Radiation Detector 2018/19 (SPA6309)

Radiation safety

Radiation units (Leo, 3.1)

type	*unit*	*name*	*definition*
radioactivity	*Bq*	*Becquerel*	number of nuclear decays per second
radioactivity	*Ci*	*Curie*	37 GBq
exposure	*R*	*Roentgen*	X-rays to produce ionization of 2.58×10^{-4}Coulomb/kg in air
dose	*rad*	*rad*	energy absorption of$100\ erg/g = 0.01Gy$
dose	*Gy*	*Gray*	energy absorption of$1\ J/kg = 100\ rad$
dose equivalent	*rem*	*rem*	$1\ rad \times QF$
dose equivalent	*Sv*	*Sievert*	$1\ Gy \times QF = 100\ rem$

Roentgen (R) is an old unit. It measures a namount of X-rays and γ-rays, so clearly useless to measure radiation other than photons. Let's convert Roentgen to dose unit. 1 electron has 1.6×10^{-19} Coulomb, also average energy to need 1 ion-electron pair is 33.7 eV, then

In [1]:

```
R=2.58E-4
C=1.6E-19
eV=33.7
print "1 R contains",R/C,"ion-electron pairs"
print "1 R corresponds to",R/C*eV,"eV/kg, or", R/C*eV*C,"J/kg"
```

```
1 R contains 1.6125e+15 ion-electron pairs
1 R corresponds to 5.434125e+16 eV/kg, or 0.0086946 J/kg
```

Thus 1 R is roughly 0.0087 Gy or 0.87 rad or more simply 1 R ~ 1 rad.

rad (rad) and **Gray** (Gy) describes **dose**, the amount of energy received from radiations. Although these are more universal and useful than R, it still doesn't tell about biological damages. **dose equivalent** is designed to describe biological radiation damages, by multiplying **quality factor** (QF) on a dose. QF depends on particles since each particle has a different interaction process, and some are more dangerous than others.

particle	*kinetic energy*	*quality factor*
γ	*any*	1
e	*any*	1
μ	*any*	1
p	$> 2\,MeV$	2
$\pi^{\pm}$	*any*	2
n	$< 10\,keV$	~ 5
	$10\,keV < T < 100\,keV$	~ 10
	$100\,keV < T < 2\,MeV$	~ 20
	$2\,MeV < T < 20\,MeV$	~ 10
	$> 20\,MeV$	~ 5
α	*any*	20
heavy nuclei	*any*	20

As you see leptons and photons are less dangerous. Neutron damage depends on their energy. Low energy neutrons are not dangerous because they are not likely to penetrate the skin deeply. High energy neutrons are not dangerous because cross section is low ($\sigma \sim \frac{1}{v}$) and likely to penetrate your body without interactions. Then $\sim 1\ MeV$ neutron becomes the most dangerous. Heavy nuclei and alpha give lots of ionization loss and damage cells, and so they are always most dangerous (cf. Bragg peak). However, they are the easiest ones to prevent, since their penetrating power is very low.

Dose limits

The International Commission on Radiological Protection (ICRP) recommends **20 mSv** in a single year limit for a radiation worker. More precisely, 50 mSv is the one year limit, and 100 mSv is the total limit for consecutive 5 years for a radiation worker. So if you work at the radiation site and you receive 49 mSv in a year, this is not the violation of the radiation rule but you should be careful next 4 years because your limit is now 51 mSv in next 4 years. For public people, 1 mSv is the given limit, excluding medical radiation exposure.

For simplicity, we use **20 mSv/yr** as a radiation safety limit in this module.

Shielding

High-density materials are used to protect from any charged particles except electrons, to maximize $\frac{dE}{dx}$. Materials with large atomic number (high Z materials) are used to protect from e and γ, by minimizing their radiation length. Since neutrons lose energy effectively with light elements (moderator of nuclear fission reactors are light elements), borated polyethlene (boron mixed polyethlene) is often used in nuclear reactor sites.