 400 R. The minimum single dose for cataract production is 200 rads, and a dose of 750 rads results in a high incidence of cataracts.

E. Miscellaneous

1. For x and gamma radiation, the exposure rate varies as $1/\text{distance}^2$ at distances greater than 2 times the diameter of the detection chamber from a point source. The exposure rate varies as 1/d for a line radiation source, where "d" is the distance from the source to the point of interest, and "d" is no greater than the length of the line source.

2. The fractional efficiency (E) of a radiation counting system is equal to the net counts per minute (CPM) of a standard in the counting system divided by the activity of standard in disintegrations per minute (DPM). E = CPM/DPM.

3. The activity of an radioisotope in reduced to less than 1% after 7 half-lives.

4. For radioisotopes with a half-life greater than 6 days, the change in activity in 24 hours will be less than 10%.

5. A G-M instrument, even when equipped with a thin window probe, should not be used to monitor for low energy beta radiation emitter contamination (^3H, 0.018 MeV, will not penetrate the end window).

6. The relationship between activity and mass of a radioisotope (specific activity) may be determined as follows:

   Curies/gm = $1.308 \times 10^8/AT_{1/2}$; where "A" = atomic weight and $T_{1/2}$ = half life in days.

7. Neither diagnostic x-rays nor radiation emitted by radioisotopes (gamma, or beta radiation) results in activation of body tissues. There is no residual radioactivity; persons or materials do NOT become radioactive as a result of exposure to these radiations.

SI CONVERSION UNITS

1 Gray (Gy) = 100 rads

1 Sievert (Sv) = 100 rems

1 Bequerel (Bq) = 1 disintegration/second

3.7×10^{10}Bq = 1 curie