# Chapter 18

# *Radiation safety*


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Unit of activity = Curie:

$1\,\text{Ci} = 3.7 \times 10^{10}$ disintegration $\text{s}^{-1}$.

Unit of exposure dose for X- and $\gamma$-radiation = Roentgen:

$1\,\text{R} = 1\,\text{esu cm}^{-3} = 87.8\,\text{erg g}^{-1}$ ($5.49 \times 10^7\,\text{MeV g}^{-1}$) of air.

Unit of absorbed dose = rad:

$1\,\text{rad} = 100\,\text{erg g}^{-1}$ ($6.25 \times 10^7\,\text{MeV g}^{-1}$) in any material.

Unit dose equivalent (for protection) = rem:

rems (Roentgen equivalent for man) = rad $\times$ $QF$,

where $QF$ (quality factor) depends upon the type of radiation and other factors. For $\gamma$-rays and HE protons, $QF \simeq 1$; for thermal neutrons, $QF \simeq 3$; for fast neutrons, $QF$ ranges up to 10; and for $\alpha$ particles and heavy ions, $QF$ ranges up to 20.

Maximum *permissible occupational dose* for the whole body:

$5\,\text{rem yr}^{-1}$ (or $\sim 100\,\text{mrem wk}^{-1}$).

Fluxes (per $\text{cm}^2$) to liberate 1 rad in carbon:

$3.5 \times 10^7$ minimum ionizing singly charged particles,
$1.0 \times 10^9$ photons of 1 MeV energy

(These fluxes are correct to within a factor of 2 for all materials.)

Radiation exposure ($\text{mrem yr}^{-1}$) of a typical person in the US:

| *Natural sources* | | *Artificial sources* | |
|---|---|---|---|
| Cosmic radiation | 28 | Environmental | 8 |
| Terrestrial radiation | 26 | Medical | 92 |
| Internal isotopes | 26 | Occupational | 1 |
| | | Nuclear power | 0.3 |
| | | Miscellaneous | 5 |

(This table has been adapted from *Particle Properties Data Booklet*, Lawrence Berkeley Laboratory, Berkeley, CA, 1980, and Upton, A. C., 'The biological effects of low-level ionizing radiation', *Sci. Amer.*, **246**, 41, Feb. 1982.)

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**Maximum permissible flux for occupational exposure to various types of ionizing radiations**

| Type of radiation | QF or RBE[a] | Average exposure rate[b] (mrad $wk^{-1}$) | Approximate flux to give a maximum permissible exposure in an 8-hr day[c] |
|---|---|---|---|
| X- and gamma-rays | 1 | 100 | [1400/$E$] photons $cm^{-2} s^{-1}$ in free air at 0 °C (error < 13% for $E$ = 0.07 to 2 MeV) |
| Beta-rays and electrons | 1 | 100 | $[(4.3 \times 10^7)/((RBE)P)]$ electrons or beta-rays $cm^2 s^{-1}$ [d] |
| Thermal neutrons | 2.5 | 40 | 700 thermal neutrons $cm^{-2} s^{-1}$ [d] |
| Fast neutrons | 10 | 10 | 19 neutrons of 2-MeV energy $cm^{-2} s^{-1}$ [d] |
| Alpha particles | 10 | 10 | $[(4.3 \times 10^7)/((RBE)P)]$ alpha particles $cm^{-2} s^{-1}$ [d] |
| Protons | 10 | 10 | $[(4.3 \times 10^7)/((RBE)P)]$ protons $cm^{-2} s^{-1}$ [d] |
| Heavy ions | 20 | 5 | $[(4.3 \times 10^7)/((RBE)P)]$ heavy ions $cm^{-2} s^{-1}$ [d] |

[a] RBE, relative biological effectiveness.

[b] Average occupational exposure rate permissible to blood-forming organs (essentially total body exposure), gonads, and eyes of persons of age 18 or over. These values may be averaged over a year, provided the dose in any thirteen weeks does not exceed 3 rem (rem = RBE × rad). All rates may be increased by a factor of 6 if the exposure is primarily to the skin, thyroid, or bone. They may be increased by a factor of 3 if the exposure is limited to organs other than blood-forming organs, gonads, or eyes.

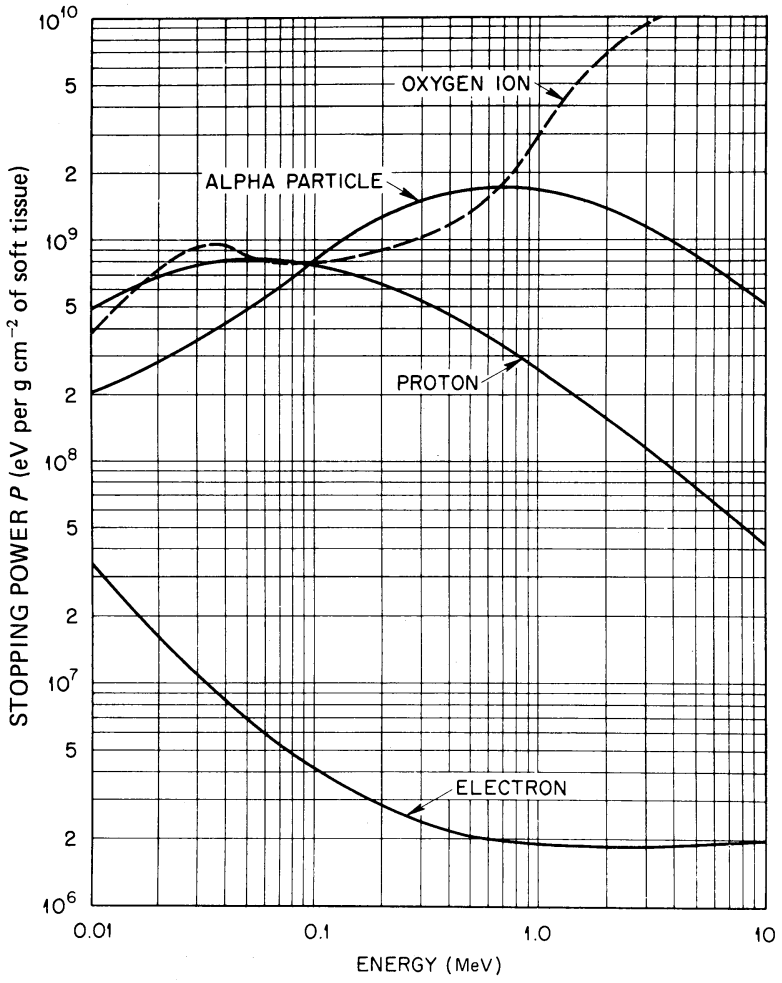
[c] Maximum permissible exposure rate based on a 20-mrem dose delivered to tissue in an 8-hr day. $P$ is the stopping power in units of electron volts per $g\,cm^{-2}$ of soft tissue.

[d] Incident on tissue.

(Adapted from *Nuclear Instruments and Their Uses*, A. H. Snell, ed., John Wiley and Sons, 1962.)

## Maximum permissible flux for occupational exposure to various types of ionizing radiations (*cont.*)

Stopping power as a function of energy. (Adapted from *Nuclear Instruments and Their Uses*, A. H. Snell, ed., John Wiley and Sons, 1962.)




## Clinical effects of acute exposure to ionizing radiation

| Dose (rem) | Probable effect |
|---|---|
| 0–100 | No illness |
| 100–200 | No or slight illness |
| 200–600 | 0–90% deaths, 2–12 weeks |
| 600–1000 | 90–100% deaths, 1–6 weeks |
| 1000–5000 | 100% deaths, 2–14 days |
| > 5000 | 100% deaths, 0–2 days |

(Adapted from Glasstone, S. & Dolan, P. J., *The Effects of Nuclear Weapons*, US Government Printing Office, 1977.)

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# Chapter 19

# *Astronomical catalogs*


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*Machine-readable astronomical catalogues*

The Astronomical Data Center of the NASA-Goddard Space Flight Center, Greenbelt, MD 20771, maintains a large number of machine-readable astronomical catalogues. See *Astronomical Data Center Bulletin*, NSSDC/WDC NASA-Goddard Space Flight Center.

## **Selected astronomical catalog prefixes** (see references in previous section)

*X-ray and gamma-ray*

| | |
|---|---|
| IE | HEAO-2 (Einstein). |
| H | HEAO-1, A-2 experiment (GSFC). |
| XRS | Amnuel *et al.* compilation. |
| 4U, 3U, etc. | Uhuru catalogs. |
| IM | OSO-7 catalog (MIT). |
| 2A, A | Ariel catalogs. |
| 2S | SAS-3 source (MIT). |
| CGS | Bradt *et al.* galactic sources. |
| MXB | MIT burst source (Bradt *et al.*). |
| CG | (cosmic gamma-ray), usually COS-B source. |

*Radio*

| | |
|---|---|
| G | (galactic coordinates), various sources – usually continuum surveys. |
| 3C | (3rd Cambridge) 1959, *Mem. R.A.S.*, **68**, 37; 1962, **68**, 163. |
| 4C | (4th Cambridge) 1965, *Mem. R.A.S.*, **69**, 183; 1967, **47**, 49. |
| W | (Dwingeloo) Westerhout 1958, *B.A.N.*, **14**, 215. |

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| | |
|---|---|
| CTA, CTB, CTD | (Cal Tech) 1960, *Publ. A.S.P.*, **72**, 237; *Cal. Tech. Radio. Obs. Reports* (#2) 1960–65. 1963, *A.J.*, **68**, 181. |
| NRAO | (Green Bank) 1966, *Ap. J. Suppl.*, **116**. |
| PKS | (Parkes) 1964, *Australian J. Phys.*, **17**, 340; 1965, **18**, 329; 1966, **19**, 35; 1966, **19**, 837; 1968, **21**, 377. |
| MSH | (Sydney) Mills, Slee & Hill, 1958, *Australian J. Phys.*, **11**, 360; 1960, **13**, 676; 1961, **14**, 497. |
| OA–OZ | (Ohio State) 1966, *Ap. J.*, **144**; 1967, *A.J.*, **72**, 536; 1968, **73**, 381; 1969, **74**, 612; 1970, **75**, 351; 1971, **76**, 777. |
| AMWW | (Bonn) Altenhoff, Mezger, Wendkar & Westerhout, 1960, *Publ. Univ. Obs. Bonn.*, No. 59. |

*Optical–stars–general*

| | |
|---|---|
| HD | *Henry Draper Catalog* 1918–25, *Harvard Ann., 91–100.* |
| AGK # | *Astronomische Gesellschaft Katalog.* |
| FK # | *Fundamental Katalog.* |
| SAO or ##### | *Smithsonian Astrophysical Observatory Catalog.* |
| GC | *General Catalog*, Boss. 1936, Carnegie Inst. Wash. Publ. 468. |
| BD | *Bonner Durchmusterung*, 1860, *Beob. Bonn. Obs.*, **3**; **4**; **5**. |
| SD | *Southern Durchmusterung*, 1886, *Beob. Bonn. Obs.*, **8**. |
| CD (or CoD) | *Cordoba Durchmusterung*, 1892, *Result. Natl. Obs. Argentina*, **16**; **17**: **18**; **21a**; **21b**. |
| CPD | *Cape Photographic Durchmusterung*, 1896, *Ann. Cape Obs.*, **3**; **4**; **5**. |
| DM | BD, CP, CPD combined. |
| ± # #°... | Usually DM catalogs. |
| HR | (Harvard revised) *Harvard Ann.*, 1908, **50**. |
| BS | (Bright star) *Yale Bright Star Catalog.* Follows HR numbering system (BS = HR #). |

*Optical–stars–proper motion*

| | |
|---|---|
| G ###–### (or GD, HG) | Lowell P.M. Surveys. |
| BPM (or L) | Bruce P.M. Survey. |
| LP | (Luyten-Palomar) 1969a, 1969b, Luyten 1963, *P.M. Survey with the 48-Inch Schmidt*, Univ. Minn., Minneapolis. |
| LHS | (Luyten Half-Second) Luyten, 0.5″ $yr^{-1}$. P.M. Survey. |
| LTT | Luyten, 0.2″ $yr^{-1}$. P.M. Survey. |
| NLTT | Luyten, new P.M. Catalog. |
| LB, etc. | other Luyten P.M. Catalogs. |

*Optical–stars–miscellaneous*

| | |
|---|---|
| EG or GR | (White Dwarfs) Eggen and/or Greenstein; EG: *Ap. J.*, 1965, **141**, 83; 1965, **142**, 925; 1967, **150**, 927; 1969, **158**, 281. GR: *Ap. J.*, 1970, **162**, L55; 1974, **189**, L131; 1975, **196**, L117; 1976, **207**, L119; 1977, **218**, L21; 1979, **227**, 244. Also Greenstein, 1976, *A.J.*, **81**, 323; 1976, *Ap. J.*, **210**, 524. |
| GL | Gliese, W., 1969, *Catalog of Nearby Stars*, G. Braun, Karlsruhe. |

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| | |
|---|---|
| Y | (Yale) Jenkins, L. F., 1952, *General Catalog of Trigonometric Stellar Parallaxes*, Yale Univ. Obs., New Haven. (Also 1963, *Suppl.*)<br>(Yerkes) van Altena *et al.*, *A.J.*, 1969, **74**, 2; 1971, **76**, 932; 1973, **78**, 781; 1973, **78**, 201; 1975, **80**, 647. |
| HZ | Humason & Zwicky, 1946, *Ap. J.*, **105**, 85–91. |
| Wolf (or W) | Nearby star discovered by Max Wolf (see Gliese catalog for data). |
| Ross (or R) | Nearby star discovered by Frank Ross (see Gliese catalog for data). |
| PHL (Ton, Tn, TS) | (Palomar-Haro-Luyten) Haro and Luyten, 1962, *Bol. Obs. Tonantzintla y Tacubaya*, **3**, 37. (Faint blue stars.) |
| VB | Van Biesbroeck, G., 1961, *A.J.*, **66**, 528. |
| Feige (or F) | Feige, 1958, *Ap. J.*, **128**, 267. |

*Optical–stars–variable*

Naming convention (if no standard name):

Constellation preceded by the following combinations in order of variability discovery:
R, S, T, . . . , Z, RR, RS, . . . , RZ, SS, . . . , SZ, . . . , ZZ, AA, AB, . . . , AZ, BB, . . . , BZ, . . . , QQ, . . . , QZ, V335, V336, . . . (Note: the letter J is not used.)

*Optical–miscellaneous galactic*

| | |
|---|---|
| TR | Trumpler, R., 1930, *Lick Obs. Bull.*, No. 420 (associations). |
| Coll | Collinder, P., 1931, *Ann. Obs. Lund.*, No. 2 (associations). |
| RCW | Rodgers, Campbell & Whiteoak, 1960, *M.N.R.A.S.*, **121**, 103 (H II regions). |
| R | Reflection nebula, preceded by constellation, as in Mon R2. |
| S | Sharpless, 1959, *Ap. J. Suppl.*, **4**, 257 (H II regions). |
| SS | Stevenson and Sanduleak object. |
| HH | Herbig-Haro object. Herbig, 1951, *Ap. J.*, **113**, 697; Haro, 1952, *Ap. J.*, **115**, 572; Herbig, 1974, *Lick Obs. Bull.*, **658**. |

*Optical–general–non-stellar*

| | |
|---|---|
| NGC | Dreyer's *New General Catalog.* |
| IC | Dreyer's *Index Catalog.* |

*Optical–extragalactic*

| | |
|---|---|
| Mrk (or Mkn) | Markarian, *Astrofizika* (in Russian), 1967, **3**, 55; 1969, **5**, 443; 1969, **5**, 581; 1971, **7**, 511; 1971, **8**, 155; 1973, **9**, 488; 1974, **10**, 307; 1976, **12**, 390; 1976, **12**, 657; 1977, **13**, 225. |
| Zw | Zwicky. |
| MCG | *Morphological Catalog of Galaxies.* |

*Infrared*

| | |
|---|---|
| IRC (or TMSS) | (Infrared Catalog) Neugebauer, G. & Leighton, R. B., 1969, *Two-Micron Sky Survey*, Cal. Tech., NASA SP-3047. |
| AFGL | Air Force Geophys. Lab. |
| GMS | Gillett, Merrill & Stein, 1971, *Ap. J.*, **164**, 83. |
| Hall | Hall, R. J., 1974, *A Catalog of 10-μm Celestial Objects*, Space and Missile Systems Org., SAMSO-TR-74-212. |
| MIRC | *Merged Infrared Catalog.* |
| BN | Becklin–Neugebauer object (in Orion Nebula), 1967, *Ap. J.*, **147**, 799. |
| KL | Kleinmann–Low object (in Orion Nebula), 1967, *Ap. J.*, **149**, L1. |

(The material in this chapter was prepared by C. W. Maxson of the Harvard/Smithsonian Center for Astrophysics.)

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