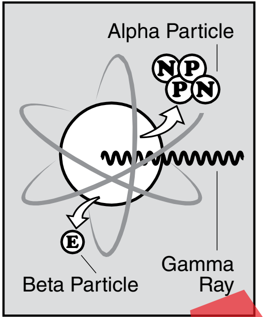
Radioactive Materials Quick Reference Card

(second edition)

Post Office Box 110848, Campbell, CA 95011-0848
Phone: (800) 477-7151 or (408) 866-2081 / Fax: (408) 866-6108
Web Site: www.firebelleproductions.com

Types of Radiation



Radioactive materials are unstable atoms throwing off excess energy or particles to achieve stability. This is called **radioactive decay** or **disintegration**.

Many radioactive materials emit two or three types of radiation. Alpha, beta, and gamma radiation are the three emergency responders are most likely to encounter. Neutron radiation is rare; it's primarily associated with nuclear power plants and nuclear bombs. Most x-rays are produced by x-ray machines that emit no radiation once turned off.

Type	Composition
Alpha	Particles (Protons & Neutrons)
Beta	Particles (Electrons)
Gamma	Electromagnetic Waves
X-Rays	Electromagnetic Waves
Neutron	Particles (Neutrons)

Alpha and beta emitters present the greatest danger if they enter the body through inhalation, ingestion, or contamination of an open wound. (Some high-energy beta particles can also penetrate intact skin.) Once inside the body, alpha and beta emitters will deposit their ionizing energy in adjacent tissues. Gamma radiation has strong penetrating power and presents the greatest risk of exposure. Most exposures to gamma rays are from external radioactive sources.

Units of Radiation Measure

Roentgen (R) identifies the amount of radiation (energy) produced by gamma rays and x-rays. It is a measure of the exposure (dose) rate—the ionization in air. Dose rate is commonly expressed in roentgens per hour (R/hr), meaning that a person would have to be in that environment for 60 minutes to be exposed to the amount of radiation displayed on the detector.

Roentgen Measures Gamma and X-Ray Radiation (Energy) in Air (**Dose Rate**)

Rad and **Gray** Measure Energy Absorbed By Any Matter (Living or Not)

Rem and **Sievert** Measure Energy Absorbed By Living Tissue (**Dose**) and Reflect Biological Damage

Rad (radiation absorbed dose) describes radiation energy absorbed by exposed matter (living or not). The international equivalent is **gray (Gy)**, but 1 gray equals 100 rads.

Rem (roentgen equivalent man) is used to measure energy absorbed by living tissue (the dose received). It reflects the biological damage done by an absorbed dose. The international equivalent is **sievert (Sv)**, but 1 sievert equals 100 rems.

Shown below is the approximate relation between these five primary units of measure.

100 roentgens = 100 rads (1 gray) = 100 rems (1 sievert)

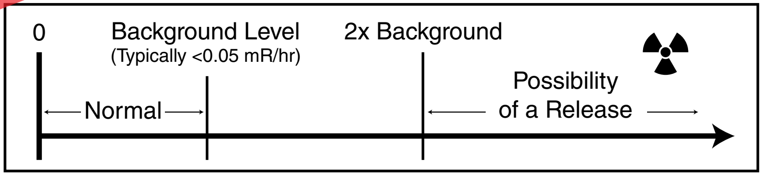
Units of Radiation Measure (continued)

Pay attention to **prefixes**, such as *milli* (one thousandth) and *micro* (one millionth). One roentgen (R/hr) equals 1000 milliroentgens (mR/hr) or 1,000,000 microroentgens (μR/hr). Likewise, one rem equals 1000 millirems (mrem) or 1,000,000 microrems (μrem).

1 R/hr	=	1000 mR/hr	=	1,000,000 μR/hr
1 rem	=	1000 mrem	=	1,000,000 μrem

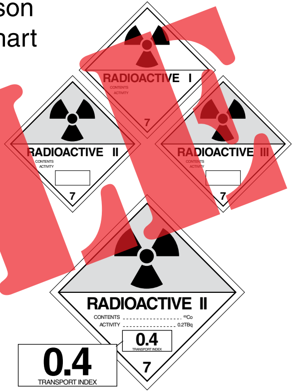
Know what scale you are reading on your radiation meter. If your meter is set to the x1 (times 1) scale, the exposure rate is what you see on the meter. However, if the selector switch is set to x0.1, x10, x100, or x1000, the meter readings must be multiplied by 0.1, 10, 100, or 1000 respectively. For example, if your meter is reading 1.5 mR/hr, but the selector switch is set to x1000, the true exposure rate is 1500 mR/hr (or 1.5 R/hr).

Remember that some background radiation is normal. It's typically less than 0.05 mR/hr, but that can vary with elevation, geology, etc. Knowing the normal background levels in your area can help you quickly determine the likelihood of a problem. If meter readings exceed two or three times the normal background level, suspect that radioactive materials are present, and respond accordingly.



Radiation Labels and Placards

Three **labels** reflect the maximum potential radiation exposure a person could receive per hour in close proximity to an intact package (see chart below). Materials labeled Radioactive I are the least hazardous, while those labeled Radioactive III are the most hazardous. The designation of Radioactive I, II, or III is based on dose rate (above normal background radiation levels) as measured both at the surface of the package and at 1 meter (3 feet) away.



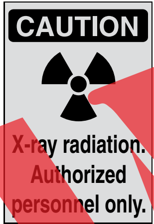
Label	At Package Surface	At 1 Meter (3 Feet) Away
I	0.5 mR/hr	None
II	50 mR/hr	1 mR/hr
III	200 mR/hr	10 mR/hr

The **transportation index (TI)** on Radiation II and III labels identifies the maximum radiation level (in mR/hr) allowed at 1 meter (3 feet) from an undamaged package.

Placards are required on vehicles transporting Radioactive III materials. A radioactive placard on a square white background means that the vehicle contains a high-level radioactive material (e.g., spent fuel) that must be shipped along designated routes.

Facility Signage (Postings)

Signage (postings) at fixed facilities differs from that in transportation. The **wording on facility signage reflects the potential radiation exposure.** (Source: 10 CFR 20.1902.)



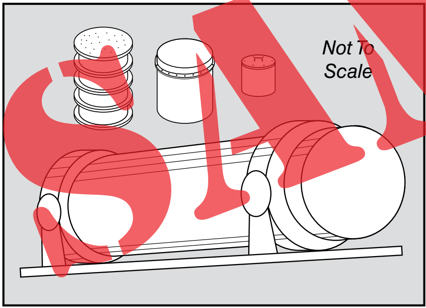
Facility Signage	Potential Radiation Exposure
Caution Radiation Area	>0.005 rem (0.05 mSv) in 1 hour at 30 centimeters (11.8 inches)
Caution or Danger High Radiation Area	>0.1 rem (1 mSv) in 1 hour at 30 centimeters (11.8 inches)
Grave Danger Very High Radiation Area	>500 rads* (5 grays*) in 1 hour at 1 meter (39.37 inches)
Caution or Danger Airborne Radioactivity Area	Airborne dusts, fumes, particulates, mists, vapors or gases
Caution or Danger Radioactive Materials	Licensed material greater than 10 times the licensing threshold for the radionuclide

* 10 CFR 20 switches to rads/grays when referring to very high doses received at high dose rates.

Packaging for Radioactive Materials

Radioactive materials and wastes are placed in different types of packages based on level of radioactivity. The higher the level of radioactivity, the stronger the package must be to shield against radiation and to protect against loss of contents in an accident.

Package Type	Radioactivity of Materials Inside	Life-Endangering Levels?
Excepted	Extremely Low	No
Industrial	Low	No
Strong-Tight	Low	No
Type A	Higher	No
Type B	Highest	Potentially
Type C	Highest	Potentially



Packages vary from cardboard boxes and wooden crates to steel drums and heavily shielded casks. Some containers are generic enough that responders must **look for a label or stencil** (or shipping papers) **to know the contents are radioactive.** Type B packages (and Type C packages, authorized only for international air transport) are the only ones containing potentially life-endangering levels of radioactivity.

Radiation Exposure Limits

The EPA has published recommended dose limits for workers performing emergency services. Doses to all workers during emergencies should, to the extent practicable, be limited to 5 rem. The chart below shows situations for which higher doses may be justified if the benefits outweigh the risks. Exceeding the 25-rem limit to save lives should be considered only on a voluntary basis and only with full awareness of the risks involved, including the health effects at the anticipated doses.

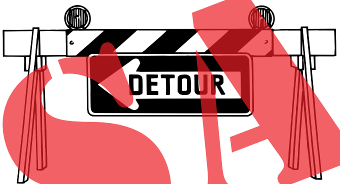
<table>
<tr><th>Dose Limit</th><th>Activity</th><th>Condition</th></tr>
<tr><td>5 rem</td><td>all</td><td></td></tr>
<tr><td>10 rem</td><td>protecting valuable property</td><td rowspan="2">lower dose
not practicable</td></tr>
<tr><td>25 rem</td><td rowspan="2">life saving or
protecting large populations</td></tr>
<tr><td>> 25 rem</td><td>voluntary basis, fully aware of risks</td></tr>
</table>

The EPA limits still leave a safety margin. Although there may be some mild effects as low as 30 rems, most people won't develop "radiation sickness" at less than 70 to 100 rems. Nonetheless, **radiation exposures should always be kept as low as reasonably achievable**. This is known as the **ALARA Principle**.

Initial Isolation & Protective Action Distances

Establish an initial isolation zone (perimeter). The initial perimeter should be set up where radiation levels are at or below 2 mR/hr. If you can't determine actual radiation levels, use the current edition of the Emergency Response Guidebook to establish distances. Guides 161 through 165 in the ERG2008 recommend the following minimum initial isolation/evacuation distances:

- 75 feet (25 meters) - isolation of spill or leak
- 330 feet (100 meters) - downwind evacuation for large spill
- 1000 feet (300 meters) - evacuation for large fire



Use common sense when establishing isolation zones. It's appropriate to err on the side of safety if you are unsure of the risks. However, incidents involving dangerous levels of radiation are rare, and releases are uncommon due to the sturdy packaging. Thus seldom is it necessary to evacuate large areas.

The U.S. EPA *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents* (also known as the *EPA PAG Manual*) recommends implementing **protective actions (evacuation or shelter-in-place)** when the projected radiation dose is between 1 and 5 rems. (Protective actions should normally begin at 1 rem.)

Incident Stay Time

Understanding the relation between time and exposure can help you stay within the EPA exposure limits identified on page 8. Roentgens are expressed in roentgens per hour (R/hr) or milliroentgens per hour (mR/hr). That means, for example, that you could be in a 50-R/hr atmosphere for 30 minutes without exceeding the 25-rem limit to save a life. (Note: One roentgen equals 1000 milliroentgens.)

An **Incident Stay Time Table** is one tool you can use to plan the work mission duration. (You should also wear a personal dosimeter to monitor your exposure.)

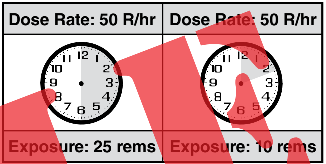
Dose Rate	Time to Receive Maximum Dose		
	5 rem	**10 rem**	**25 rem**
1 R/hr	5 hours	10 hours	25 hours
20 R/hr	15 minutes	30 minutes	75 minutes
50 R/hr	6 minutes	12 minutes	30 minutes
100 R/hr	3 minutes	6 minutes	15 minutes

EPA Limit	Constant		Meter Reading		Stay Time
25 rems ...	1500	÷	___ R/hr	=	___ Minutes
10 rems ...	600	÷	___ R/hr	=	___ Minutes
5 rems ...	300	÷	___ R/hr	=	___ Minutes

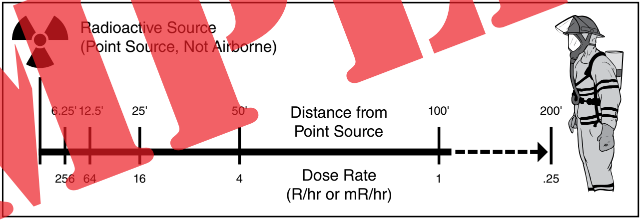
Or you can **calculate incident stay time** with any of the equations here. To understand where the “constant” comes from, multiply 60 by the appropriate EPA limit (e.g., 25 rems times 60 minutes results in a constant of 1500).

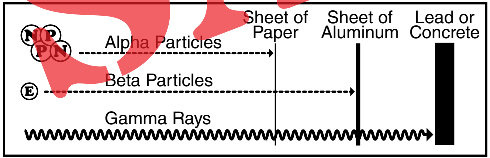
Time, Distance, and Shielding

Minimize exposure time. Radiation doses are directly proportional to length of exposure.



Maintain a safe distance. Doubling your distance from a radioactive source reduces exposure by 75%. This is known as the Inverse Square Law. Distance also helps reduce type of exposure. Alpha particles travel only a couple inches; beta particles, several feet to several yards. So unless radioactive materials are being spread by wind, rain, or other forces, once you back out, you need only worry about gamma radiation.





Use PPE and shielding available on scene to protect against inhalation, ingestion, and absorption of radioactive materials and to reduce exposure to penetrating radiation.

Health Effects

Health effects vary depending on the type of radiation, how much of the body was exposed, the depth of penetration, the dosage received, and whether the exposure is from a single event or multiple events. Health effects also vary based on individual factors, such as age and state of health. **The following health effects apply to acute whole body exposures**:

- There may be mild symptoms with doses as low as **30 rems** (0.3 Sv), but most people won't develop what is considered "radiation sickness" at less than **70 to 100 rems** (0.7 to 1.0 Sv).

- Whole body exposures **above 70 to 100 rems** (0.7 to 1.0 Sv) may cause nausea and vomiting for 1 to 2 days and a temporary drop in the production of new blood cells.

- **As the exposure increases**, so do the signs and symptoms of radiation sickness. Initial effects may include nausea, vomiting, diarrhea, dizziness, fatigue, headache, and loss of appetite. Higher doses may also cause fever, sweating, and difficulty breathing.

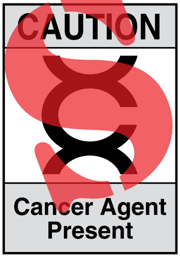
- **Above 350 rems** (3.5 Sv), the initial effects will be followed by a period of apparent wellness. But usually within 2 to 3 weeks, patients will become sick again and experience infection, electrolyte imbalance, diarrhea, bleeding, cardiovascular problems, and sometimes lapses in consciousness. Medical care is required.

Health Effects (Continued)

- The experts don't agree on a precise number, but a whole body exposure in the range of **250 to 500 rems** (2.5 to 5.0 Sv) **is considered the LD_{50}/60 days**, meaning that 50% of patients exposed to this level of radiation will die within 60 days if untreated. However, all can survive with proper medical attention.

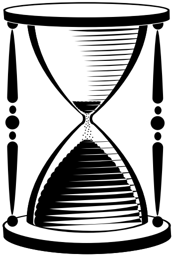
- **Above 1000 rems** (10 Sv), the chances of survival drop significantly, even with aggressive treatment.

- Patients exposed to **5000 rems** (50 Sv) will die within 48 hours. There is no effective treatment for such acute exposures. Treatment is limited to making patients as comfortable as possible.



Aside from the radiation sickness described above, **ionizing radiation can disrupt normal cell growth and repair processes**, resulting in an increased risk of cancer—often considered the primary health effect. Or radiation can cause changes in DNA—mutations that affect a developing fetus or that can be passed from parent to child. Other health effects include damage to the blood-forming organs, sterility, or other damage to the reproductive system.

Health Effects (Continued)



The speed with which initial signs and symptoms appear increases with exposure level. Onset of nausea and vomiting—the earliest clinical signs of acute radiation sickness—usually takes several hours. So **when health effects are observed right after an incident, one should first suspect other causes**, such as traumatic injuries, exposure to other hazardous materials, or other hazardous properties (e.g., corrosivity or toxicity) of the radioactive materials. However, if nausea and vomiting occur shortly after exposure, one must also consider the possibility that patients received a high absorbed dose of radiation.

Partial body exposure results in radiation burns that develop slowly, although patients may also experience the early nausea and vomiting typical of whole body exposures.

- Roughly 2 to 3 weeks after partial body exposures of 300 to 1000 rems (3 to 10 Sv), effects may resemble a first-degree sunburn.
- Higher exposures—up to 2500 rems (25 Sv)—will produce blisters within 1 to 2 weeks.
- Partial body exposures exceeding 3000 rems (30 Sv) may cause slow-healing ulcers or gangrene.
- Extremely high exposures manifest with tingling, pain, redness, and swelling very soon after exposure.

Patient Care for Radiation Exposures

Rescue and serious medical problems take precedence over radiation concerns, such as monitoring and decon, because radiation injuries are not immediately life-threatening, whereas other injuries can be. With that in mind, the following are some general patient care guidelines.

- Ensure your safety. (Consider all hazards on scene.)
- If patients are not contaminated, use standard universal precautions (gloves, handwashing, etc.). Otherwise, a face mask (N-95 HEPA filter or equivalent), eye protection, and clothing that provides full skin protection is recommended.
- Decontaminate patients as needed.
  - Remove and isolate contaminated clothing as soon as practical.
  - Cleanse the skin with lukewarm water or soap and water. Use low water pressure and a gentle spray. (If contamination is minimal, cleansing with a mister or wet towel may be preferable.)
  - Avoid flushing material into eyes, nose, mouth, wounds, or uncontaminated areas.
  - Pay particular attention to body areas where chemicals may become trapped.
  - Protect patients' modesty as much as possible.
  - Use radiation detectors to ensure patients are fully decontaminated.
- Provide basic and advanced life support as appropriate.
- Coordinate with medical facilities before transporting patients.

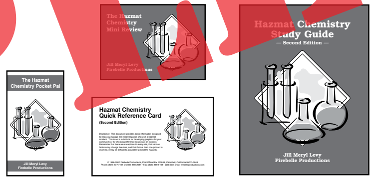
More Resources from Firebelle Productions

Hazmat & Terrorism Field Guides

- The First Responder's Field Guide to Hazmat & Terrorism Emergency Response
- Hazardous Materials and WMDs: A Field Guide for Awareness Level Personnel
- The First Responder's Pocket Guide to Radiation Incidents

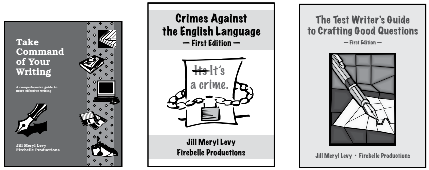
Hazardous Materials Chemistry Resources

- Hazmat Chemistry Study Guide
- The Hazmat Chemistry Mini Review
- The Hazmat Chemistry Pocket Pal
- Hazmat Chemistry Quick Reference Card



Writing Books

- Take Command of Your Writing
- Crimes Against the English Language
- The Test Writer's Guide to Crafting Good Questions



Preview these products at www.firebelleproductions.com.