Safe Transport of Radioactive Materials – Student Notes

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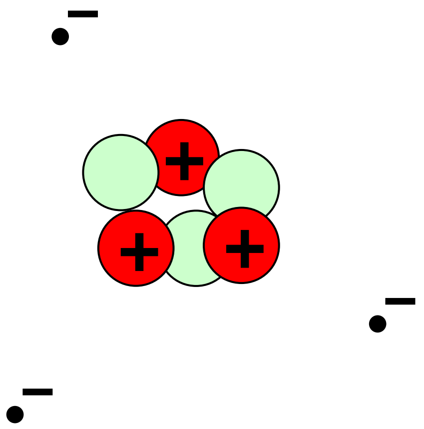
THE SCIENTIFIC BACKGROUND

ELEMENTS

The number of protons in the nucleus of an atom is called the atomic number it is denoted by the capital letter Z. Atoms with the same number of protons have the same chemical properties because they have the same electron configuration and therefore the same chemical binding properties. An element is made up of atoms all containing the same number of protons. That is, having the same atomic number.



An atom; Lithium, with:

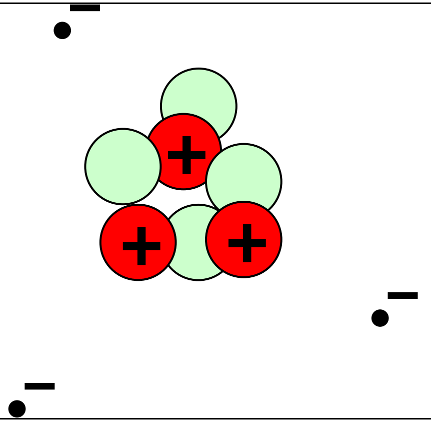
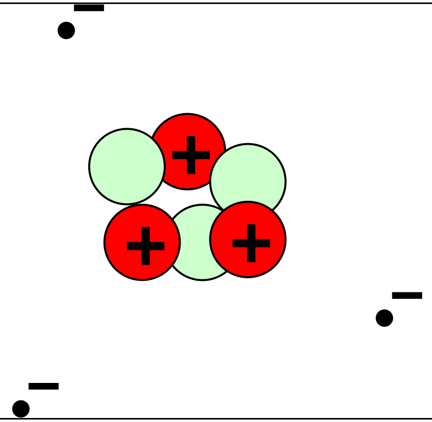
- 3 positively charged protons in the nucleus
- 3 neutral neutrons in the nucleus
- 3 negatively charged electrons outside the nucleus

NUCLIDES AND ISOTOPES

The total number of protons and neutrons in an atom is called the atomic mass number, which is denoted by the capital letter A. Nuclides are atoms characterised by the number of protons and neutrons in their nucleus. They are represented symbolically as: ${}^{A}_{Z}X$

where A = mass number
Z = number of protons or atomic number
X = chemical symbol

An element may have several different types of atoms, all containing the same number of protons but a different number of neutrons. These different types of atoms are called isotopes of that particular element.

		
Isotope 1: Lithium 7 ($^{7}_{3}Li$)		Isotope 2: Lithium 6 ($^{6}_{3}Li$)

Isotopes of a particular element all have the same chemical properties and are impossible to separate chemically. For example, oxygen (Z = 8) has three isotopes, one containing 8 neutrons (A = 16), one containing 9 neutrons (A = 17) and the other containing 10 neutrons (A = 18). 0 is the chemical symbol for oxygen and the isotopes of oxygen are represented symbolically as:

$$^{16}_{8}O \qquad ^{17}_{8}O \qquad ^{18}_{8}O$$

Frequently, the atomic number Z is not included as the chemical's symbol defines the element which, in turn, defines the atomic number. For example, ^{125}I. Here, the capital letter I represents the element iodine which, has an atomic number of 53. The mass number 125 specifies which isotope of iodine, that is, the one with 72 neutrons in the nucleus.

RADIOACTIVITY

Most elements consist of a number of isotopes. Some particular isotopes are unstable and spontaneously break down or disintegrate at a constant rate into isotopes of different elements, giving out nuclear radiation (alpha, beta or gamma) in the process. In some cases the newly formed nuclides are also unstable and decay further into isotopes of different elements again. This process continues until the final decay product is stable. The process is called radioactive decay or radioactivity, and isotopes (or nuclides) possessing this property are known as radioisotopes (or radionuclides).

The rate at which a radioactive material decays and the nuclear radiations given out are unique characteristics of the particular radionuclide. The activity of a sample is described by the number of nuclear disintegrations per unit time. The SI unit of activity is the Becquerel (Bq), where:

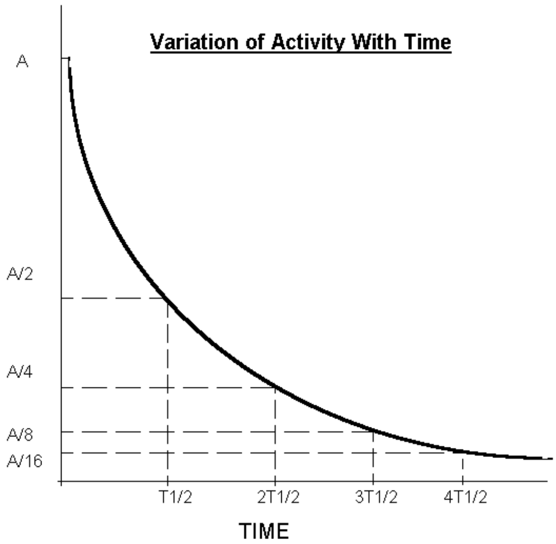
1 Bq = 1 disintegration per second

The older, non-SI unit of activity is the Curie (Ci), where:

1 Ci = 3.7 x 10^{10} disintegrations per second

Radioactive decay is an exponential process and can be described mathematically by the formula:

$A_t = A_o e^{-\lambda t}$ where A_o is the original activity
A_t is the activity at time t
and λ is the radioactive decay constant.



The half-life of a particular radionuclide is the time taken for it to decay to half its original activity, see figure.

If $t_{1/2}$ is the half-life then:

$$A_0/2 = A_0 e^{-\lambda t_{1/2}}$$

Where:

$$t_{1/2} = 0.693/\lambda$$

Substituting back in the exponential equation gives:

$$A_t = A_0 e^{-0.693t/t_{1/2}}$$

An easier working equation is:

$$A_t = A_0/2^n$$

Where n is number of half-lives expired in time t. Note: both t and $t_{1/2}$ must be in same time units

Practice problem

At the time of dispensing, the activity of a vial of technetium-99m was 6 GBq. The half-life of technetium-99m is 6 hours. What is the activity of the sample after 24 hours has expired?

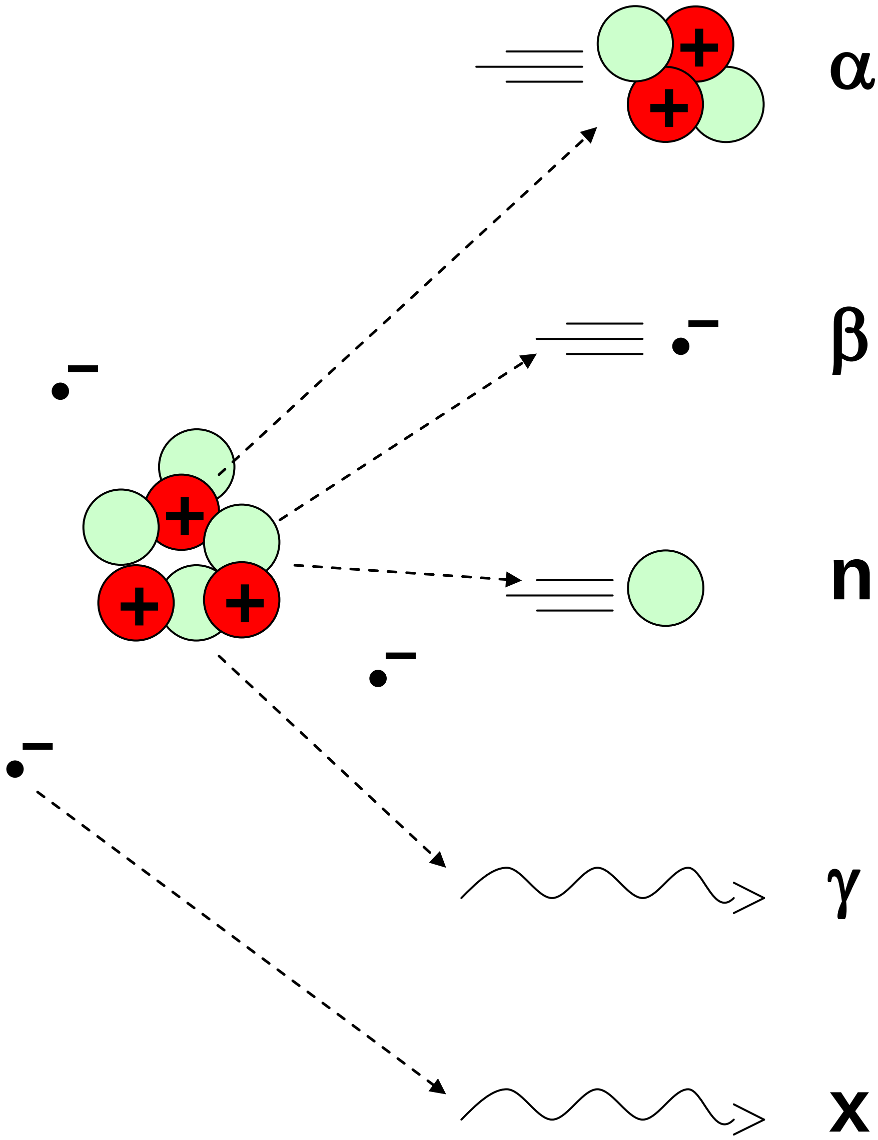
- 24 hr is equal to 4 half-lives (4 x 6 hrs = 24 hrs)
- let A_o = 6 GBq

$$A_t = A_0/2^n$$

$$= 6GBq/2^4$$

$$= 0.375GBq$$

RADIATION



Beta Radiation

Beta radiation is a particle. It is a particle that behaves like an electron (negatively charged) however originates from the conversion of a neutron (n) into a proton (p). Beta radiation has limited penetration, usually in the order of 2 -3 cm deep. Beta radiation is shielded with Perspex. The low density of Perspex shields the Beta particles without converting them to x-rays as would happen if a dense shielding material (like Lead) was used. The process of converting Beta radiation to X-rays is referred to as Bremsstrahlung radiation.

Alpha Radiation

Alpha radiation is also a particle however in this case it is a helium nucleus (2 protons and 2 neutrons so therefore positively charged). Alpha radiation has a very limited penetration usually about 2-3 cell layers and as such is not usually an external hazard. However the inhalation, ingestion or injection of an Alpha emitting isotope can cause significant damage to vital organs. Alpha radiation is easily shielded with things like paper, a few cm of air or even the dead skin on the outside of your body.

Neutron Radiation

Neutron radiation is a particle (a neutron – no charge). Neutrons travel incredibly quickly and have an extremely larger penetration (potentially Km). Neutrons are shielded with materials that contain Hydrogen (Water, Wax etc), this allows the shielding material to adsorb the energy of the fast travelling incoming Neutron. The side effect of this is that over time and with enough Neutrons the shield will also build up heat. Neutron radiation is the only radiation type that can make something else radioactive, this occurs when a Neutron is captured by the target nucleus, which therefore changes the Isotope and potentially results in a radioactive isotope of the host element.

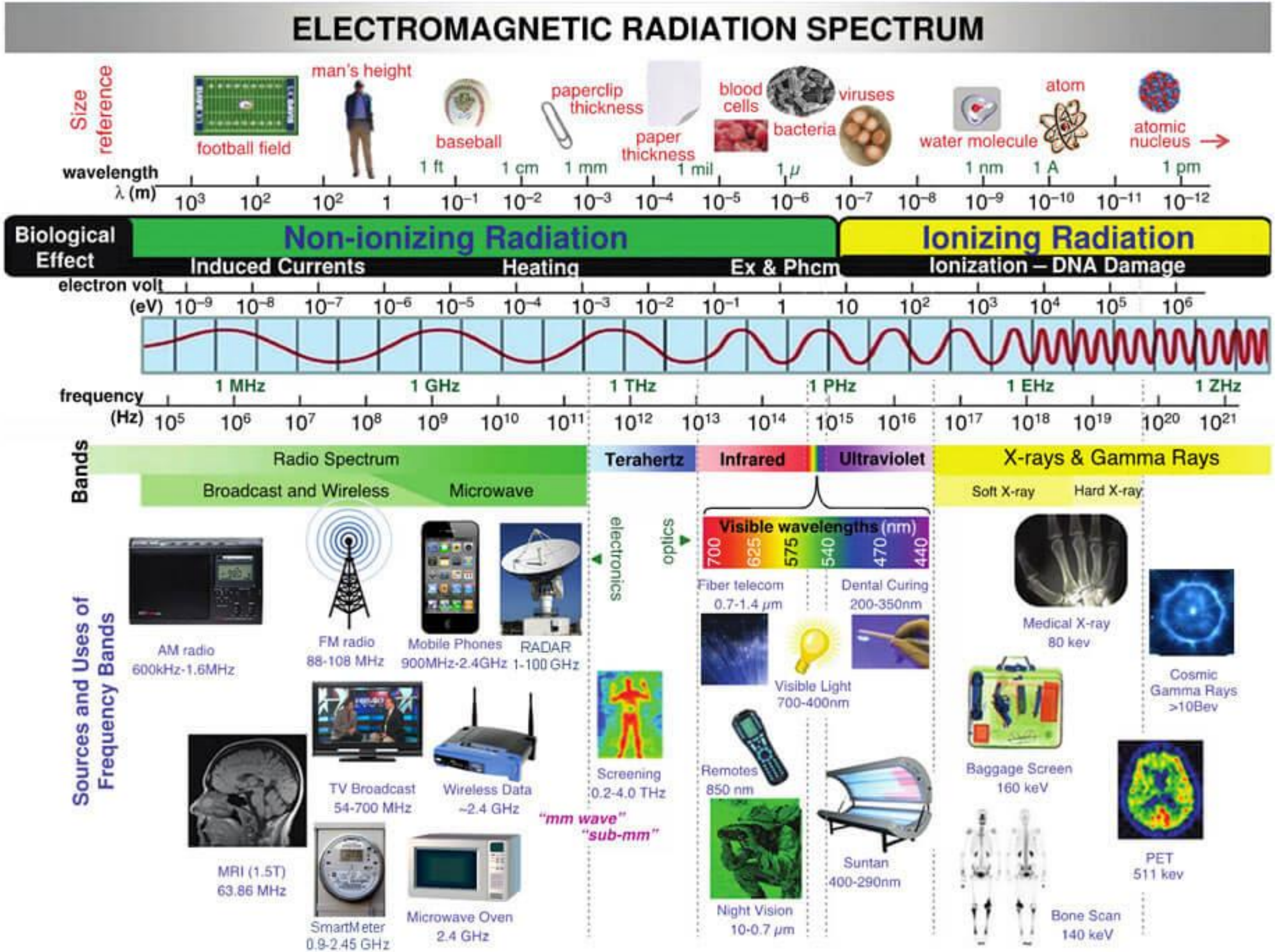
X-Ray Radiation

X-ray radiation is electromagnetic radiation. X-rays are essentially light from part of the electromagnetic spectrum that humans cannot see. As X-rays are light they have no mass and no charge. They travel in straight lines and can penetrate in the order of Metres in the human body. X-rays are shielded with dense materials like Lead, Steel or Concrete. The vast majority of X-rays are electrically generated and are therefore much more easily able to be controlled and protected.

Gamma Radiation

Gamma radiation is electromagnetic radiation. Gamma radiation is essentially light from part of the electromagnetic spectrum that humans cannot see. As Gamma rays are light they have no mass and no charge. They travel in straight lines and can penetrate in the order of Metres in the human body. Gamma rays are shielded with dense materials like Lead, Steel or Concrete. Gamma rays originate from the nucleus of an unstable atom (through the rearrangement of Neutrons and protons).

The main difference between X-rays and Gamma rays is where they originate from. Gamma comes from the nucleus, X-rays from the orbital electrons.


ELECTROMAGNETIC RADIATION SPECTRUM
Size reference
football field
man's height
baseball
paperclip thickness
paper thickness
blood cells
bacteria
viruses
water molecule
atom
atomic nucleus
wavelength λ (m)
1 ft
1 cm
1 mm
1 mil
1 μ
1 nm
1 A
1 pm
Biological Effect
Non-ionizing Radiation
Induced Currents
Heating
Ex & Phcm
Ionizing Radiation
Ionization – DNA Damage
electron volt (eV)
frequency (Hz)
1 MHz
1 GHz
1 THz
1 PHz
1 EHz
1 ZHz
Bands
Radio Spectrum
Broadcast and Wireless
Microwave
Terahertz
Infrared
Ultraviolet
X-rays & Gamma Rays
Soft X-ray
Hard X-ray
electronics
optics
Visible wavelengths (nm)
700 625 575 540 470 440
Sources and Uses of Frequency Bands
AM radio 600kHz-1.6MHz
FM radio 88-108 MHz
Mobile Phones 900MHz-2.4GHz
RADAR 1-100 GHz
MRI (1.5T) 63.86 MHz
TV Broadcast 54-700 MHz
Wireless Data ~2.4 GHz
SmartMeter 0.9-2.45 GHz
Microwave Oven 2.4 GHz
"mm wave"
"sub-mm"
Screening 0.2-4.0 THz
Fiber telecom 0.7-1.4 μm
Dental Curing 200-350nm
Visible Light 700-400nm
Remotes 850 nm
Night Vision 10-0.7 μm
Suntan 400-290nm
Medical X-ray 80 kev
Baggage Screen 160 keV
Bone Scan 140 keV
Cosmic Gamma Rays >10Bev
PET 511 kev

Ionising radiation includes the high frequency part of the spectrum starting after ultra violet (x-rays, gamma rays and cosmic rays). It also includes the emission of certain very high energy sub atomic particles from the nucleus of radioactive material, but these types of ionising radiation are not produced by x-ray equipment.

BASIC RADIATION PROTECTION

IONISING RADIATION

When ionising radiation interacts with matter, electrons are removed from atoms leaving them positively charged, i.e. they become positive ions. The removed electrons quickly recombine with other atoms to form negative ions. Ion pairs (positive and negative) have been created, hence the name ionising radiation. Examples of ionising radiations are alpha, beta, gamma, x-rays and neutrons.

BASIC PRINCIPLES OF RADIATION PROTECTION

Avoid Exposure

When ionising radiation falls on human tissue it has the potential to cause injury. The greater the exposure the greater the potential for injury. Therefore, a basic principle of radiation protection is to **avoid all unnecessary exposures** to ionising radiation.

A.L.A.R.A.

When exposure is necessary in the course of ones work then exposures should be maintained below the recommended dose limits. The basic tenet in radiation protection is to ensure that all exposures are kept **As Low As Reasonably Achievable**, social and economic factors taken into account - the ALARA principle.

Benefits must outweigh Risks

The benefits derived from the use of radioactive materials or apparatus that emit ionising radiations, should outweigh the risk of injury from exposure to radiation as a result of their use. This is readily demonstrated in the case of medical x-rays, where the benefit to the patient from the diagnostic procedure outweighs the risk from exposure to the x-rays.

DOSE UNITS

Absorbed dose

Absorbed dose is a measure of the energy absorbed from ionising radiation per unit mass of the absorbing material. The SI unit of absorbed dose is the Gray, which is the amount of ionising radiation required to produce one joule per kilogram in the absorbing medium.

$$1 \text{ Gy} = 1 \text{ J kg}^{-1}$$

In the past, the unit for absorbed dose was the rad which was the amount of ionising radiation to produce 100 erg per gram (0.01 J kg^{-1}) in the absorbing medium.

$$1 \text{ Gy} = 100 \text{ rad.}$$

Equivalent Dose

Different types of radiation can have different biological effect for the same absorbed dose. To take account of this we use quality factors and define equivalent dose = absorbed dose x quality factor.

The unit for equivalent dose is the **sievert**. Sv = Gy x QF

Table 1 - Quality Factors (ICRP 60)

Type of Radiation	Weighting Factor
beta	1
alpha	20
x-rays	1
γ-rays	1
neutrons < 10 keV	5
neutrons (10 keV - 100 keV)	10
neutrons (100 keV - 2 MeV)	20
neutrons (2 MeV - 20 MeV)	10
neutrons >20 MeV	5

Note: For beta, X and gamma radiation the quality factor is one, therefore the number of grays is the same as the number of sieverts for these radiations. For alpha radiation the quality factor is 20, i.e. for alpha radiation there are 20 sieverts for every Gray.

The old unit for equivalent dose was the rem.
rem = rad x QF and
1 Sv = 100 rem

Table 2 - Radiation Dose Units

Type	Unit	Symbol	Old Unit	Symbol	Conversion
Absorbed dose	Gray	Gy	rad	r	1 Gy = 100 r
Dose equivalent	sievert	Sv	rem	rem	1 Sv = 100 rem

DOSE LIMITS

In general there are 2 categories of people, Radiation Workers and Members of the Public. The dose limits are as follows;

Radiation Workers (Including people transporting radioactive material).

- 20mSv per year to the whole body
- 500mSv per year to the extremity
- 150mSv per year per eye
- 500mSv per year per square centimetre of skin.

Member of the Public (anyone who isn't a Radiation Worker)

- 1mSv per year to the whole body
- 15mSv per year per eye
- 50mSv per year per square centimetre of skin

It is hypothesised that some harmful biological effects such as cancer have a probability of occurring no matter how low the dose is (obviously the lower the dose the lower the probability). Other effects such as cataract formation in the lens of the eye have a threshold dose below which the effect will not occur. Dose limits are set to limit the former and prevent the latter, (known as deterministic and non-deterministic effects, respectively).

To prevent non-deterministic effects, the annual dose limit is 500 mSv for all tissues except the lens of the eye, for which an annual limit of 150 mSv applies.

To limit deterministic effects the annual dose limit for uniform irradiation of the whole body is 20 mSv. For non-uniform irradiation of the body an annual effective dose equivalent limit of 20 mSv is used. Here weighting factors for the various tissues/organs are used to convert organ and tissue doses to effective whole body doses for the purpose of comparison with the 20 mSv annual dose limit.

Table 3 - Tissue weighting factors

Tissue	w_t
Gonads	0.2
Breast	0.05
Red bone marrow	0.12
Lung	0.12
Colon	0.12
Stomach	0.12
Thyroid	0.05
Bladder	0.05
Liver	0.05
Oesophagus	0.05
Skin	0.01
Bone Surfaces	0.01

Hence a dose equivalent to the lung of 20 mSv is the same as an effective dose equivalent of 20 × 0.12 = 2.4 mSv to the whole body. A 20 mSv effective dose equivalent would be the same as 20 / 0.12 = 167 mSv lung dose.

The formal mathematical expression for limiting the annual effective dose equivalent is:

$$\sum w_t H_t < 20 \text{ mSv}$$

Where w_t is the weighting factor for tissue t and H_t is the dose equivalent to tissue t.

DOSE RATE

The annual dose limit for radiation workers is 20 mSv. Pro-rating this over 50 weeks gives 0.4 mSv/week and pro-rating this over a working week of 40 hours gives 10 μSv h^{-1}. i.e. If a worker works for 40 hours per week for 50 weeks exposed to a dose rate of 10 μSv h^{-1} that person will receive the annual dose limit of 20 mSv.

IONISING RADIATION IN THE NATURAL ENVIRONMENT

Before we go any further, it should be noted that everyone is exposed to natural sources of ionising radiation in our everyday environment. This generally low level exposure is referred to as natural background radiation and varies from place to place depending on the natural radioactive content of the rocks and soils in the locality, the altitude, the latitude, the building materials, etc.

Small amounts of natural radioactive material, mainly potassium 40 are incorporated within our bodies. The food we eat, the air we breathe, the water we drink, all contain trace quantities of naturally occurring radioactive elements.

Table 4 indicates typical effective whole body dose equivalents from natural sources in regions of “average” background. The total dose from such sources is around 2 mSv per year on average, however, in some places around the world this figure can be up to ten times higher and comparable with occupational exposures.

Table 3 - Average Effective Whole Body Dose Equivalent 'Natural' Radiation

Source	Annual Effective Dose Equivalent (µSv y^{-1})		
	External	**Internal**	**Total**
Cosmic rays and Neutrons	30		30
Cosmogenic		15	15
*^{40}K	150	180	330
*^{87}Rb		6	6
*^{238}U series	100	1,239	1,340
*^{232}Th series	160	176	350
Total µSv y^{-1} (rounded)	440	1,620	2,060

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POTENTIAL HAZARDS OF IONISING RADIATIONS

Human senses cannot detect ionising radiations, therefore, we must rely on instruments capable of detecting them to give us warning of potential exposures. Radiation injury to people can be classed in two main ways:

(a) **Somatic effects**, where the effects occur in the exposed individual, and

(b) **Genetic effects**, where the effects occur in the exposed individual's descendants.

Somatic effects can be subdivided into:

(a) **Acute effects**, which occur when a large exposure is received over a very short time. Here we must protect the worker from large accidental exposures.

(b) **Late effects**, which can occur when low exposures are received continuously over a long period of time. Here we must keep the worker's radiation exposure within the acceptable dose limits set by ICRP.

When persons are exposed to ionising radiations from outside the body, this is known as an external radiation exposure. When persons take radioactive material into their bodies (by inhalation, ingestion or absorption through the skin) this is known as an internal radiation exposure.

Radioactive sources may be sealed (e.g. Gamma radiography source) or unsealed (e.g. Radioactive tracer). Unsealed radioactive sources may give rise to surface or airborne contamination. The working environment must be monitored for external radiation, surface contamination and/or airborne contamination when these hazards are likely. The worker must be monitored for personal radiation exposures and personal contamination.

CONTROL OF INTERNAL RADIATION EXPOSURES

To prevent radioactive material entering the body the following general rules are applied:

1. Provide proper and adequate containment for unsealed sources.
2. Carry out regular monitoring for contamination.
3. Use suitable protection clothing.
4. Decontaminate immediately after spills.
5. Maintain good housekeeping
6. Do not smoke, eat, use cosmetics or pipette by mouth in potentially contaminated areas.
7. Check yourself for personal contamination on leaving a potentially contaminated area.

PERSONAL DOSIMETERS

It is normally required by law that radiation workers be provided with personal dosimeters and that each individual's accumulated dose be recorded in a personal dose record.

The most common personal dosimeter used is the thermoluminescent dosimeter (TLD). Thermoluminescent dosimeters when heated give off light in proportion to the amount of ionising radiation they have received. TLD material is available in powder, chip and strip or disc form. Lithium fluoride and Calcium fluoride are two common thermoluminescent materials. A TLD reader is used to heat the dosimeters and measure their light output and is calibrated in dose units.

TLDs measure beta, X, gamma and neutron radiation, are physically small, and can be worn on the finger to measure finger doses. The holder comprises a set configuration of filters that suit the desired application; i.e. - β, γ or neutron dosimetry. The dose range which can be covered is large, typically from 10 (100 mSv) to 10000 (100 Sv).

When immediate readout of dose is required along with the approved dosimeter, other devices can be worn. These devices may not be assumed, for official purposes, to imply doses received by operators. They are useful tools, however, and give operationally important information immediately. Recent advances in electronic technology have made these devices smaller, more reliable and more affordable.

BIOLOGICAL EFFECTS OF IONISING RADIATION

If a person is exposed to a high dose in a short period of time this is known as **acute radiation exposure** and depending on the severity can cause illness and even death. This would only happen in major accidents.

If a person is exposed to low doses over a lifetime this long term, low level exposure or **chronic exposure**, can lead to cancer. This is a very low probability for radiation workers who comply with safety rules and regulations and stay below dose limits. The table below shows the dose levels for short term effects after whole body irradiation over a short period of time.

DOSES FOR ACUTE BIOLOGICAL EFFECTS

Doses for Acute Biological Effects	mSv
No discernable effect	250
Blood changes, no illness	1000
Radiation sickness, no deaths	2000
Death to 50% of irradiated people (within 3 months – LD50/30)	4500
Death to 100% of irradiated people	10 000

The current best estimate of the fatality risk from radiation induced cancer is 2 per 100 person sieverts. This means that if say, 10,000 people were each given 1 mSv, two of them may die 20 - 30 years later due to a cancer induced by that dose. In that population of 10,000 people however, about 1600 of them would die from other "normal" cancers.

CONCEPTS AND TERMINOLOGY

Exposure: Delivery of radiation to an organism. Exposure can be acute (chest X-ray) or chronic (cosmic rays).

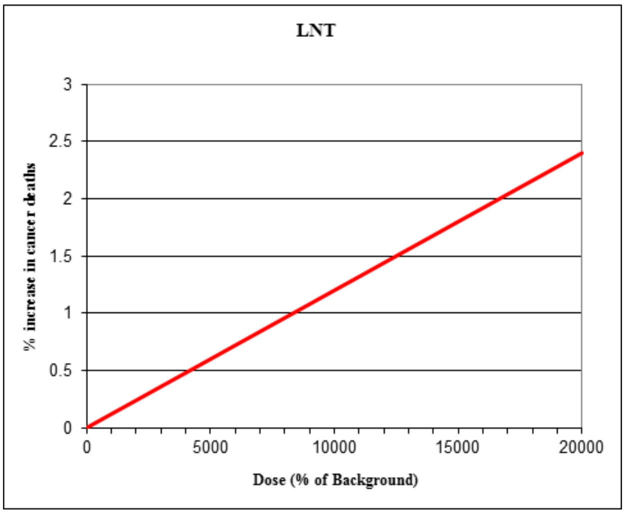
Effects: Changes to an organism caused by radiation exposure. Effects can be acute (skin burns) or chronic (life shortening). Acute effects can be “early” or “early but delayed” while chronic effects are “late”.

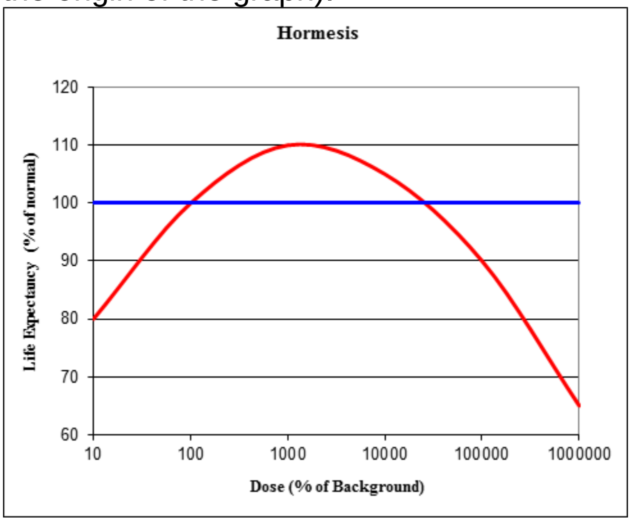
Deterministic Effects: Effects which are inevitable, often the severity of deterministic effects depend on the magnitude of the dose or dose rate. Deterministic effects exhibit a “threshold” in their dose response relationship. Doses below the threshold can not induce the effect. Skin burns and cataracts are deterministic effects.

Non Deterministic Effects: Effects where occurrence is based on probability. Non deterministic effects do not exhibit a “threshold” in their dose response relationship. In the absence of sufficient contrary evidence the dose response relationship is assumed to be linear. Induction of cancer is a non deterministic effect.

LINEAR NO THRESHOLD HYPOTHESIS (LNT)

Hypothesis stating that the dose response relationship for cancer induction in humans is linear and has no threshold (passes through the origin of the graph).





Hormesis: An effect where a toxic substance acts like a stimulant in small doses, but it is an inhibitor in large doses.

What are the Mechanisms of Injury?

The mechanisms of injury can be direct via ionisation, and/or indirect - through the action of free radicals formed by ionisation of other molecules.

Injury is to individual cells, critical damage is to the DNA in the nucleus. This damage can cause cell death, block or delay cell division, or cause transmission of a mutated (changed) gene to cell descendants. Multiple cell damage will have increased effects on the body and its organs.

What Factors Influence the Biological Effects of IR?

Physical factors influencing the effects of IR are the type, energy and dose of IR; how it is given; over what time period; whether it is external IR or internal contamination; and whether the whole body or only part is irradiated.

Chemical factors such as oxygen content of tissues increase (radiosensitise) effects of radiation exposure while other factors such as oestrogen and alcohol reduce (radioprotect) the effects of exposure.
Biological factors like species, individual and cell sensitivity and the recipient's age, are important.

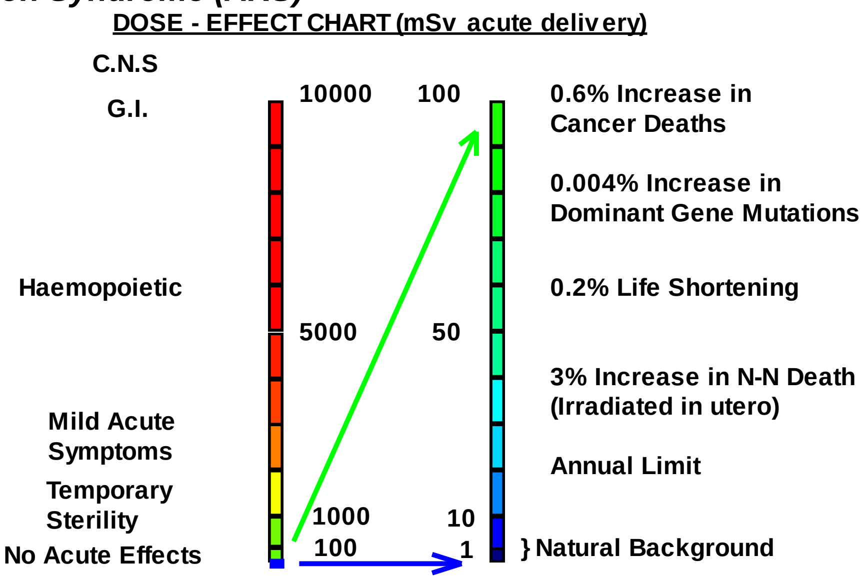
WHAT ARE THE BIOLOGICAL EFFECTS?

Deterministic effects of large accidental doses of IR include destruction of lymphocytes in the blood, destruction of cells lining the inner intestinal wall and skin burns.
Fibrosis (scarring) of lung tissue can be a delayed effect.
Cataract of the lens of the eye is a late deterministic effect with a probable threshold of 3500mSv.
Late stochastic effects are an increase in the incidence of certain cancers and (in animals) hereditary effects.

How do we know the Biological Effects?

Sources of knowledge about IR include the known examples of inadvertent human exposure from military, occupational, medical, experimental animal studies and experiments on mammalian cell cultures. Primary data for the LNT Hypothesis is information gathered following the bombings of Hiroshima and Nagasaki.

Acute Radiation Syndrome (ARS)



- The early (acute) effects of a single dose in excess of 1 Gy (1000 mSv) of X or gamma IR will be generalised, with vomiting, malaise, rapid pulse and fever.

- 5 - 10 Gy, untreated, is likely to give enough bone marrow damage to cause death from secondary/opportunistic infection after a few weeks.
- 10 - 50 Gy will cause rapid desquamation of the intestinal epithelium resulting in death within a few days from loss of fluid and dehydration.
- 50+ Gy will cause immediate massive damage to all soft tissues including the relatively radio-resistant central nervous system, death follows within a few hours.

Foetal Irradiation

Irradiation of a foetus with 100+ mSv has been shown to cause foetal development problems (a somatic effect) particularly in the central nervous system usually presenting as mental retardation.

It has also been suggested that foetal X-rays may contribute to later childhood cancers.

Foetal protection consists of restricting lower abdominal X-rays in women of reproductive capacity, particularly from 28 days from the start of the last menstrual peroid, after which foetal harm is possible. Central nervous system abnormality does not occur with IR before 8 weeks from the start of the last menstrual peroid. Total occupational exposure throughout a pregnancy must be limited to 2 mSv from the time of diagnosis by law.

Delayed Effects

Delayed deterministic effects of IR include skin atrophy and scarring, possible sterility, and arrest of growth of developing cartilage. Very large doses are required to cause these effects.

Late Effects

Lens cataracts are a possible late deterministic effect of IR.

Late stochastic effects are cancer and hereditary changes.

Cancer

High doses of IR are known to cause cancer in some organs. There has been controversy among experts over the risk of lower IR doses.

Risk Estimates for Radiation Induced Malignancies

Malignancy	**Risk Estimate** ***Cases*** per million (10mSv acute delivery)	**Mean Latency** Years
Leukaemia	15-25 30-50 for in utero exposure	5
Thyroid	50-150	20
Breast	50-200	23
Lung	50	25
Bone	2-5	25
Skin	Low – doses greater than 10Sv required	25
Other Organs	Low risk	
All Cancers (upper limit)	50 – 125 ***Deaths***	

Causes of Fatal Cancer

Cause	
Dietary	35%
Chemical Atmospheric Pollutants	25%
Other Environmental	20-30%
Spontaneous	10-20%
Background Radiation (Estimate based on LNT)	< 1%

For several reasons it is not possible to establish low dose effects with certainty. The ICRP has calculated the worst case risk of death from cancer at 40 persons per million per mSv for adults and 50 per million per mSv for the whole population (5×10^{-2} Sv^{-1}).
50 deaths per million is an increase of 0.005% on the natural cancer death rate in Australia of 25%

Hereditary Effects

No hereditary effects have been observed in humans, not even in the 75,000 children born to atomic bomb survivors. An increased incidence of leukaemia among children of nuclear workers in the UK was claimed to be caused by IR but the British High Court, after a long test case, ruled recently that there was no evidence for this.

Sterility

Sex	Dose to Gonads (Acute Delivery)	
	Temporary Sterility	**Permanent Sterility**
Male	300 mGy	6 Gy
Female	3 Gy	4 Gy

The hereditary risks, as derived from animal studies, are very uncertain. The doubling dose, that dose required to double the natural incidence of mutations of 6 - 10%, is considered to be about 1 Gy. The ICRP has calculated the overall risks, averaged over the whole population, to be 10 serious effects per million persons per mSv (1 X 10^{-2} Sv^{-1}).

Summary

- Effects relating to Natural and Occupational exposure levels are non deterministic and therefore statistical and inconclusive.
- Exposures in well managed, hygienic radiation handling areas should be well below the occupational limits.
- The most important non deterministic effect is the induction of cancer.
- It is estimated that exposure to 10 mSv of ionising radiation (acute delivery) increases the risk of death from cancer by 0.05%

THE EXTERNAL RADIATION HAZARD

The external radiation hazard arises from sources of radiation outside the body. When radioactive material actually gets inside the body it gives rise to an internal radiation hazard, which requires quite different methods of control.

Alpha radiation is not normally regarded as an external radiation hazard as it cannot penetrate the outer layers of the skin. The hazard may be due to beta, X, gamma or neutron radiation, all of which can penetrate to the sensitive organs of the body. The external hazard is controlled by applying the three principles: time, distance and shielding.

TIME

The dose accumulated by a person working in an area having a particular dose rate is directly proportional to the time that person spends in the area. Their dose can thus be controlled by limiting the time spent in the area:

i.e. Dose = dose rate x time

Example I The annual dose limit for radiation workers is 20 mSv per year which, assuming a 50 week working year, corresponds to 400 μSv per week. How many hours could a worker spend each week in an area in which the dose rate is 50 μSvh^{-1}?

Dose = dose rate x time

400 = 50 x *t*

t = *8* h

Example 2 If a radiation worker has to spend a full 40 h working week in a particular area, what is the maximum dose rate which can be allowed?

Dose = dose rate x time

400 = dose rate x 40

dose rate = 10 μSvh^{-1}

Example 3 The dose limit for individual members of the public is 1 mSv per year. What is the maximum dose rate permitted in an area which could be continuously occupied (i.e. 168 hours per week) by members of the public?

Answer 0.11 μSvh^{-1}

DISTANCE

Consider a point source of radiation which is emitting uniformly in all directions. The flux at a distance from a point source is inversely proportional to the square of the distance. Since the radiation dose rate is directly related to flux it follows that the dose rate also obeys the inverse square law. It should be noted that this is only strictly true for a point source, a point detector and negligible absorption of radiation between source and detector. When the absorber is air, no allowance is made for air absorption at close distances (i.e. a few metres) The inverse square law may be written:

$D_1 r_1^2 = D_2 r_2^2$

where D_1 is the dose rate at distance r_1 from the source and D_2 is the dose rate at distance r_2 from the source.

Example 4 The dose rate at 2 m from a particular gamma source is 400 μSvh^{-1}. At what distance will it give a dose rate of 10 μSvh^{-1}?

$$D_1 r_1^2 = D_2 r_2^2$$

$$400 \times 2^2 = 10 \times r_2^2$$

$$\text{therefore} \quad r_2^2 = 160$$

$$r_2 = 12.6 \text{ m}$$

SHIELDING

The third method of controlling the external radiation hazard is by means of shielding. Generally, this is the preferred method because it results in intrinsically safe working conditions, whilst reliance on distance or time of exposure may involve continuous administrative control over workers.

Shielding requirements are dictated by the dose rate which is acceptable in work areas; bearing in mind the occupancy factor in these areas and the dose constraints in operation by the organisation carrying out the work.

Alpha particles

Alpha particles are very easily absorbed. A thin sheet of paper is sufficient to stop alpha particles and their range in air is only a few tens of millimetres so they never present a shielding problem.

Beta radiation

Beta radiation is more penetrating than alpha radiation. In the energy range which is normally encountered (1-10 MeV), beta radiation requires shielding of up to I0 mm of perspex for complete absorption. The ease with which beta sources may be shielded sometimes leads to the erroneous impression that they are not as dangerous as gamma or neutron sources and large open beta sources are often handled directly. With certain types of beta sources this can be a dangerous practice. For instance, the absorbed dose rate at a distance of 3 mm from a beta source of 1 MBq is about 1 Gy/h. All high energy beta sources should always be handled remotely for this reason.

One important problem encountered when shielding against beta radiation concerns the emission of secondary X-rays, which result from the rapid slowing down of the beta particles. This X-radiation is known as *bremsstrahlung.* The fraction of beta energy reappearing as bremsstrahlung is approximately F = ZE/3000 where Z is the atomic number of the absorber and E is the beta energy (Emax) in MeV. This means that beta shields should be constructed of materials of low mass number (e.g. aluminium or perspex) to reduce the amount of bremsstrahlung emitted.

A beta source emits beta rays with energies covering the complete spectrum from zero up to a characteristic maximum energy, E_{max}. The mean beta energy is, in most cases, about 1/3 E_{max}. The penetrating power of beta particles depends on their energy. This fact can be used to estimate the energy of beta rays in order to aid identification of an unknown source.

Gamma and X-radiations

Gamma and X-radiations are attenuated exponentially when they pass through any material. The dose rate due to X or gamma radiation emerging from a shield can be written as:

$$D_1 = D_0 e^{-\mu}$$

where D_0 is the dose rate without shielding, D_1 is the dose rate after passing through a shield of thickness t, and μ is the linear absorption coefficient of the material of the shield

The linear absorption coefficient, u, is a function of the type of material used for the shield and also of the energy of the incident photons. It has the dimensions of (length) and is usually expressed in m^{-1} or mm^{-1}.

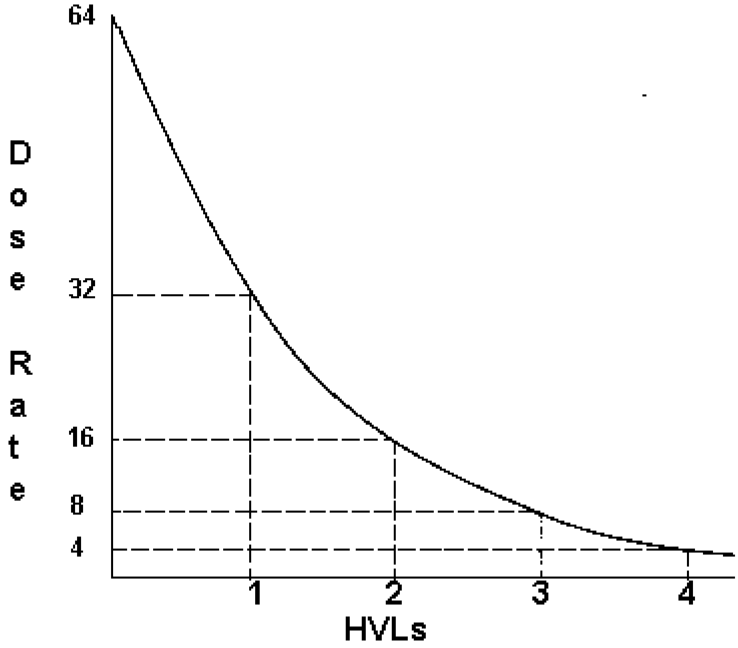
HALF-VALUE LAYER

The half thickness or half-value layer (HVL) for a particular shielding material is the thickness required to reduce the intensity to one half its incident value. The equation can be written as follows:

$$\mathbf{I = I_0/2^n}$$

Where n = the number of half value layers
I_0 = the unshielded dose rate
I = the shielded dose rate

The concept of half-value layer is very useful in doing rapid, approximate shielding calculations. One HVL reduces the intensity to one half, two HVLs reduces the intensity to one quarter, three HVLs to one eighth and so on as illustrated below.



It is very important to realise the significance of *energy* and *density* in quoting half value layers. At all times the density (or type of material) of the shield and the energy or radionuclide (implying a certain energy spectrum) must be quoted when referring to half value layers.

Hence a typical value would be stated thus:

1 HVL of *Lead* for ^{137}Cs = approx. 6.5 mm

NEUTRON SHIELDING

Neutron shielding is complicated by the very wide range of energies encountered. The most important reactions are:

Elastic scatter

Elastic scatter, in which the neutron collides with the target nucleus and bounces off it in a manner similar to the collision of two billiard balls. During the collision, the neutron loses some of its initial energy and this energy is transferred to the target nucleus. All of this transferred energy appears as kinetic energy of the target nucleus. Light elements are best for slowing down neutrons by elastic scatter and so materials with a high hydrogen content (such as paraffin, water, concrete) are used.

Inelastic scatter

Inelastic scatter, in this process the incoming neutrons impart some of their energy to the scattering material and excite the target nuclei. These target nuclei usually emit gamma radiation later when they return to their ground state. The inelastic scatter process is most important for heavy nuclei.

Neutron capture

Neutron capture reactions of many kinds, in these reactions neutrons are captured by nuclei which then de-excite by emitting another particle or photon. One very important neutron capture reaction is:

$$^{10}B(n,alpha)^{7}Li$$

The importance of this reaction, from a shielding point of view, lies in the fact that the emitted particle (an alpha) is very easily absorbed. Thus the incorporation of boron-10 in shields means that neutrons are absorbed and the resulting alpha particles cause no further shielding problems.

Unfortunately, the most common neutron capture reactions lead to the emission of penetrating gamma radiation, for example

$$^{58}Fe(n,gamma)^{59}Fe$$

Capture gamma radiation is usually a limitation in shield design and a material of high atomic number is often incorporated to absorb these capture gammas.

NEUTRON SOURCES

Apart from the production of neutrons by various methods are available for producing relatively small neutron sources. The most common types depend on the reaction:

$$^{9}Be(alpha,n)^{12}C$$

the a-particles being obtained from nuclides such as ^{241}Am or ^{226}Ra although ^{226}Ra neutron sources are not favoured because of the attendant gamma emissions. For Am/Be sources, the source strength is about 70 neutrons/MBq) of ^{241}Am. The spectrum of neutrons emitted from an alpha - beryllium source is not monoenergetic but is highly peaked at energies between 3 and 6 MeV. That is, these neutron sources produce mainly fast neutrons.

Another reaction used to produce neutrons is the photoneutron process, that is the (gamma, n) reaction. The most common type of photoneutron source consists of a mixture of equal volumes of antimony and beryllium, in which high energy X-rays from antimony - 124 interact with beryllium nuclei causing the ejection of neutrons. Neutrons produced by the (alpha, n) process are, for most practical purposes, monoenergetic

To calculate the flux at a distance r from a source of strength *Q,* the following expression is used:

$$F = Q/4r^2$$

Flux to equivalent dose rate conversion

For fast neutrons a flux of 10^5 neutrons/m^2/s ~ 25 μSvh^{-1} while for slow neutrons a flux of - 3 x I 0^6 n/m^2 /s ~25 μSvh^{-1}. These two approximate values for fast and slow neutrons are very useful in converting calculated neutron fluxes to equivalent dose rates.

Example 9 Calculate the dose equivalent rate at I m from a.0.1 TBq americium - beryllium source. 1 TBq ^{241}Am-Be emits 7x 10^7 n/s.
(Answer: 140 μSvh^{-1})

PERSONAL DOSE CONTROL

Routine control of personal dose is based on a system of area classification. Various systems and terminology's are in use, but there is a trend towards that recommended by the ICRP to segregate areas according to the radiological hazard. In areas where the exposure is unlikely to exceed one tenth of the dose limit for exposed workers, i.e. 2 mSv per year, no special arrangements are necessary.

Where workers could exceed this level of exposure, but are unlikely to exceed three-tenths of the dose limit, i.e. 6 mSv per year, ICRP suggests that this should be termed a *supervised area.* This would correspond to working condition B defined by ICRP Areas in which exposure could exceed three tenths of the dose limit, i.e. in which working condition A applies, are called *controlled areas.* Within these controlled areas there may be regions where further demarcation is required to avoid over-exposure. In some establishments these are called *restricted areas.*

A typical system of classification might consider four types of area:

Uncontrolled areas

in which the dose rate does not exceed 1.0 μSvh^{-1}. Personnel can work for 40 hours per week and 50 weeks per year without exceeding 2 mSv per year.

Supervised areas

in which the dose rate does not generally exceed 3 μSvh^{-1} and hence, in which personnel will not exceed three-tenths of the dose limit. As implied by the name, these areas are subject to some form of supervision, and personnel working regularly in such areas could be subject to routine personal monitoring.

Controlled areas

in which the dose rate exceeds 3 μSvh^{-1}. Personnel working regularly in controlled areas are designated as category A workers and are subject to medical supervision and routine personal monitoring.

Restricted areas

in which the dose rate exceeds 10 μSvh^{-1}. Access to these areas would be subject to special precautions, such as limitation of access time and the use of protective equipment and monitoring devices.

When operating a system of area classification it is necessary to survey the area regularly in order to confirm that the classification of the area is correct and that adequate precautions are being taken. In controlled and restricted areas, film badges or thermoluminescent dosimeter, (TLD) must be worn to measure the accumulated dose to the worker. In addition a direct reading dosimeter such as a quartz fibre electrometer, (QFE) or digital adding dosimeter, (DAD) may be worn to give more immediate information about accumulated dose. Readings from these latter devices are not to be taken as an official record of doses received by personnel as the devices do not conform to international standards of quality assurance.

SAFE TRANSPORT OF RADIOACTIVE MATERIALS

INTRODUCTION

Since the IAEA Transport Regulations forms the basis of all Australian States legislation for the safe transport of radioactive materials it may be helpful to review the broad requirements of these Regulations. Note that this discussion can only cover the subject very briefly and it is essential to refer to the Regulations for firm information.

The IAEA Transport Regulations are based on meeting four basic safety requirements:

(a) Adequate containment of the radioactive material

(b) Adequate shielding against the radiation emitted by the material

(c) The dissipation of the heat generated by high activity radioactive material

(d) Prevention of nuclear criticality when the material is fissile

When the above requirements are adequately met, radioactive materials can be safely transported as simply and conveniently as other potentially dangerous goods, if not more so. This is evidenced by the fact that there has been essentially complete safety achieved in the transport of radioactive materials throughout the world. No death or injury has occurred in over 25 years of transport that could be attributed to the radioactive nature of the materials being transported.

A further important requirement, which is particularly relevant to the transport of short-lived medical radioisotopes, is for consignments to be transported rapidly as well as safely. This means that they should be able to be handled as far as possible in the same way as non-dangerous goods, and by transport workers who have no specialised training or experience. To achieve this aim, it is important that the safety features of a radioactive package should be incorporated into the design of the package. The carrier should only be called upon to observe some simple rules for separating packages from undeveloped film and from persons, based on information on the label affixed to each package.

The method of meeting the four basis safety requirements as listed above for packages of radioactive materials will now be considered in turn.

CONTAINMENT

The toxicity of radionuclides varies by a factor of about 10^8 and so there is clearly a need for a number of packaging standards. Packages have therefore been divided into five main types of packaging: Type A, Type B, low specific activity, low level solid, and exempt.

Type A packaging is designed to withstand the normal transport conditions. In an accident, however, it is accepted that the containment may be breached and that some of the contents may escape. The maximum activity of each radionuclide which can be transported in a Type A package is therefore limited so that in the event of an accident, the risk to transport workers and members of the public will not be unacceptable. Calculations have been performed based on the radiotoxicity and the external radiation emitted by each individual radionuclide. Upper limits have been specified for the activities of materials in "special form" (A_1) and in non-special form (A_2) which may be transported in a Type A package. "Special form" material is defined as material that is indispersible because it is either a hard solid material or is contained in a sealed capsule. Prescribed tests must be passed in order for a material to qualify as special form. In general, the special form concept permits the inclusion of an activity greater than the A_2 value in a Type A package.

Type A Packaging must be capable of passing a prescribed series of tests which are intended to simulate the damage caused by driving rain and minor mishaps that would be encountered during rough handling of packages under normal transport conditions. The tests include a water spray test, a free drop test, a compression test and a penetration test. Type A packaging for liquid or gaseous materials, which are more dispersible for liquid or gaseous materials, which are more dispersible than solids, must be capable of passing additional tests including a 9 metre drop test. The approval of the competent authority is not required for Type A packages unless they contain fissile material.

Type B packaging is intended to retain adequate containment and shielding, even in the event of a severe accident such as a drop while loading, a vehicle or ship collision, derailment followed by impact with a bridge or other abutment, or an air to ground crash. There is therefore no regulatory upper limit for the activity that can be transported in a suitably designed Type B packaging.
Type B packaging must be capable of passing all the Type A tests. In addition, Type B packaging must pass a series of mechanical tests where the one specimen is:

- dropped onto a flat target from a height of 9 metres, and
- dropped onto the end of a circular metal bar from a height of one metre, and

- exposed to a temperature of 800^{o}C for 30 minutes.

A separate specimen must also be capable of passing a water immersion test where the specimen is immersed under a head of water of at least 15 metres for a period of not less than eight hours.

The design, and in some cases the shipment, of Type B packages requires the approval of the national competent authority because of the greater potential hazard of such packages as compared with Type A packages. Type B packages are subdivided into two groups, Type B (U) and Type B (M), depending on whether the package design is such as to warrant the approval of all competent authorities en route, i.e. Type B Multilateral, or whether the approval of the competent authority of the country of origin can reasonably be held binding on others, i.e. Type B Unilateral.

Type B(U) packages must meet a series of design criteria as specified in the IAEA Transport Regulations and must also require no operational controls during transport. Approval of the design of Type B (U) packages by the competent authority of the country of origin only is required. Type B (M) packages on the other hand do not meet all the above design criteria, or else require operational controls during transport. Approval of the design of Type B (M) packages, and for certain large shipments approval of the shipment, by the competent authorities of the country of origin and of all countries through or into which the package will be transported is required.

Low specific activity materials are materials which are regarded as inherently safe because their specific activity is so low that it is considered inconceivable that under any circumstances arising in transport a sufficient mass of material could be taken into the body to give rise to a significant radiation dose. Uranium and thorium ores and their concentrates are an example of low specific activity materials. Low specific activity materials can be transported either in bulk as a full load, or in commercial packages which meet less stringent requirements than those for Type A packages.

Low level solid radioactive materials represent an extension of the low specific activity material concept to include certain types of consignments of low and medium level radioactive wastes. Such materials are not inherently safe and so must be transported in strong industrial packaging under full load conditions.
Exempt items consist of small quantities of radioactive materials, such as samples and radioactive components of instruments and articles which have a low potential hazard. These items are free from most regulatory requirements.

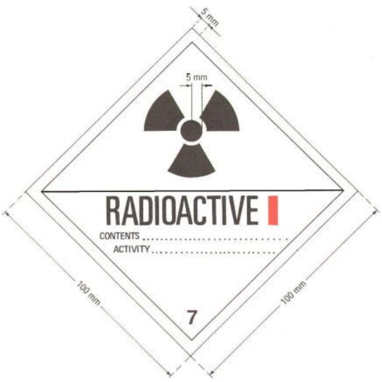
SHIELDING

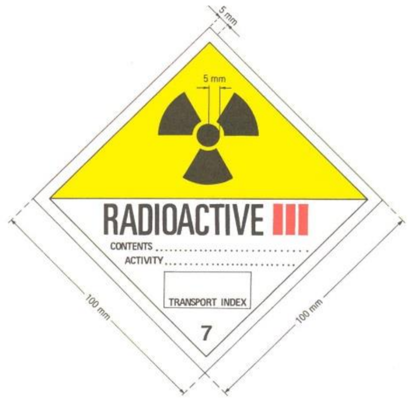
All packages are classified into three categories based on the external radiation at the surface of the package and at a distance of 1 metre from the surface. The radiation level (mrem h^{-1}) at a distance of 1 metre from the surface of the package is referred to as the transport index. The three categories are as follows:

Category I White	Radiation level at surface <5 μSv h^{-1} Package not Fissile Class II or Class III
Category II Yellow	Radiation level at surface between 5 and 500 μSvh-1 Transport index < 1.0 Package not Fissile Class III.
Category III Yellow	Radiation level at surface between 500 and 2000 μSvh-1 Transport index < 10.

The above surface radiation levels have been adopted on the basis of safe operating experience. The level of 5μSv h^{-1} for Category I - White packages for example was determined on the basis that an exposure of 100 μSv is the maximum that could be accepted for undeveloped photographic film. It has been assumed that 24 hours would be the longest period for which boxes of such film would be close to packages of radioactive material during transport. Category I - White packages can therefore be handled and transported with no requirements for segregation from persons or film.

The above radiation categories are identified with three defined labels as illustrated in the IAEA Transport Regulations. On the Category II - Yellow and Category III - Yellow labels it is important that the transport index be inserted on the label. The transport index is used to control the number of packages which can be grouped together in order to ensure that the external radiation level from a group of packages does not exceed safe levels and also as a criticality control device.





Higher external radiation levels are allowable on the external surface of a package when it is transported under full load conditions. That is: for a load from a single consignor having the sole use of a vehicle and in respect of which all initial, intermediate and final loading and unloading is carried out in accordance with the directions of the consignor or consignee.

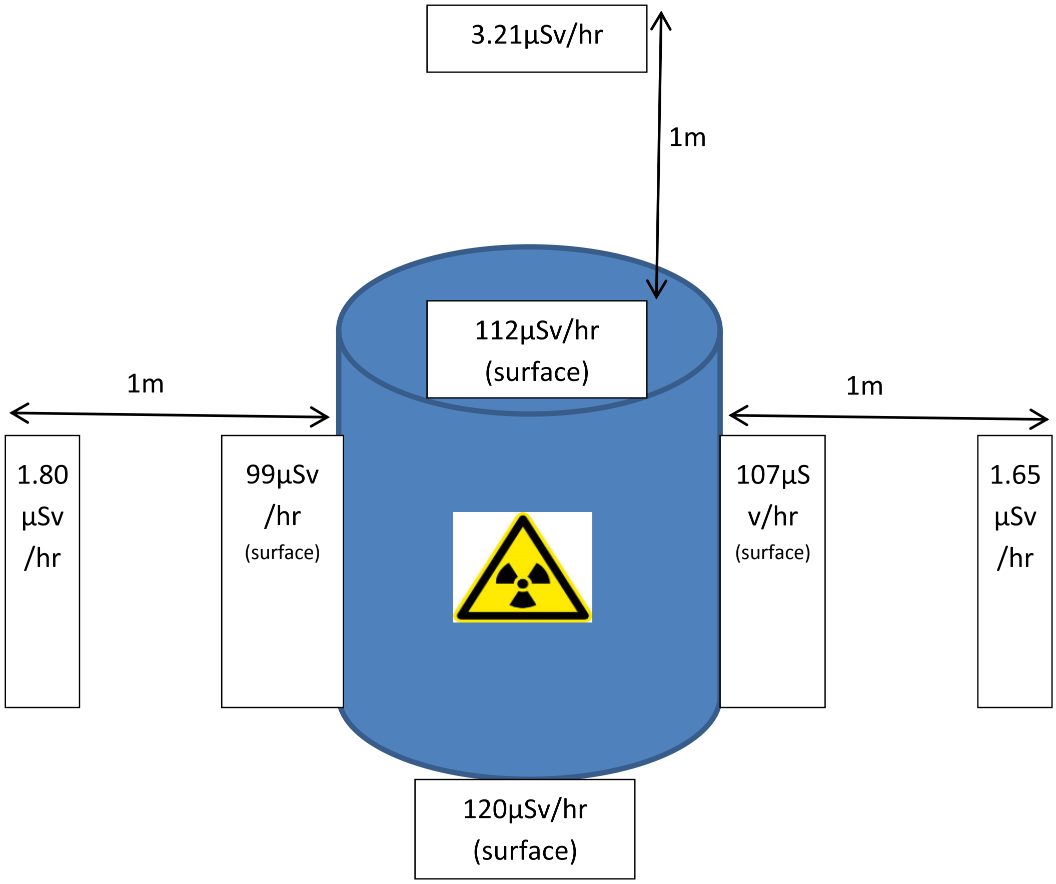
Similar provisions also exist for identifying freight containers with Category I - White, Category II - Yellow and Category III Yellow labels.

TRANSPORT INDEX (TI)

TI = The Dose Rate in mSv per hour @ 1m from the surface of the package × 100 (or µSv per hr @ 1m ÷10)

TI For criticality control = N/50 where N is:

- one fifth of the no. of packages which would remain sub -critical when stacked in any arrangement and surrounded by water AND
- one half of the no. of packages which would remain sub -critical when stacked in any way separated by and surrounded by the most effective moderator available



TI = The Dose Rate in µS v per hour at 1m from the surface of the package ÷10

TI = 3.21µSv.h-1 @1m ÷10

TI = 0.321

Max surface dose rate = 120 µSv.h-1 (Between 5µSv.h-1 and 500µSv.h-1)

Therefore Category II – Yellow

DISSIPATION OF HEAT

Some Type B packages give off heat as a result of radiation being absorbed in the shielding of the package and converted to heat energy. The heat must be dissipated in such a way that it does not damage the containment and shielding characteristics of the package and also so that the temperature of the outer surface of the package does not rise to such a level that the package could burn people or damage nearby goods during transport.

The IAEA Transport Regulations prescribe that the temperature of the accessible surfaces of a Type B (U) package shall not exceed 50^{o}C in the shade (to prevent damage to nearby goods) except under full load conditions, in which case the maximum temperature shall not exceed 82^{o}C in the shade (to prevent burning people) under normal conditions of transport. Provided the average surface heat flux does not exceed 15 watts/m^2 and the surrounding cargo is not in sacks or bags, Type A, Type B (U) or Type B(M) packages may normally be carried among packaged general cargo without any special stowage provisions.

PREVENTION OF CRITICALITY

The IAEA Regulations require that all fissile materials, apart from exempt quantities, shall be packaged and transported in such a manner that criticality cannot be reached under any foreseeable circumstances of transport. In order to achieve this situation, packages for transporting fissile materials are divided into three types: Fissile Class I, Class II and Class III.

Fissile Class I packages "are nuclearly safe in any number and in any arrangement under all foreseeable circumstances of transport". The package design may require unilateral or multilateral competent authority approval, but because no operational controls in respect of fissile properties are required during transport, no approval of individual shipment is required.

Fissile Class II packages "in limited numbers are nuclearly safe in any arrangement under all foreseeable circumstances of transport". The transport index of the package provides a convenient method of limiting the number of Fissile Class II packages which can be grouped together. For Fissile Class II and III packages only, the transport index of the package is defined as the larger of either the number expressing the maximum radiation level in μSv/h ÷ 10 at a distance of one metre from the surface of the package, or the number obtained by dividing 50 by the "allowable number" of such packages.

50 is the maximum number of transport indices which can be carried together in a group except under full load conditions. The package design may require unilateral or multilateral competent authority approval, but individual shipments do not require competent authority approval.

Fissile Class III packages "are nuclearly safe under all foreseeable circumstances of transport by reason of special precautions, or special administrative of operational controls imposed upon the transport of the consignment. As for Fissile Class II packages, the transport index is used to control the number of packages carried together. The package design may require unilateral or multilateral approval, but because of the operational controls required during transport, multilateral competent authority approval of each shipment is required.

RPS 2 - Safe Transport of Radioactive Materials - Carrier requirements

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SCOPE

109. For *radioactive material* having subsidiary risks, and for transport of *radioactive material* with other dangerous goods, the relevant transport regulations for dangerous goods of each of the countries through or into which the material is to be transported shall apply in addition to these Regulations.

RADIATION PROTECTION

301. Doses to persons shall be below the relevant dose limits. Protection and safety shall be optimized in order that the magnitude of individual doses, the number of persons exposed, and the likelihood of incurring exposure shall be kept as low as reasonably achievable, economic and social factors being taken into account, within the restriction that the doses to individuals be subject to dose constraints. A structured and systematic approach shall be adopted and shall include consideration of the interfaces between transport and other activities.

302. A *Radiation Protection Programme* shall be established for the transport of *radioactive material*. The nature and extent of the measures to be employed in the programme shall be related to the magnitude and likelihood of radiation exposures. The programme shall incorporate the requirements of paras 301,

303_305 and 311. Programme documents shall be available, on request, for inspection by the relevant *competent authority*.

303. For occupational exposures arising from transport activities, where it is assessed that the effective dose:

(a) Is likely to be between 1 and 6 mSv in a year, a dose assessment programme via workplace monitoring or individual monitoring shall be conducted;

(b) Is likely to exceed 6 mSv in a year, individual monitoring shall be conducted.
When individual monitoring or workplace monitoring is conducted, appropriate records shall be kept.

EMERGENCY RESPONSE

304. In the event of accidents or incidents during the transport of *radioactive material*, emergency provisions, as established by relevant national and/or international organizations, shall be observed to protect persons, property and the environment. Appropriate guidelines for such provisions are contained in Ref. [4].

305. Emergency procedures shall take into account the formation of other dangerous substances that may result from the reaction between the contents of a *consignment* and the environment in the event of an accident.

QUALITY ASSURANCE

306. *Quality assurance* programmes based on international, national or other standards acceptable to the *competent authority* shall be established and implemented for the design, manufacture, testing, documentation, use, maintenance and inspection of all *special form radioactive material*, *low dispersible radioactive material* and *packages* and for transport and in-transit storage operations to ensure compliance with the relevant provisions of these Regulations. Certification that the *design* specification has been fully implemented shall be available to the *competent authority*. The manufacturer, *consignor* or user shall be prepared to provide facilities for *competent authority* inspection during manufacture and use and to demonstrate to any cognizant *competent authority* that:

(a) The manufacturing methods and materials used are in accordance with the approved design specifications; and

(b) All packagings are periodically inspected and, as necessary, repaired and maintained in good condition so that they continue to comply with all relevant requirements and specifications, even after repeated use.

Where *competent authority approval* is required, such *approval* shall take into account and be contingent upon the adequacy of the *quality assurance* programme.

309. In the event of non-compliance with any limit in these Regulations applicable to *radiation level* or *contamination*:

(a) The consignor shall be informed of the non-compliance by:

(i) The carrier if the non-compliance is identified during transport; or

(ii) The consignee if the non-compliance is identified at receipt;

(b) The carrier, consignor or consignee, as appropriate, shall:

(i) Take immediate steps to mitigate the consequences of the noncompliance;

(ii) Investigate the non-compliance and its causes, circumstances and consequences;

(iii) Take appropriate action to remedy the causes and circumstances that led to the non-compliance and to prevent a recurrence of circumstances similar to those that led to the non-compliance; and

(iv) Communicate to the relevant competent authority(ies) on the causes of the non-compliance and on corrective or preventive actions taken or to be taken; and

(c) The communication of the non-compliance to the consignor and relevant competent authority(ies), respectively, shall be made as soon as practicable and it shall be immediate whenever an emergency exposure situation has developed or is developing.

SPECIAL ARRANGEMENT

310. *Consignments* for which conformity with the other provisions of these Regulations is impracticable shall not be transported except under *special arrangement*. Provided the *competent authority* is satisfied that conformity with the other provisions of these Regulations is impracticable and that the requisite standards of safety established by these Regulations have been demonstrated through means alternative to the other provisions, the *competent authority* may approve *special arrangement* transport operations for single or a planned series of multiple *consignments*. The overall level of safety in transport shall be at least equivalent to that which would be provided if all the applicable requirements had been met. For *consignments* of this type, *multilateral approval* shall be required.

TRAINING

311. Workers shall receive appropriate training concerning radiation protection including the precautions to be observed in order to restrict their occupational exposure and the exposure of other persons who might be affected by their actions.

312. Persons engaged in the transport of *radioactive material* shall receive training in the contents of these Regulations commensurate with their responsibilities.

313. Individuals such as those who classify *radioactive material*; pack *radioactive material*; mark and label *radioactive material*; prepare transport documents for *radioactive material*; offer or accept *radioactive material* for transport; carry or handle *radioactive material* in transport; mark or placard or load or unload packages of *radioactive material* into or from transport *vehicles*, bulk *packagings* or *freight containers*; or are otherwise directly involved in the transport of *radioactive material* as determined by the *competent authority*; shall receive the following training:

(a) General awareness/familiarization training:

(i) Each person shall receive training designed to provide familiarity with the general provisions of these Regulations;

(ii) Such training shall include a description of the categories of radioactive material; labelling, marking, placarding and packaging and segregation requirements; a description of the purpose and content of the radioactive material transport document; and a description of available emergency response documents;

(b) Function specific training: Each person shall receive detailed training concerning specific radioactive material transport requirements which are applicable to the function that person performs; (c) Safety training: Commensurate with the risk of exposure in the event of a release and the functions performed, each person shall receive training on:

(i) Methods and procedures for accident avoidance, such as proper use of package handling equipment and appropriate methods of stowage of radioactive material;

(ii) Available emergency response information and how to use it;

(iii) General dangers presented by the various categories of radioactive material and how to prevent exposure to those hazards, including if appropriate the use of personal protective clothing and equipment; and

(iv) Immediate procedures to be followed in the event of an unintentional release of radioactive material, including any emergency response procedures for which the person is responsible and personal protection procedures to be followed.

314. The training required in para. 313 shall be provided or verified upon employment in a position involving *radioactive material* transport and shall be periodically supplemented with retraining as deemed appropriate by the *competent authority*.

TRANSPORT OF OTHER GOODS

503. A *package* shall not contain any items other than those that are necessary for the use of the *radioactive material.* The interaction between these items and the *package*, under the conditions of transport applicable to the *design*, shall not reduce the safety of the *package*.

504. *Tanks* and *intermediate bulk containers* used for the transport of *radioactive material* shall not be used for the storage or transport of other goods unless decontaminated to below the level of 0.4 Bq/cm2 for beta and gamma emitters and *low toxicity alpha emitters* and 0.04 Bq/cm2 for all other alpha emitters.

505. The transport of other goods with *consignments* being transported under *exclusive use* shall be permitted provided the arrangements are controlled only by the *consignor* and it is not prohibited by other regulations.

506. *Consignments* shall be segregated from other dangerous goods during transport in compliance with the relevant transport regulations for dangerous goods of each of the countries through or into which the materials will be transported, and, where applicable, with the regulations of the cognizant transport organizations, as well as these Regulations.

OTHER DANGEROUS PROPERTIES OF CONTENTS

507. In addition to the radioactive and fissile properties, any other dangerous properties of the contents of the *package*, such as explosiveness, flammability, pyrophoricity, chemical toxicity and corrosiveness, shall be taken into account in the packing, labelling, marking, placarding, storage and transport in order to be in compliance with the relevant transport regulations for dangerous goods of each of the countries through or into which the materials will be transported, and, where applicable, with the regulations of the cognizant transport organizations, as well as these Regulations.

REQUIREMENTS AND CONTROLS FOR CONTAMINATION AND FOR LEAKING PACKAGES

508. The *non-fixed contamination* on the external surfaces of any *package* shall be kept as low as practicable and, under routine conditions of transport, shall not exceed the following limits:

(a) 4 Bq/cm2 for beta and gamma emitters and low toxicity alpha emitters, and

(b) 0.4 Bq/cm2 for all other alpha emitters.

These limits are applicable when averaged over any area of 300 cm2 of any part of the surface.

509. Except as provided in para. 514, the level of *non-fixed contamination* on the external and internal surfaces of *overpacks*, *freight containers*, *tanks*, *intermediate bulk containers* and *conveyances* shall not exceed the limits specified in para. 508.

510. If it is evident that a *package* is damaged or leaking, or if it is suspected that the *package* may have leaked or been damaged, access to the *package* shall be restricted and a qualified person shall, as soon as possible, assess the extent of *contamination* and the resultant *radiation level* of the *package*. The scope of the assessment shall include the *package*, the *conveyance*, the adjacent loading and unloading areas, and, if necessary, all other material which has been carried in the *conveyance*. When necessary, additional steps for the protection of persons, property and the environment, in accordance with provisions established by the relevant *competent authority*, shall be taken to overcome and minimize the consequences of such leakage or damage.

511. *Packages* which are damaged or leaking *radioactive contents* in excess of allowable limits for normal conditions of transport may be removed to an acceptable interim location under supervision, but shall not be forwarded until repaired or reconditioned and decontaminated.

512. A *conveyance* and equipment used regularly for the transport of *radioactive material* shall be periodically checked to determine the level of *contamination*. The frequency of such checks shall be related to the likelihood of *contamination* and the extent to which *radioactive material* is transported.

513. Except as provided in para. 514, any *conveyance*, or equipment or part thereof which has become contaminated above the limits specified in para. 508 in the course of the transport of *radioactive material*, or which shows a *radiation level* in excess of 5 μSv/h at the surface, shall be decontaminated as soon as possible by a qualified person and shall not be re-used unless the *non-fixed contamination* does not exceed the limits specified in para. 508 and the *radiation level* resulting from the *fixed contamination* on surfaces after decontamination is less than 5 μSv/h at the surface.

514. A *freight container, tank, intermediate bulk container* or *conveyance* dedicated to the transport of unpackaged *radioactive material* under *exclusive use* shall be excepted from the requirements of paras 509 and 513 solely with regard to its internal surfaces and only for as long as it remains under that specific *exclusive use*.

523. *LSA material* and *SCO* in groups *LSA-I* and *SCO-I* may be transported unpackaged under the following conditions:

(a) All unpackaged material other than ores containing only naturally occurring radionuclides shall be transported in such a manner that under routine conditions of transport there will be no escape of the radioactive contents from the conveyance nor will there be any loss of shielding;

(b) Each conveyance shall be under exclusive use, except when only transporting SCO-I on which the contamination on the accessible and the inaccessible surfaces is not greater than ten times the applicable level specified in para. 214; and

TABLE 4. INDUSTRIAL PACKAGE REQUIREMENTS FOR LSA MATERIAL AND SCO

Radioactive contents	***Industrial package type***	
	Exclusive use	**Not under *exclusive use***
LSA-I		
Solid[a]	*Type IP-1*	*Type IP-1*
Liquid	*Type IP-1*	*Type IP-2*
LSA-II		
Solid	*Type IP-2*	*Type IP-2*
Liquid and gas	*Type IP-2*	*Type IP-3*
LSA-III	*Type IP-2*	*Type IP-3*
SCO-I[a]	*Type IP-1*	*Type IP-1*
SCO-II	*Type IP-2*	*Type IP-2*

[a] Under the conditions specified in para. 523, *LSA-I material* and *SCO-I* may be transported unpackaged.

(c) For SCO-I where it is suspected that non-fixed contamination exists on inaccessible surfaces in excess of the values specified in para. 241(a)(i), measures shall be taken to ensure that the radioactive material is not released into the conveyance.

525. The total activity in a single hold or compartment of an inland watercraft, or in another *conveyance*, for carriage of *LSA material* or *SCO* in *Type IP-1*, *Type IP-2*, *Type IP-3* or unpackaged, shall not exceed the limits shown in Table 5.

DETERMINATION OF TRANSPORT INDEX

526. The *transport index (TI)* for a *package*, *overpack* or *freight container*, or for unpackaged *LSA-I* or *SCO-I*, shall be the number derived in accordance with the following procedure:

TABLE 5. CONVEYANCE ACTIVITY LIMITS FOR LSA MATERIAL AND SCO IN INDUSTRIAL PACKAGES OR UNPACKAGED

Nature of material	Activity limit for *conveyances* other than by inland waterway	Activity limit for a hold or compartment of an inland watercraft
LSA-I	No limit	No limit
LSA-II and *LSA-III* non-combustible solids	No limit	100*A2*
LSA-II and *LSA-III* combustible solids, and all liquids and gases	100*A2*	10*A2*
SCO	100*A2*	10*A2*

(a) Determine the maximum radiation level in units of millisieverts per hour (mSv/h) at a distance of 1 m from the external surfaces of the package, overpack, freight container or unpackaged LSA-I and SCO-I. The value determined shall be multiplied by 100 and the resulting number is the transport index. For uranium and thorium ores and their concentrates, the maximum radiation level at any point 1 m from the external surface of the load may be taken as:

(i) 0.4 mSv/h for ores and physical concentrates of uranium and thorium;

(ii) 0.3 mSv/h for chemical concentrates of thorium;

(iii) 0.02 mSv/h for chemical concentrates of uranium, other than uranium hexafluoride.

(b) For tanks, freight containers and unpackaged LSA-I and SCO-I, the value determined in step (a) above shall be multiplied by the appropriate factor from Table 6.

(c) The value obtained in steps (a) and (b) above shall be rounded up to the first decimal place (e.g. 1.13 becomes 1.2), except that a value of 0.05 or less may be considered as zero.

527. The *transport index* for each *overpack*, *freight container* or *conveyance* shall be determined as either the sum of the *TI*s of all the *packages* contained, or by direct measurement of *radiation level*, except in the case of non-rigid *overpacks*, for which the *transport index* shall be determined only as the sum of the *TI*s of all the *packages*.

CATEGORIES

533. *Packages* and *overpacks* shall be assigned to either category I-WHITE, II-YELLOW or III-YELLOW in accordance with the conditions specified in Table 7 and with the following requirements:

(c) If the surface radiation level is greater than 2 mSv/h, the package or overpack shall be transported under exclusive use and under the provisions of paras 573(a), 575 or 579, as appropriate.

TABLE 7. CATEGORIES OF PACKAGES AND OVERPACKS

Conditions		**Category**
Transport index	**Maximum *radiation level* at any point on external surface**	
0[a]	Not more than 0.005 mSv/h	I-WHITE
More than 0 but not more than 1[a]	More than 0.005 mSv/h but not more than 0.5 mSv/h	II-YELLOW
More than 1 but not more than 10	More than 0.5 mSv/h but not more than 2 mSv/h	III-YELLOW
More than 10	More than 2 mSv/h but not more than 10 mSv/h	III-YELLOW[b]

[a] If the measured *TI* is not greater than 0.05, the value quoted may be zero in accordance with para. 526(c).

[b] Shall also be transported under *exclusive use*.

541. Where *LSA-I* or *SCO-I material* is contained in receptacles or wrapping materials and is transported under *exclusive use* as permitted by para. 523, the outer surface of these receptacles or wrapping materials may bear the marking 'RADIOACTIVE LSA-I' or 'RADIOACTIVE SCO-I' as appropriate.

LABELLING

542. Each package, overpack and freight container shall bear the labels which conform to the models in Fig. 2, Fig. 3 or Fig. 4, except as allowed under the alternative provisions of para. 547 for large freight containers and tanks, according to the appropriate category. In addition, each package, overpack and freight container containing fissile material, other than fissile material excepted under the provisions of para. 672, shall bear labels which conform to the model in Fig. 5. Any labels which do not relate to the contents shall be removed or covered. For radioactive material having other dangerous properties see para. 507.

543. The labels conforming to the models in Fig. 2, Fig. 3 and Fig. 4 shall be affixed to two opposite sides of the outside of a *package* or *overpack* or on the outside of all four sides of a *freight container* or *tank*. The labels conforming to the model in Fig. 5, where applicable, shall be affixed adjacent to the labels conforming to the models in Fig. 2, Fig. 3 and Fig. 4. The labels shall not cover the markings specified in paras 535–540.

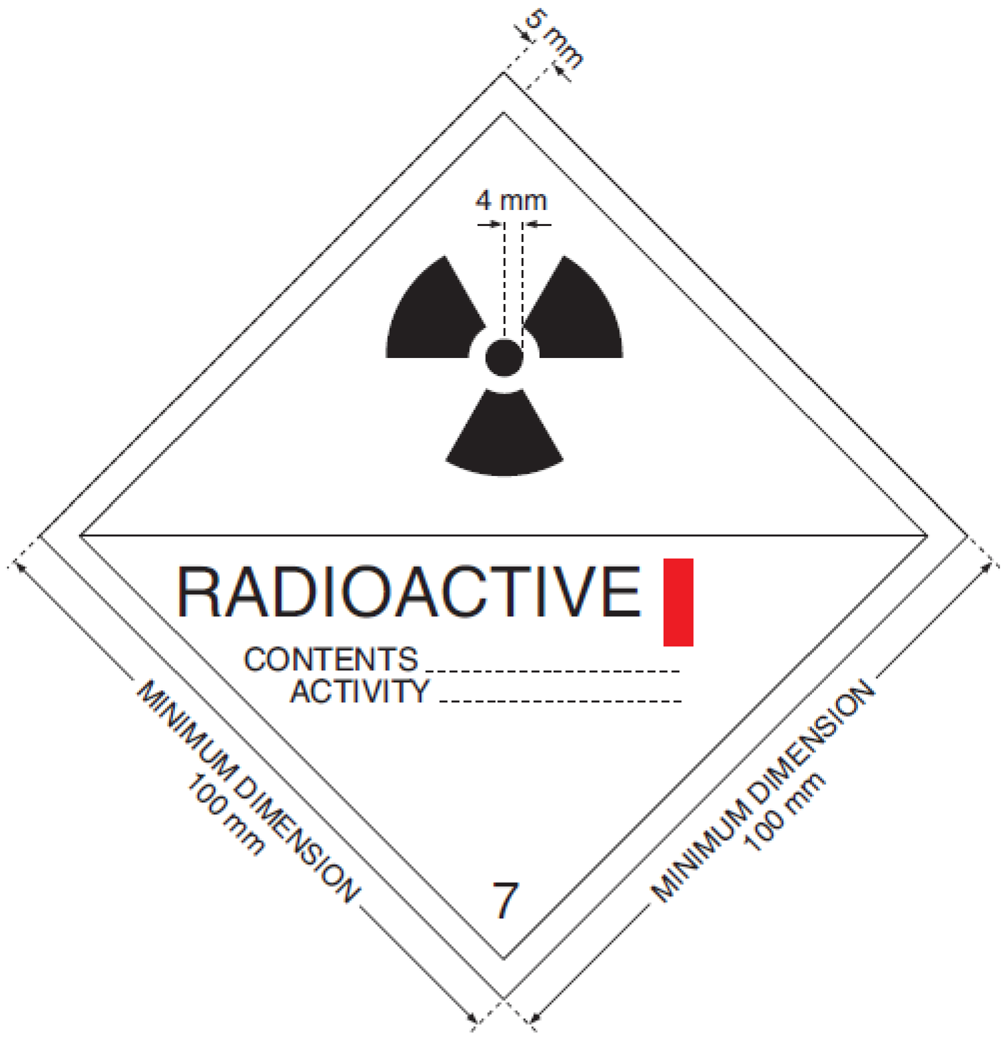


FIG. 2. Category I-WHITE label. The background colour of the label shall be white, the colour of the trefoil and the printing shall be black, and the colour of the category bar shall be red.

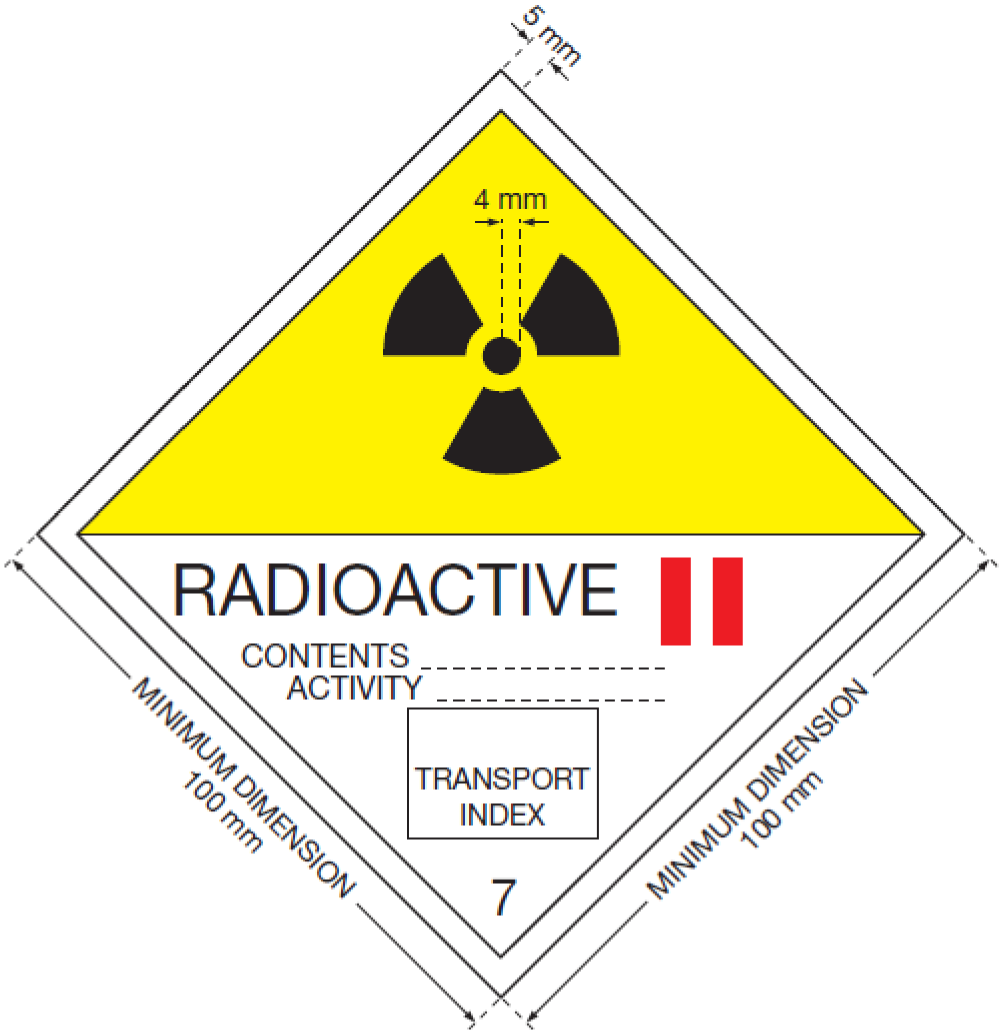


FIG. 3. Category II-YELLOW label. The background colour of the upper half of the label shall be yellow and the lower half white, the colour of the trefoil and the printing shall be black, and the colour of the category bars shall be red.

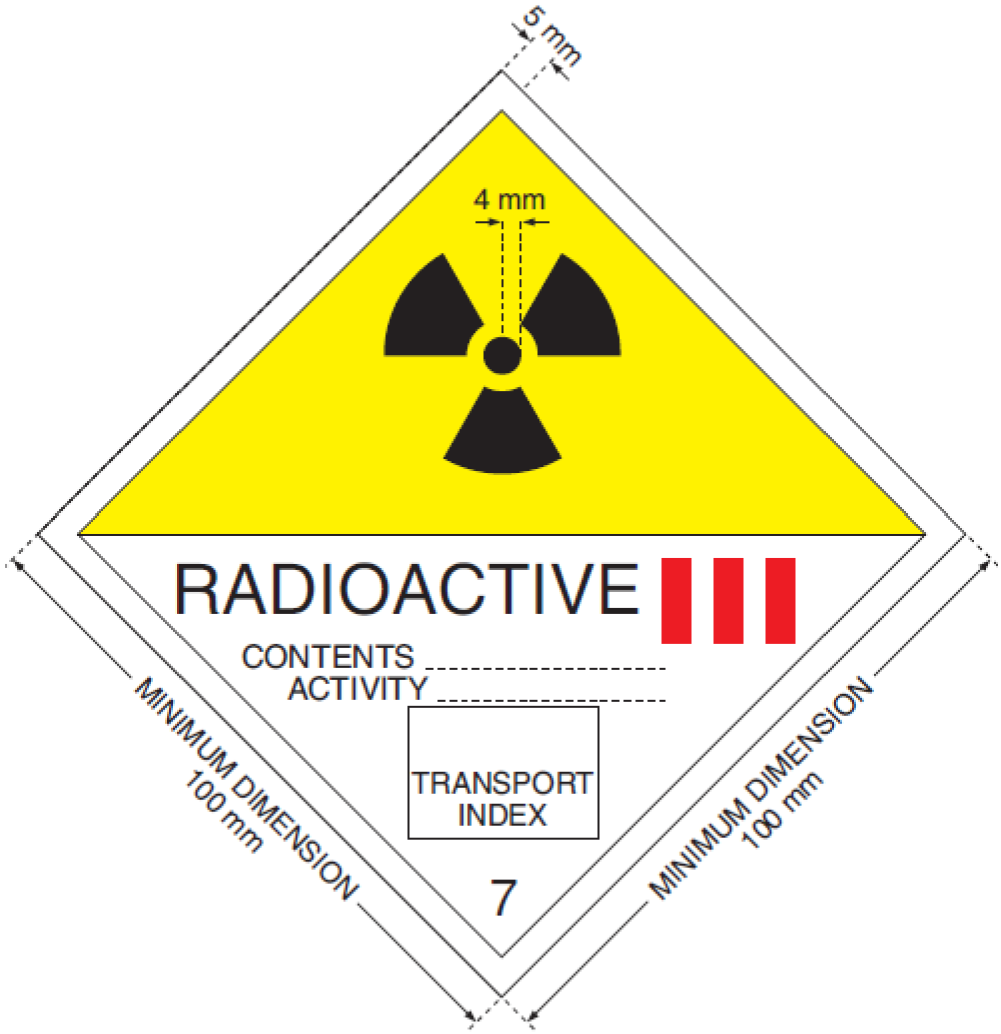


FIG. 4. Category III-YELLOW label. The background colour of the upper half of the label shall be yellow and the lower half white, the colour of the trefoil and the printing shall be black, and the colour of the category bars shall be red.

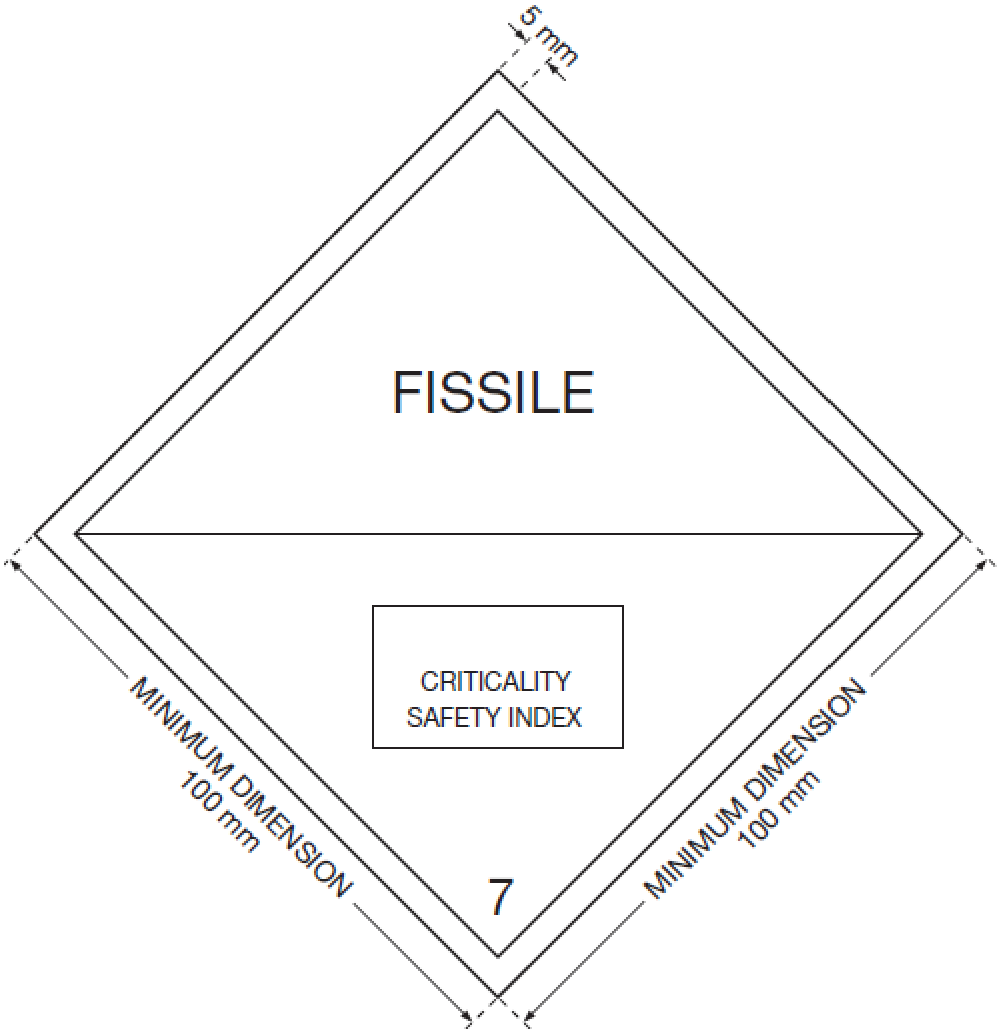


FIG. 5. Criticality safety index label. The background colour of the label shall be white, the colour of the printing shall be black.

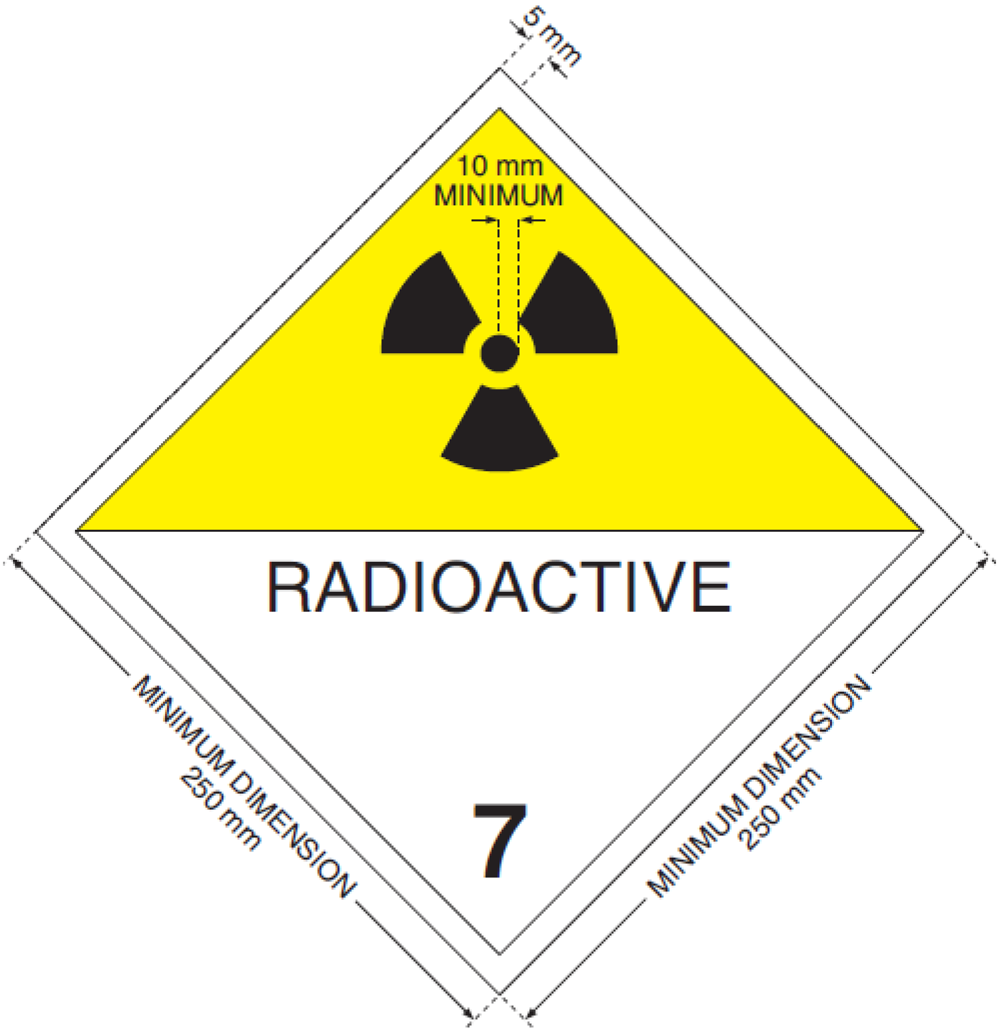


FIG. 6. Placard. Except as permitted by para. 571 minimum dimensions shall be as shown; when different dimensions are used the relative proportions must be maintained. The number '7' shall not be less than 25 mm high. The background colour of the upper half of the placard shall be yellow and of the lower half white, the colour of the trefoil and the printing shall be black. The use of the word "RADIOACTIVE" in the bottom half is optional to allow the alternative use of this placard to display the appropriate United Nations number for the consignment.

LABELLING FOR RADIOACTIVE CONTENTS

544. Each label conforming to the models in Fig. 2, Fig. 3 and Fig. 4 shall be completed with the following information:

(a) Contents:

(i) Except for LSA-I material, the name(s) of the radionuclide(s) as taken from Table 1, using the symbols prescribed therein. For mixtures of radionuclides, the most restrictive nuclides must be listed to the extent the space on the line permits. The group of LSA or SCO shall be shown following the name(s) of the radionuclide(s). The terms “LSA-II”, “LSA-III”, “SCO-I” and “SCO-II” shall be used for this purpose.

(ii) For LSA-I material, the term “LSA-I” is all that is necessary; the name of the radionuclide is not necessary.

(b) Activity: The maximum activity of the radioactive contents during transport expressed in units of becquerels (Bq) with the appropriate SI prefix symbol (see Annex II). For fissile material, the mass of fissile material in units of grams (g), or multiples thereof, may be used in place of activity.

(c) For overpacks and freight containers the “contents” and “activity” entries on the label shall bear the information required in paras 544(a) and 544(b), respectively, totalled together for the entire contents of the overpack or freight container except that on labels for overpacks or freight containers containing mixed loads of packages containing different radionuclides, such entries may read “See Transport Documents”.

(d) Transport index: See paras 526 and 527. (No transport index entry is required for category I-WHITE.)

PLACARDING

547. Large *freight containers* carrying *packages* other than *excepted packages*, and *tanks*, shall bear four placards which conform to the model given in Fig. 6.
The placards shall be affixed in a vertical orientation to each side wall and each end wall of the large *freight container* or *tank*. Any placards which do not relate to the contents shall be removed. Instead of using both labels and placards, it is permitted as an alternative to use enlarged labels only, where appropriate, as shown in Fig. 2, Fig. 3, Fig. 4 and Fig. 5, with dimensions of the minimum size shown in Fig. 6.

548. Where the *consignment* in the *freight container* or *tank* is unpackaged *LSA-I* or *SCO-I* or where an *exclusive use consignment* in a *freight container* is packaged *radioactive material* with a single United Nations number, the appropriate United Nations number for the *consignment* (see Table 8) shall also be displayed, in black digits not less than 65 mm high, either:

(a) in the lower half of the placard shown in Fig. 6 and against the white background, or

(b) on the placard shown in Fig. 7.

When the alternative given in (b) above is used, the subsidiary placard shall be affixed immediately adjacent to the main placard, on all four sides of the freight container or tank.

TRANSPORT AND STORAGE IN TRANSIT - SEGREGATION DURING TRANSPORT AND STORAGE IN TRANSIT

563. *Packages*, *overpacks* and *freight containers* containing *radioactive material* and unpackaged *radioactive material* shall be segregated during transport and during storage in transit:

(a) From workers in regularly occupied working areas by distances calculated using a dose criterion of 5 mSv in a year and conservative model parameters;

(b) From members of the critical group of the public, in areas where the public has regular access, by distances calculated using a dose criterion of 1 mSv in a year and conservative model parameters;

(c) From undeveloped photographic film by distances calculated using a radiation exposure criterion for undeveloped photographic film due to the transport of radioactive material of 0.1 mSv per consignment of such film; and

(d) From other dangerous goods in accordance with para. 506.

564. Category II-YELLOW or III-YELLOW *packages* or *overpacks* shall not be carried in compartments occupied by passengers, except those exclusively reserved for couriers specially authorized to accompany such *packages* or *overpacks*.

STOWAGE DURING TRANSPORT AND STORAGE IN TRANSIT

565. *Consignments* shall be securely stowed.

566. Provided that its average surface heat flux does not exceed 15 W/m2 and that the immediately surrounding cargo is not in sacks or bags, a *package* or *overpack* may be carried or stored among packaged general cargo without any special stowage provisions except as may be specifically required by the *competent authority* in an applicable approval certificate.

567. Loading of *freight containers* and accumulation of *packages*, *overpacks* and *freight containers* shall be controlled as follows:

(a) Except under the condition of exclusive use, and for consignments of LSA-I material, the total number of packages, overpacks and freight containers aboard a single conveyance shall be so limited that the total sum of the transport indexes aboard the conveyance does not exceed the values shown in Table 9.

(b) The radiation level under routine conditions of transport shall not exceed 2 mSv/h at any point on, and 0.1 mSv/h at 2 m from, the external surface of the conveyance, except for consignments transported under exclusive use by road or rail, for which the radiation limits around the vehicle are set forth in paras 573(b) and (c).

TABLE 9. TI LIMITS FOR FREIGHT CONTAINERS AND CONVEYANCES NOT UNDER EXCLUSIVE USE

Type of *freight container* or *conveyance*	**Limit on total sum of *transport indexes* in a *freight container* or aboard a *conveyance***
Freight container — Small	50
Freight container — Large	50
Vehicle	50
Aircraft	
Passenger	50
Cargo	200
Inland waterway *vessel*	50
Seagoing *vessel*[a] (1) Hold, compartment or defined deck area: Packages, overpacks, small *freight containers*	50
Large *freight containers*	200
(2) Total *vessel*: *Packages*, *overpacks*, small *freight containers*	200
Large *freight containers*	No Limit

[a] *Packages* or *overpacks* carried in or on a *vehicle* which are in accordance with the provisions of para. 573 may be transported by *vessels* provided that they are not removed from the *vehicle* at any time while on board the *vessel*.

(c) The total sum of the criticality safety indexes in a freight container and aboard a conveyance shall not exceed the values shown in Table 10.

568. Any *package* or *overpack* having a *transport index* greater than 10, or any *consignment* having a *criticality safety index* greater than 50, shall be transported only under *exclusive use*.

SEGREGATION OF PACKAGES CONTAINING FISSILE MATERIAL DURING TRANSPORT AND STORAGE IN TRANSIT

569. Any group of *packages, overpacks* and *freight containers* containing *fissile material* stored in transit in any one storage area shall be so limited that the total sum of the *criticality safety indexes* in the group does not exceed 50. Each group shall be stored so as to maintain a spacing of at least 6 m from other such groups.

TABLE 10. CSI LIMITS FOR FREIGHT CONTAINERS AND CONVEYANCES CONTAINING FISSILE MATERIAL

Type of *freight container* or *conveyance*	Limit on total sum of *criticality safety indexes* in a *freight container* or aboard a *conveyance*	
	Not under *exclusive use*	Under *exclusive use*
Freight container — Small	50	n/a
Freight container — Large	50	100
Vehicle	50	100
Aircraft		
Passenger	50	n/a
Cargo	50	100
Inland waterway *vessel*	50	100
Seagoing *vessel*[a] (1) Hold, compartment or *defined deck area*: *Packages*, *overpacks*, small *freight containers*	50	100
Large *freight containers*	50	100
(2) Total *vessel*: *Packages*, *overpacks*, small *freight containers*	200[b]	200[c]
Large *freight containers*	No limit[b]	No limit[c]

[a] *Packages* or *overpacks* carried in or on a *vehicle* which are in accordance with the provisions of para. 573 may be transported by *vessels* provided that they are not removed from the *vehicle* at any time while on board the *vessel*. In that case the entries under the heading 'under *exclusive use'* apply.

[b] The *consignment* shall be so handled and stowed that the total sum of *CSI*s in any group does not exceed 50, and that each group is handled and stowed so that the groups are separated from each other by at least 6 m.

[c] The *consignment* shall be so handled and stowed that the total sum of *CSI*s in any group does not exceed 100, and that each group is handled and stowed so that the groups are separated from each other by at least 6 m. The intervening space between groups may be occupied by other cargo in accordance with para. 505.

570. Where the total sum of the *criticality safety indexes* on board a *conveyance* or in a *freight container* exceeds 50, as permitted in Table 10, storage shall be such as to maintain a spacing of at least 6 m from other groups of *packages*, *overpacks* or *freight containers* containing *fissile material* or other *conveyances* carrying *radioactive material*.

571. Rail and road *vehicles* carrying *packages*, *overpacks* or *freight containers* labelled with any of the labels shown in Fig. 2, Fig. 3, Fig. 4 or Fig. 5, or carrying *consignments* under *exclusive use*, shall display the placard shown in Fig. 6 on each of:

(a) The two external lateral walls in the case of a rail vehicle;

(b) The two external lateral walls and the external rear wall in the case of a road vehicle.

In the case of a vehicle without sides, the placards may be affixed directly on the cargo carrying unit provided that they are readily visible; in the case of physically large tanks or freight containers, the placards on the tanks or freight containers shall suffice. In the case of vehicles which have insufficient area to allow the fixing of larger placards, the dimensions of the placard as described in Fig. 6 may be reduced to 100 mm. Any placards which do not relate to the contents shall be removed.

572. Where the *consignment* in or on the *vehicle* is unpackaged *LSA-I material* or *SCO-I* or where an *exclusive use consignment* is packaged *radioactive material* with a single United Nations number, the appropriate United Nations number (see Table 8) shall also be displayed, in black digits not less than 65 mm high, either:

(a) In the lower half of the placard shown in Fig. 6, against the white background; or

(b) On the placard shown in Fig. 7.

When the alternative given in (b) above is used, the subsidiary placard shall be affixed immediately adjacent to the main placard, either on the two external lateral walls in the case of a rail *vehicle* or on the two external lateral walls and the external rear wall in the case of a road *vehicle*.

573. For *consignments* under *exclusive use*, the *radiation level* shall not exceed:

(a) 10 mSv/h at any point on the external surface of any package or overpack, and may only exceed 2 mSv/h provided that:

(i) The vehicle is equipped with an enclosure which, during routine conditions of transport, prevents the access of unauthorized persons to the interior of the enclosure; and

(ii) Provisions are made to secure the package or overpack so that its position within the vehicle enclosure remains fixed during routine conditions of transport; and

(iii) There is no loading or unloading during the shipment;

(b) 2 mSv/h at any point on the outer surfaces of the vehicle, including the upper and lower surfaces, or, in the case of an open vehicle, at any point on the vertical planes projected from the outer edges of the vehicle, on the upper surface of the load, and on the lower external surface of the vehicle; and

(c) 0.1 mSv/h at any point 2 m from the vertical planes represented by the outer lateral surfaces of the vehicle, or, if the load is transported in an open vehicle, at any point 2 m from the vertical planes projected from the outer edges of the vehicle.

574. In the case of road *vehicles*, no persons other than the driver and assistants shall be permitted in *vehicles* carrying *packages*, *overpacks* or *freight containers* bearing category II-YELLOW or III-YELLOW labels.

ADDITIONAL REQUIREMENTS RELATING TO TRANSPORT BY VESSELS

575. *Packages* or *overpacks* having a surface *radiation level* greater than 2 mSv/h, unless being carried in or on a *vehicle* under *exclusive use* in accordance with Table 9, footnote (a), shall not be transported by *vessel* except under *special arrangement*.

576. The transport of *consignments* by means of a special use *vessel* which, by virtue of its design, or by reason of its being chartered, is dedicated to the purpose of carrying *radioactive material*, shall be excepted from the requirements specified in para. 567 provided that the following conditions are met:

(a) A Radiation Protection Programme for the shipment shall be approved by the competent authority of the flag state of the vessel and, when requested, by the competent authority at each port of call;

(b) Stowage arrangements shall be predetermined for the whole voyage including any consignments to be loaded at ports of call en route; and

(c) The loading, carriage and unloading of the consignments shall be supervised by persons qualified in the transport of radioactive material.

ADDITIONAL REQUIREMENTS RELATING TO TRANSPORT BY AIR

577. *Type B(M) packages* and *consignments* under *exclusive use* shall not be transported on *passenger aircraft*.

578. Vented *Type B(M) packages*, *packages* which require external cooling by an ancillary cooling system, *packages* subject to operational controls during transport and *packages* containing liquid pyrophoric materials shall not be transported by air.

579. *Packages* or *overpacks* having a surface *radiation level* greater than 2 mSv/h shall not be transported by air except by *special arrangement*.

UNDELIVERABLE CONSIGNMENTS

583. Where a *consignment* is undeliverable, the *consignment* shall be placed in a safe location and the appropriate *competent authority* shall be informed as soon as possible and a request made for instructions on further action.

REQUIREMENTS FOR RADIOACTIVE MATERIALS AND FOR PACKAGINGS AND PACKAGES

625. Tank containers may also be used as *Type IP-2* or *Type IP-3*, provided that:

(a) They satisfy the requirements for Type IP-1 specified in para. 621;

(b) They are designed to conform to the standards prescribed in the chapter on Recommendations on Multimodal Tank Transport of the United Nations Recommendations on the Transport of Dangerous Goods [7], or other requirements at least equivalent to those standards, and are capable of withstanding a test pressure of 265 kPa; and

(c) They are designed so that any additional shielding which is provided shall be capable of withstanding the static and dynamic stresses resulting from handling and routine conditions of transport and of preventing more than a 20% increase in the maximum radiation level at the external surface of the tank containers.

626. *Tanks*, other than tank containers, may also be used as *Type IP-2* or *Type IP-3* for transporting *LSA-I* and *LSA-II* liquids and gases as prescribed in Table 4, provided that they conform to standards at least equivalent to those prescribed in para. 625.

627. *Freight containers* may also be used as *Type IP-2* or *Type IP-3*, provided that:

(a) The radioactive contents are restricted to solid materials;

(b) They satisfy the requirements for Type IP-1 specified in para. 621; and

(c) They are designed to conform to the standards prescribed in the International Organization for Standardization document ISO 1496/1: “Series 1 Freight Containers — Specifications and Testing — Part 1: General Cargo Containers” [9] excluding dimensions and ratings. They shall be designed such that if subjected to the tests prescribed in that document and to the accelerations occurring during routine conditions of transport they would prevent:

   (i) Loss or dispersal of the radioactive contents; and

   (ii) More than a 20% increase in the maximum radiation level at the external surface of the freight containers.

628. Metal *intermediate bulk containers* may also be used as *Type IP-2* or *Type IP-3*, provided that:

(a) They satisfy the requirements for Type IP-1 specified in para. 621; and

(b) They are designed to conform to the standards prescribed in the chapter on Recommendations on Intermediate Bulk Containers (IBCs) of the United Nations Recommendations on the Transport of Dangerous Goods [7], for Packing Group I or II, and if they were subjected to the tests prescribed in that document, but with the drop test conducted in the most damaging orientation, they would prevent:

(i) Loss or dispersal of the radioactive contents; and

(ii) More than a 20% increase in the maximum radiation level at the external surface of the intermediate bulk container

Radiation Protection Programme

for the

Transport of Radioactive Materials

Version: 1.4
Date: 9 April 2013

Radiation Protection Programme for the Transport of Radioactive Materials

Contents

1. Introduction

The protection and safety of persons during the transport of radioactive materials must be optimised in order that:

- the magnitude of individual radiation doses,
- the number of persons exposed, and
- the likelihood of incurring exposure

are kept as low as reasonably achievable, economic and social factors being taken into account. In addition to this, radiation doses to persons must be below the relevant dose limits.

To achieve these goals, in Queensland, it is a legislated requirement that all packaging, transport and stowage of radioactive materials is conducted as safely as possible and in compliance with the ARPANSA *Code of practice for the safe transport of radioactive material (2008)* (Transport Code). The Transport Code has been adopted in each State and Territory of Australia.

The Transport Code requires that a radiation protection programme be established for the transport of radioactive materials by the person or organisation undertaking the carriage of radioactive materials (ie. carrier). The programme must contain the systematic arrangements that are in place to ensure adequate consideration of radiation protection measures. This document has been prepared for adoption by carriers of radioactive materials so that they satisfy the Transport Code requirement for developing a radiation protection programme.

This document represents a summary of the key radiation safety elements of the Transport Code that are applicable to the transport of radioactive materials in Queensland and, as such, must not be construed as being a full interpretation of the requirements of the Code.

Nevertheless, compliance with the Transport Code and this programme is mandatory.

2. Definitions

The following definitions provide clarification of the terms used in this document, and are consistent with the definitions given in the Transport Code.

Carrier - An individual or organisation transporting radioactive materials.

Consignment - A package, or load of radioactive materials, which is presented by a consignor for transport.

Consignor - An individual or organisation who prepares a consignment of radioactive materials for transport, and who is named as consignor in the transport documents.

Exclusive use - The sole use of a conveyance or of a large freight container by a single consignor where all initial, intermediate and final loading and unloading is carried out in accordance with the directions of the consignor or consignee.

Package - This includes the packaging together with its radioactive contents as presented for transport.

Transport Index (TI) - A number assigned to a package, overpack or freight container, or to unpackaged LSA-1 or SCO-1, to assist in providing control over radiation exposure. In general, the TI corresponds to the radiation level (in units of millisieverts per hour) at 1 metre from the surface of a package multiplied by 100.

3. Legislated Requirements

People involved in the transport of radioactive materials must receive appropriate training on the radiation hazards that may be encountered during the transport of radioactive materials, including the precautions that must be observed to restrict their own exposure and the exposure of other persons who might be affected by their actions.

Additionally, under section 14 of the *Radiation Safety Act 1999*, a licence must be held by persons who wish to transport radioactive substances. All licences authorizing the holder to transport radioactive substances are subject to the condition that the licensee complies with the Transport Code.

(a) Transport by road

Only an individual may hold a licence to transport radioactive substances on roads. If radioactive substances are being transported, there must be a person licensed under the *Radiation Safety Act 1999* in charge of the vehicle. To obtain a licence, a person must successfully complete a training course, approved by the Department of Health, which includes the requirements to transport class 7 (radioactive substances) dangerous goods.

(b) Transport other than by road

A company or individual is permitted to hold a licence authorising the transport of radioactive substances by means other than by road (i.e. air, sea or rail). Corporate licensees must provide appropriate training to staff in relation to the transport of radioactive substances.

This training must address the following:

- a direction to refer to the Transport Code
- details of the responsibilities of the consignor and carrier
- a direction that consignments must be checked before they are accepted for transport
- details of where and when radiation warning placards are to be placed on the vehicle, and other signage requirements
- details of the limitations on the packages which may be transported
- information on how packages must be stored while in transit
- procedures to be followed in the event of an incident

This document may provide a basis for the training programme.

(c) Exemption provisions

Under section 70 of the *Radiation Safety Regulation 2010*, a transport licence is not required if a radioactive substance is transported in accordance with the Transport Code, and if:

1. a radioactive substance is enclosed in an excepted package as defined in the Transport Code; or

2. a sealed radioactive substance, incorporated in a sealed source apparatus, is transported by a person who is licensed to use the apparatus to carry out one of the following radiation practices:
   - borehole logging
   - density-gauging or moisture-gauging, for geo-technical purposes
   - industrial radiography.

Those who are exempt from the requirement to hold a transport licence by virtue of holding a use licence for a prescribed radiation practice are considered to be adequately trained to transport specific radioactive materials under industry specific conditions. They received this training during the radiation safety training required as a pre-requisite to obtaining a licence. In addition to this, these individuals are required to comply with the possession licensee's approved radiation safety and protection plan (i.e. the plan approved by the Chief Executive of the Department of Health).

4. Responsibilities

The responsibility for the transport of radioactive materials is shared by consignors and carriers with each group being responsible for different aspects of compliance with the Transport Code. Specific responsibilities for consignors and carriers are detailed respectively in sections 2.8 and 2.9 of the Transport Code.

(a) Consignor's responsibilities

To ensure that packages containing radioactive material are safe to handle under normal conditions, the consignor is responsible for:

- packaging and labelling radioactive materials for transport in accordance with the Transport Code; and
- preparing and certifying the transport documentation as required by the Transport Code.

(b) Carrier's responsibilities

The carrier is responsible for:

- checking that appropriate documentation is provided with the package, and has been completed in accordance with the Transport Code;
- verifying that the information on the consignment note, consignor's declaration for dangerous goods (if applicable) and the package containing the radioactive materials is consistent (Note: A check list is provided in section 7 of the *Safety Guide for the Safe Transport of Radioactive Material (2008)* which may be used to ensure that all the necessary information is provided);
- identifying labels to ensure appropriate decisions are made about storage, loading and transport;
- the loading, handling, transport and interim storage of packages where appropriate;
- unloading of packages and freight containers; and
- emergency procedures in the event of an incident while loading, transporting, unloading or storage of a package.

The carrier must also adhere to all handling, transport, stowage and unloading instructions detailed in the transport documentation by the consignor. This may contain such information as:

- operational instructions for loading, stowage, transport, and unloading and any special stowage provisions for the safe dissipation of heat;
- restrictions on the mode of transport and any necessary routine instructions; or
- emergency arrangements specific to the consignment.

5. Radiation Monitoring

The Transport Code is designed to ensure that radiation exposures to any person involved in the transport of radioactive material do not exceed those permitted for members of the public. Consequently, provided that this Code and safe practices are being followed, there is no requirement for personal radiation monitoring of carriers.

6. Documentation

The following documentation is required for transport of radioactive material by road or rail:

- a movement order (e.g. waybill, consignment note);
- details of the consignment (including radionuclide, total activity, number of packages);
- a consignment declaration (Note: A consignment declaration is not required for the transport of an excepted package);
- package certification, as required;
- special form certificate, if applicable, for sealed sources;
- competent authority approval, where required; and

- any supplementary information for carriers (e.g. additional handling requirements, emergency arrangements, restrictions on loading).

It is the responsibility of the consignor to ensure that the required documents are provided and correctly completed.

Individuals transporting their own radioactive materials are not required to complete a consignment note or a consignor's declaration for dangerous goods.

7. Types of Packages

There are specifications and limitations on the type of packaging to be used in the transport of radioactive materials. The type of package required depends on the activity and type of the radioactive material to be transported. The types of packages covered by the Transport Code are:

- Excepted package
- Industrial package Type 1 (Type IP-1)
- Industrial package Type 2 (Type IP-2)
- Industrial package Type 3 (Type IP-3)
- Type A package
- Type B(U) package
- Type B(M) package
- Type C package

The package type relates to package performance standards, with the Type C package being subject to the most stringent testing. Information on the testing requirements that must be satisfied for the classification of a package is detailed in section VI of the Transport Code.

The majority of radioactive materials in Queensland are transported in Type A packages, excepted packages and Type B(U) packages. It is the responsibility of the consignor to ensure that the correct type of package is used for the transport of radioactive material.

8. Categories of Packages

Other than excepted packages, packages and large or small freight containers must be labelled with category I-White, II-Yellow or III-Yellow labels, depending on the content of radioactive material and radiation levels at the surface of the package.

Each category of label represents the potential hazard of the package. A category I-White label means that the radiation levels at the surface of the package is very low, and a category III-Yellow label means that the package has the highest accessible radiation field at the surface of the package and in its near vicinity.

The labels to be used must conform to the requirements in paragraph 542 of the Transport Code. This categorisation of packages is the responsibility of the consignor.

Category I-White, II-Yellow or III-Yellow labels must include the type of and activity of the radionuclide being transported. Category II-Yellow and III-Yellow labels also include the Transport Index.

9. Labelling and Placarding

The requirements for the labelling of packages and the placarding of vehicles are described in the following table.

	Excepted packages	Other packages
Labelling of packages		
Package category	Not applicable	The package category (i.e. I-White, II-Yellow or III-Yellow) must be displayed on

	Excepted packages	Other packages
		the outside of each package or freight container. A package must bear two (2) appropriate labels affixed to opposite sides of the package. A freight container must be labelled on all four (4) sides.
Package type	Not applicable	The type of package must be marked on the outside of the package (eg. type A or B(U) etc).
Identification	The package must be legibly marked on the outside of the packaging with an identification of either the consignee or the consignor.	The package must be legibly marked on the outside of the packaging with an identification of either the consignee or the consignor.
UN Number	The outside of the package must bear the letters 'UN' followed by the United Nations number (refer to Table 8 of the Transport Code).	The outside of the package must bear the letters 'UN' followed by the United Nations number and the proper shipping name. This must comply with Table 8 of the Transport Code.
Mass	Each package of gross mass exceeding 50kg must have its permissible gross mass marked on the outside of the packaging.	Each package of gross mass exceeding 50kg must have its permissible gross mass marked on the outside of the packaging.
Placarding of vehicles		
Road vehicles	Not applicable	Road vehicles must display the placard, shown in Figure 6 of the Transport Code, on the outside of the two external lateral walls and on the external rear wall.
Railway vehicles	Not applicable	Railway vehicles must display the placard, shown in Figure 6 of the Transport Code, on each of the two external lateral walls of the carriage.

10. Transport Procedures

In general, radiation exposure to personnel is dependent upon the amount of time they spend near the packages containing radioactive materials. All persons should:

- minimize contact time with the package;
- not stand or sit near or sit or on the package; and
- keep as far away as practicable from the package.

The following additional rules must be followed to minimize radiation exposure.

(a) Transport of packages

The carrier must ensure that:

- packages stay in good condition and that packaging seals remain intact during loading, transporting, unloading, and storage prior to delivery at the destination of the package;
- except for the driver and assistants, no person is carried in vehicles carrying packages of radioactive materials bearing category II-Yellow or III-Yellow labels;
- packages of radioactive materials bearing category II-Yellow or III-Yellow labels are not carried in compartments occupied by passengers;
- placards are placed on both sides and the rear of the vehicle when transporting packages of radioactive materials bearing a category label;
- packages of radioactive materials are securely stowed in the vehicle to prevent movement during transport;
- packages of radioactive materials are not loaded in the same vehicle as goods which could

damage the packaging of the radioactive materials in the event of an accident;

- ensure that the package is placed in the vehicle as far as practicable from the driver to ensure the driver's exposure to radiation is minimised while en route; and
- packages are segregated from other dangerous goods during transport, in compliance with the *Australian Code for the Transport of Dangerous Goods by Road and Rail* (Note: Section 3.2 of the *Safety Guide for the Safe Transport of Radioactive Material (2008)* provides minimum separation distances to assist in this regard).

(b) Stowage during transport and storage in transit

The carrier must ensure that:

- packages of radioactive materials are not stored near dangerous goods with which common loading or storage is prohibited under the *Australian Code for the Transport of Dangerous Goods by Road and Rail* (Note: Section 3.2 of the *Safety Guide for the Safe Transport of Radioactive Material (2008)* provides minimum separation distances to assist in this regard);
- the number of category II-Yellow and III-Yellow labelled packages in a particular group is limited so that the sum of transport indices is not more than 50. Such groups of packages must be stored at least 6 metres from other groups of such packages (When a consignment is transported under exclusive use, there is no limit on the sum of the transport indexes);
- packages containing radioactive materials are kept separated from occupied areas; and
- packages containing radioactive materials are kept separated from undeveloped photographic films or plates. As a guide this may be achieved by:
    - not transporting photographic film with any category II-Yellow or III-Yellow labelled package; and
    - ensuring at least a 2 metre separation between photographic film and an excepted package or a category I-White labelled package.

(c) Transport of unpackaged low specific activity material

Low specific activity (LSA) material is material which, by its nature, has a limited specific activity or for which limits of estimated average specific activity apply. There are three groups of LSA (LSA-I, LSA-II and LSA-III). Only material classed as LSA-I may be transported unpackaged. An example of LSA-I material is uranium and thorium ores.

To safely transport unpackaged material, the carrier must:

- comply with all the handling, transport, stowage and unloading instructions supplied on the transport documentation or provided by the consignor;
- only transport the material under exclusive use arrangements;
- ensure that all loads are fully covered before leaving the loading site – covers are not to be removed until arrival at the final destination;
- place placards on both sides and the rear of the vehicle (Note: The placards to be used must conform to the model shown in Figure 6 of the Transport Code). Additionally, the United Nations number '2912' must be displayed either on the lower half of the transport placard, or on its own separate label (Note: This label must conform to the model shown in Figure 7 of the Transport Code);
- regularly check the vehicle to ensure that no radioactive material is spilling or blowing from the vehicle;
- wash the vehicle and cover after delivery of every load of material to the final destination ensuring that no residual material remains in the vehicle or on the cover;
- ensure that the driver's compartment is kept clean of any radioactive materials; and
- ensure that, in the event of a small spillage, all of the material is cleaned up and placed back on the truck.

11. Incident Procedures

If a package containing radioactive material has been damaged and it is suspected that the damage may allow radiation leakage or spillage of the radioactive material, the carrier or other person dealing with the incident must:

- provide first aid to injured persons;
- not touch the package;
- notify the carrier's supervisor or manager and the consignor of the package;
- evacuate and control access to the incident area until the arrival of appropriate personnel to control the situation;
- immediately notify the Chief Executive or the Radiation Health Unit (Phone: 041 327 9672) of the incident;
- follow any instructions to control the incident given by the consignor, or an officer of Radiation Health;
- not eat, drink or smoke while at the incident site;
- identify persons or equipment that may have been contaminated by radioactive material or exposed to radiation; and
- provide a report to the Chief Executive (c/- the Radiation Health Unit) within 7 days, advising of:
  - (a) location of incident
  - (b) nature and cause of incident
  - (c) actions taken to contain incident
  - (d) clean up procedures and environmental concerns
  - (e) any person exposed or possibly exposed
  - (f) proposals aimed at avoiding a recurrence.

12. Further Information

If you have any questions regarding the transport of radioactive materials, please contact Radiation Health:

Postal Address:	PO Box 2368 Fortitude Valley BC Qld 4006
Physical Address:	15 Butterfield Street Herston Qld 4006
Telephone:	(07) 3328 9987
Facsimile:	(07) 3328 9622
Email:	radiation_health@health.qld.gov.au

ROAD/RAIL/INLAND WATERWAYS CONSIGNOR'S DECLARATION FOR DANGEROUS GOODS

CLASS 7 RADIOACTIVE MATERIAL

TWO COMPLETED AND SIGNED COPIES OF THIS DECLARATION MUST BE PROVIDED TO THE CARRIER

CONSIGNOR (SENDER'S NAME AND ADDRESS):	**NAME OF TRANSPORTING COMPANY AND CONSIGNMENT No.**
	CONSIGNOR'S REFERENCE No.
CONSIGNEE (RECEIVER'S NAME AND ADDRESS):	**INLAND WATERWAYS USE ONLY** PORT OF LOADING .... DATE OF LOADING.. PORT OF DISCHARGE .... VESSEL... CONTAINER No..

NATURE AND QUANTITY OF RADIOACTIVE MATERIAL

See applicable Codes: International Atomic Energy Agency (IAEA) — Safety Requirements No. TS-R-1 (2005) and the Code of Practice for Safe Transport of Radioactive Material 2008 ("The Transport Code")

PROPER SHIPPING NAME Refer overleaf	**UNITED NATIONS DANGEROUS GOODS CLASS**	**UNITED NATIONS NUMBER**	**SUBSIDIARY RISK** (if applicable) Classes 1 to 8	**RADIONUCLIDE** Name or symbol of each radionuclide e.g. Iridium-192, Ir-192 or ^{192}Ir	**PHYSICAL AND CHEMICAL FORM** "special form" or "low dispersible radioactive material" is acceptable, if applicable	**MAX ACTIVITY OF RADIOACTIVE CONTENTS** in Becquerel units (Bq) with appropriate SI prefix or Mass in grams (g) for fissile material
	7	**UN**				
CATEGORY OF PACKAGE Delete category not applicable	**TRANSPORT INDEX** Definition: 100 times the maximum radiation dose in millisievert per hour (mSv/h) at 1 metre For Yellow hazard categories only	**CRITICALITY SAFETY INDEX** For fissile material only	**COMPETENT AUTHORITY APPROVAL CERTIFICATE NUMBER(S)** required for special form r/a material, low dispersible r/a material, special arrangement, package design or shipment	**NUMBER OF PACKAGES** Information to be repeated for each package	**EXCLUSIVE USE SHIPMENT** Delete category not applicable	**TOTAL ACTIVITY OF THE CONSIGNMENT** (for LSA-II, LSA-III, SCO-I or SCO-II only) Multiple of A_2
I-WHITE OR **II-YELLOW** OR **III-YELLOW**					**YES** or **NO**	

WARNING

FAILURE TO COMPLY IN ALL RESPECTS WITH THE APPLICABLE RADIOACTIVE MATERIALS TRANSPORT REGULATIONS MAY BE IN BREACH OF THE APPLICABLE LAW, SUBJECT TO LEGAL PENALTIES. THIS DECLARATION MUST NOT, IN ANY CIRCUMSTANCES, BE COMPLETED AND/OR SIGNED BY A CONSOLIDATOR, A FORWARDER OR CARGO AGENT.

I HEREBY DECLARE THAT THE CONTENTS OF THIS CONSIGNMENT ARE FULLY AND ACCURATELY DESCRIBED ABOVE BY THE PROPER SHIPPING NAME AND ARE CLASSIFIED, PACKED, MARKED AND LABELLED, AND ARE IN ALL RESPECTS IN PROPER CONDITION FOR TRANSPORT BY ROAD/RAIL/INLAND WATERWAYS (*check transport mode/s below*) ACCORDING TO THE APPLICABLE INTERNATIONAL AND NATIONAL GOVERNMENTAL REGULATIONS.

ROAD ☐ RAIL ☐ INLAND WATERWAYS ☐

NAME OF CONSIGNOR: (PLEASE PRINT)

POSITION --

SIGNATURE ---
(SEE ABOVE WARNING)

DATE --

ADDITIONAL HANDLING INFORMATION (e.g. Schedule Number, Special arrangements, Exclusive use, other information)

SEE REVERSE FOR INFORMATION FOR CARRIERS AND EMERGENCY PROCEDURES

INFORMATION FOR CARRIERS

HANDLING RULES

Radioactive materials presented for transportation are packaged in accordance with the IAEA Regulations which ensure that they are safe to handle under normal conditions. Nevertheless, to prevent unnecessary exposure to radiation there are certain basic rules which should followed as the radiation exposure received will depend on how long and how close a person remains near the packages containing radioactive materials. To minimise radiation exposures:

- Keep contact time with the package short.
- Radioactive material package should be handled a without delay — keep it moving.
- Do not stand around, sit near or sit on a radioactive material package.
- Do not carry out time-consuming tasks, such as paperwork, near a package.
- Keep yourself and other persons as far away as practicable from packages containing radioactive material.
- Store packages well away from offices, rest rooms and occupied work areas
- When transporting packages containing radioactive material any long distance, use a vehicle that will allow you to keep a metre or more between you and the packages.
- Secure packages so that they will not move during transport — small, light packages should be stored in a basket while larger, heavy packages should be properly blocked and braced.
- Do not store in the one location packages with transport indexes that add up to more than 50. You will find the transport index written on the Yellow Category II or Category III label.

DANGEROUS GOODS CLASS LOADING RESTRICTIONS FOR ROAD AND RAIL

(Australian Dangerous Goods Code Sixth Edition 1998 – Clause 9.2.7)

(1) The requirements of this clause are additional to those of the Australian Code of Practice for the Safe Transport of Radioactive Material.

(2) Dangerous goods of Class 7 must be separated from other placard loads of dangerous goods and rolling stock listed below by at least:

(a) 24 metres from:
- dangerous goods of Class 1 or 2.1
- locomotive in power
- guard's brake van
- wagon loaded with logs, rails, beams, pipes etc. without bulkhead
- vehicle carrying passengers;

(b) 12 metres from:
- dangerous goods of Class 3, 4, 5, or 8
- operating refrigerated container.

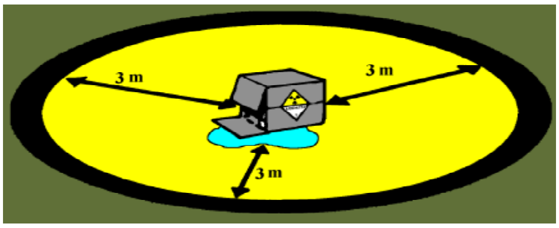
UN NUMBER	PROPER SHIPPING NAME and description	Subsidiary risks
2910	RADIOACTIVE MATERIAL, EXCEPTED PACKAGE – LIMITED QUANTITY OF MATERIAL	
2911	RADIOACTIVE MATERIAL, EXCEPTED PACKAGE – INSTRUMENTS or ARTICLES	
2909	RADIOACTIVE MATERIAL, EXCEPTED PACKAGE – ARTICLES MANUFACTURED FROM NATURAL URANIUM or DEPLETED URANIUM or NATURAL THORIUM	
2908	RADIOACTIVE MATERIAL, EXCEPTED PACKAGE – EMPTY PACKAGING	
2912	RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-I) non fissile or fissile-excepted *	
3321	RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-II) non fissile or fissile-excepted *	
3322	RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-III) non fissile or fissile-excepted *	
2913	RADIOACTIVE MATERIAL, SURFACE CONTAMI-NATED OBJECTS (SCO-I or SCO-II) non fissile or fissile-excepted *	
2915	RADIOACTIVE MATERIAL, TYPE A PACKAGE, non-special form, non fissile or fissile-excepted *	
3332	RADIOACTIVE MATERIAL, TYPE A PACKAGE, SPECIAL FORM, non fissile or fissile-excepted *	
2916	RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, non fissile or fissile-excepted *	
2917	RADIOACTIVE MATERIAL, TYPE B(M) PACKAGE, non fissile or fissile-excepted *	
3323	RADIOACTIVE MATERIAL, TYPE C PACKAGE, non fissile or fissile-excepted *	
2919	RADIOACTIVE MATERIAL, TRANSPORTED UNDER SPECIAL ARRANGEMENT, non fissile or fissile-excepted *	
2978	RADIOACTIVE MATERIAL, URANIUM HEXAFLUORIDE non fissile or fissile-excepted *	corrosive (UN Class 8)
3324	RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-II), FISSILE	
3325	RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-III), FISSILE	
3326	RADIOACTIVE MATERIAL, SURFACE CONTA-MINATED OBJECTS (SCO-I or SCO-II), FISSILE	
3327	RADIOACTIVE MATERIAL, TYPE A PACKAGE, FISSILE non-special form	
3333	RADIOACTIVE MATERIAL, TYPE A PACKAGE, SPECIAL FORM, FISSILE	
3328	RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, FISSILE	
3329	RADIOACTIVE MATERIAL, TYPE B(M) PACKAGE, FISSILE	
3330	RADIOACTIVE MATERIAL, TYPE C PACKAGE, FISSILE	
3331	RADIOACTIVE MATERIAL, TRANSPORTED UNDER SPECIAL ARRANGEMENT, FISSILE	
2977	RADIOACTIVE MATERIAL, URANIUM HEXAFLUORIDE, FISSILE	corrosive (UN Class 8)

* "Fissile-excepted" applies only to those packages complying with para. 672 of The Transport Code.

IN CASE OF ACCIDENT

If a radioactive material package has been damaged, and you suspect that the damage may allow leakage of radiation or spillage of radioactive material:

- Stay away from the package and do not touch it.
- Keep other people away from it.
- Notify your supervisor or manager, also inform them of any person who might have been contaminated — they will call for expert technical help if necessary.
- Tell anybody who might have touched the damaged package to report to the supervisor or manager — they will arrange the necessary action.
- Wash your hands thoroughly if you have touched the damaged package or objects near it and tell the supervisor or manager of your possible contamination by radioactive material.
- Have yourself checked for possible contamination before you leave work.
- Note any vehicles involved in the accident — the vehicles should remain at the accident site until cleared by the police or a competent person.
- Do not eat or smoke or drink or leave until checked for possible contamination.
- Advise the competent authority of details of the accident as soon as possible and follow any instructions subsequently issued.



EMERGENCIES:

AFTER HOURS CONTACT POLICE OR FIRE BRIGADE

AUSTRALIAN COMPETENT AUTHORITIES FOR THE TRANSPORT OF RADIOACTIVE MATERIAL BY ROAD/RAIL/INLAND WATERWAYS

COMMONWEALTH STATE / TERRITORY	CONTACT	COMPETENT AUTHORITY
Commonwealth	Chief Executive Officer ARPANSA PO Box 655 Tel: (02) 9541 8333 Miranda NSW 1490 Fax: (02) 9541 8348 Email: info@arpansa.gov.au	Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)
Australian Capital Territory	Director Health Protection Service Locked Bag 5 Tel: (02) 6205 1700 Weston Creek ACT 2611 Fax: (02) 6205 1705 Email: hps@act.gov.au	Australian Capital Territory Radiation Council
New South Wales	Manager Hazardous Materials and Radiation PO Box A290 Tel: (02) 9995 5000 Sydney South NSW 1232 Fax: (02) 9995 6603 Email: radiation@environment.nsw.gov.au	Department of Environment, Climate Change and Water
Northern Territory (i) for radioactive ores and concentrates	Chief Inspector – Radioactive Ores and Concentrates (Packaging and Transport) NT WorkSafe Department of Justice GPO Box 1722 Tel: (08) 8999 5010 Darwin NT 0801 Fax: (08) 8999 5141 Email: neil.watson@nt.gov.au	Work Health Authority
(ii) for all other radioactive substances	Manager Radiation Protection Department of Health & Families GPO Box 40596 Tel: (08) 8922 7152 Casuarina NT 0811 Fax: (08) 8922 7334 Email: envirohealth@nt.gov.au	Department of Health and Families
Queensland	Director, Radiation Health Unit Queensland Health PO Box 2368 Tel: (07) 3328 9987 Fortitude Valley BC QLD 4006 Fax: (07) 3328 9622 Email: radiation_health@health.qld.gov.au	Queensland Health
South Australia	Director, Radiation Protection Division Environment Protection Authority PO Box 2607 Tel: (08) 8463 7814 Adelaide SA 5001 Fax: (08) 8124 4671 Email: radiationprotection@epa.sa.gov.au	Minister for Environment & Conservation
Tasmania	Senior Health Physicist, Health Physics Branch Department of Health & Human Services GPO Box 125B Tel: (03) 6222 7256 Hobart TAS 7001 Fax: (03) 6222 7257 Email: health.physics@dhhs.tas.gov.au	Director of Public Health
Victoria	Team Leader, Radiation Safety Department of Health GPO Box 4057 Tel: 1300 767 469 Melbourne VIC 3001 Fax: 1300 769 274 Email: radiation.safety@dhs.vic.gov.au	Secretary, Department of Health
Western Australia	The Secretary, Radiological Council Locked Bag 2006 PO Tel: (08) 9346 2260 Nedlands WA 6009 Fax: (08) 9381 1423 Email: radiation.health@health.wa.gov.au	Radiological Council

Information Sheet

Information about Transport Licences

The Radiation Safety Act 1999 requires all individuals transporting radioactive substances by road, water, rail or air in the Queensland jurisdiction to hold a transport licence. Transport licences are granted by the Director-General of the Department of Health (*chief executive*).

All transport licences are subject to the condition that the licensee complies with the ARPANSA Code of Practice for the Safe Transport of Radioactive Material 2008 (*transport code*). Amongst other things, this means that all licensees are required to transport radioactive substances in compliance with their radiation protection programme.

Transport by road

Only an individual may hold a licence to transport radioactive substances by road. This licensed individual is the person in charge of the vehicle.

A person who wishes to obtain a transport licence must, in the person's application, detail:

- how he or she wishes to transport the radioactive substance
- the amount of radioactive substance to be transported at a time
- details demonstrating the applicant's competency in relation to the handling, packaging, transportation, storage and delivery of the substance.

Transport by other than road

A company or individual may hold a licence authorising the transport within the jurisdiction in Queensland of radioactive substances by means other than by road (i.e. air, sea or rail). If the licence is to be held by a company, the applicant will need to provide appropriate training to staff who will be involved in the transport radioactive substances. This training should include:

- a direction to refer to the transport code
- details of the responsibilities of the consignor and driver
- a direction that consignments must be checked before they are accepted for transport
- details of where and when radiation warning placards are to be placed on the vehicle
- details of the limitations on the packages which may be transported
- information on how packages must be stored while in transit
- procedures to be taken in the event of an accident or incident

The radiation protection programme for corporate applicants must contain details of this training and must be submitted for assessment along with their licence applications.

Are there any exemptions from the licensing requirements?

A transport licence is not required if a radioactive substance is transported in accordance with the transport code, and if:

1. the radioactive substance to be transported is packaged as an excepted package as defined in the transport code; or

2. the radioactive substance to be transported is in the form of a sealed radioactive substance, incorporated in a sealed source apparatus, and transported by a person who is licensed to use the apparatus to carry out one of the following radiation practices:

   (a) borehole logging
   (b) density-gauging or moisture-gauging, for geo-technical purposes
   (c) industrial radiography.

Term of Transport Licence

A transport licence may have a term of one, two or three years. Under the Radiation Safety Act 1999, applications for renewal of licences must be made prior to the expiry of a current licence.

Licensees are required to have and comply with a Radiation Protection Programme for the Transport of Radioactive Materials. The department has prepared such a programme which a large number of licensees have elected to use. A copy of this programme may be found at: www.health.qld.gov.au/radiationhealth

Enquiries

For further information, please contact the Radiation Health, Health Protection Unit of the Department of Health. The contact details for Radiation Health are:

Office
Radiation Health
Health Protection Unit
15 Butterfield Street
HERSTON QLD 4006

Postal
Radiation Health
Health Protection Unit
PO Box 2368
FORTITUDE VALLEY BC QLD 4006

Phone
07 3328 9987

Website
www.health.qld.gov.au/radiationhealth

Facsimile
07 3328 9622

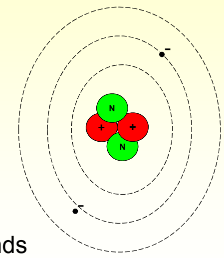
Email
radiation_health@health.qld.gov.au

Radiation Safety

1

An Atomic Model (Bohr)

- Nucleus:
  - Protons (+ve, large)
  - Neutrons (neutral, large)
- Electron orbits:
  - Electrons (-ve, small)
  - Orbit nucleus
  - Involved in chemical bonds



2

Elements, Nuclides, Isotopes

- Isotopes
  - More/less neutrons (effects nuclear stability)
  - Chemically identical
- Nuclides - Classification by numbers of nuclear particles and protons

$^{12}_{6}C$ $^{13}_{6}C$ $^{14}_{6}C$ $^{PROTONS+NEUTRONS}_{PROTONS}SYMBOL$

Example: naturally occurring isotopes of carbon

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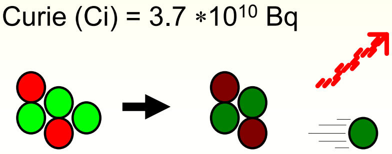
Radioactivity

- Spontaneous "nuclear" disintegration of unstable isotopes
- High to low nuclear energy transition requires energy loss (Radiation α, β, γ)
- 1 Becquerel (Bq) = 1 disintegration/second
- 1 Curie (Ci) = 3.7 $*10^{10}$ Bq



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Half Life ($t_{1/2}$)

- Activity declines with time due to the reducing number of original radioactive atoms remaining in the sample
- Half-Life ($t_{1/2}$) - Time for 50% of sample to Decay

$$A_t = A_0 e^{-\lambda t}$$

$$A_t = A_0 / 2^n$$

Co^{60}: Half Life 5 years

Time (years)	Activity (MBq)
0	100
5	50
10	25
15	13
20	7
25	4
30	2
35	1

λ is the specific nuclide decay constan n is the number of half lives expirec

Practice Problem

- **At the time of manufacture, the activity of a Co^{60} source was 8 GBq.**
- **The half life of Co^{60} is 5 years.**
- **What is the activity of the sample after 20 years?**

Practice Problem

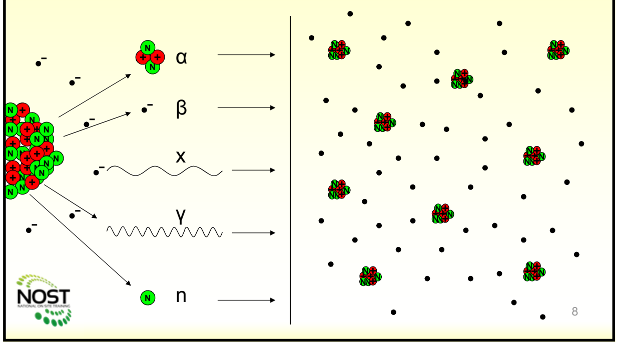
- 20 years is equal to 4 half lives (4 x 5 years = 20 yrs)
- The original activity A_0 is given as 8 GBq
- After 1 half life of 5 years the activity will be 4 GBq
- After 2 half lives it will be 2 GBq
- After 3, 1 GBq
- After 4 half lives (20 years) the activity will be 0.5GBq

Radiation Types

Proton: large, +ve charge

Neutron: large, no charge

Electron: small (1/6000 proton), -ve charge



Units

- **Bq (Ci), Activity** - number of disintegrations per second, projectiles launched per second.
- **Gy (rad), Absorbed dose** - energy absorbed per kg in the absorber, hits per kg.
- **Sv (rem), Equivalent dose** - energy absorbed per kg in human tissue, probability of damage per kg in human tissue.
  - **Sv = Gy x Wt x Wr**

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Weighting Factors

- Different body tissues are more/less sensitive to radiation (Wt)

Tissue	Wt
Lung, stomach, colon, bone marrow, breast	0.12
Gonads	0.08
Thyroid, oesophagus, bladder, liver	0.04
Bone surfaces, skin, brain, salivary glands	0.01
Whole body	1

- Different radiations cause more/less damage per unit volume (Wr)

Radiation	Wr
α	20
X,β,γ	1
η	3-20

ICRP 103

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How Much Is Too Much?

- Background < 2mSv/yr (most of Australia)
  - 0.15μSv/hr sea level
  - 3-5 μSv/hr commercial flight
- Background < 2.5mSv/yr (world average)
- Background 50-250mSv/yr 5-25μSv/hr (some areas)
- Chest X-ray 40μSv (acute dose)
- Cancer: 4 "extra" deaths/100 persons 1000mSv (acute)
- Bone marrow function depressed 500mSv (acute)
- $LD_{50/60}$ 4000mSv (acute, no medical)
- $LD_{50/60}$ 6000mSv (200mSv/hr, no medical)
- $LD_{50/60}$ 8000mSv (10mSv/hr for 1 month, no medical)

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ICRP Radiation Limits

- Radiation Workers (including Transporting)
  - Whole Body 20mSv/year
  - Extremities 500mSv/year
- Public (and Radiation Workers not currently doing a "radiation" job)
  - 1mSv/year
  - NOTE: the public limit is a design limit

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What's Your Background Dose?

- House
  - Earth Product (Brick, Stone, Cement etc), Granite Bench Tops, High Altitude (Above sea level)
- Food
  - Banana, figs, Mineral Water
- Travel
  - QLD Sand Islands (double), SA Desert (double), Kakadu (double), Alps (Denver, double. Colorado, five times), Kerala (India, ten times), Black Sands in Brazil (Guarapari, five times), Central China (Yangjiang, triple), Iran (Ramsar, one hundred times)
- Air Travel
  - Work, Overseas, (0.1mSv/30 hours)

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What Are The Actual Health Effects of Radiation? **Sterility**

Dose	Effect
100mSv (acute)	1% of males, temporary sterility, 3-9 weeks post exposure
6000mSv (acute)	1% of males, permanent sterility, 3 weeks post exposure
3000mSv (acute)	1% of females, permanent sterility 1 week post exposure

If you get enough radiation to maybe be permanently sterile, is there another, more immediate effect you would be concerned about?

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What Are The Actual Health Effects of Radiation? **Mutations**

- "There continues to be no direct evidence that exposure of parents leads to heritable disease in offspring." ICRP 103 pg 53
- However, there is evidence of mutations in mice, so we say: 0.1% increase (above baseline) per 1Sv of exposure
- This is (at worst) a very small effect.

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What Are The Actual Health Effects of Radiation? **Foetus**

Dose	Effect
Tens of mSv (acute)	low risk of lethality to early foetus and no risk of other effects
Hundreds of mSv (acute)	Malformations, including mental retardation

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What Are The Actual Health Effects of Radiation? **Cancer**

- Radiation Causes Cancer
  - Under the LNT model this is the most important effect at low doses and dose rates such as occupational exposures
  - 30% (approx) rate Australian cancer deaths
  - 34% for a 1 Sv acute exposure
  - 30.08% for a 20mSv acute exposure (maybe)

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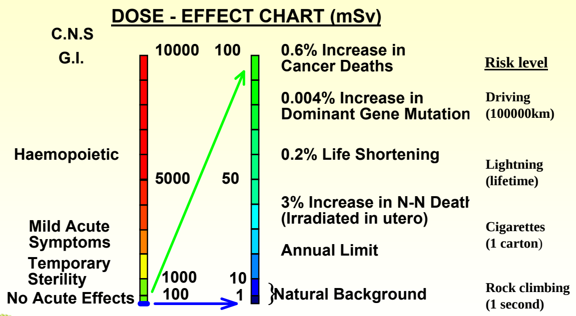
Radiation and Risk



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How Did These Limits Come About?

- ICRP Publication 103
- Linear No Threshold model
  - Atomic bomb survivors
  - Patients with therapeutic exposures
  - Worker exposures
- Public “acceptability” of risk of occupational death specifies the “acceptable” limit. (20mSv)

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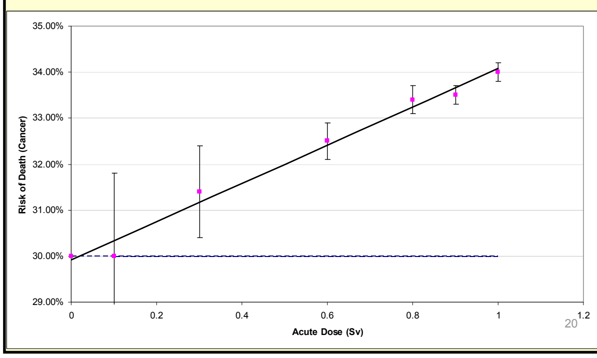
Linear No Threshold Model



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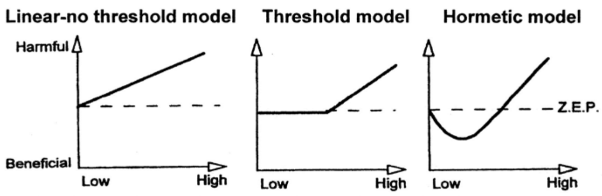
LNT, Threshold, Hormesis

- Low dose, low dose rate evidence is insufficient for world experts to move from the LNT model
- Therefore, the hormetic effect is small enough that it is likely that it is not of great concern health wise (cf: mobile phones)
- The hormetic or threshold models could change radiation safety legislation dramatically if adopted



Dose Rate Problem - Example

- In our radiation transport vehicle the dose rate is approx 15μSv/hour.
- I drive the vehicle approx one day each week for 4 hours each time.
- Will I get more than my annual limit?
- **Step 1.** Calculate total time exposed per year.
  - 4 hours/day x 1 day/week x 50 weeks/year = 200 hours total.
- **Step 2.** Measure/Calculate/Identify dose rate.
  - 15μSv/hour
- **Step 3.** Total dose per year = Time x Dose rate
  - 200 hours x 15μSv/hour = 3000μSv total for the year (approx)
- **Step 4.** Compare to annual limit (Hands? Body?)
  - 3000μSv is less than 1/4 of 20mSv annual limit

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Radiation Protection

- Justification
  - Benefits must outweigh risks
- Minimisation
  - Legal limits must be observed
- Optimisation
  - ALARA below legal limits

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Legislation, Standards and Radiation Safety Plans

- Radiation Safety Acts & Regs (by state and fed)
- Radiation Safety Standards (ARPANSA, state)
- Radiation Safety Plan:
  - Hazard Assessments
  - Responsibilities (users, supervisors, managers)
  - Radiation Safety Officer (adviser to all, not responsible!)
  - Access, training, SWP's, monitoring, maintenance/repair, remediation procedures.

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Radiation Sign

Caution Radiation

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Control Measures

- Time
  - Less time spent near radiation less dose
  - Covered in previous examples
- Distance
  - Further away is safer
- Shielding
  - Dense materials make good shields

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Distance

- Dose rate is inversely proportional to the square of the distance from the source.
- $D \propto 1/r^2$
- Formula:
- $D_1R_1^2=D_2R_2^2$
  - D=dose rate
  - R=Radius

Distance (meters)	Multiplier	Dose Rate (µSv/hr)
1	1	100
2	¼	25
3	1/9	11
10	1/100	1
0.5	4	400
0.1	100	10000

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Distance Problem

- The gamma dose rate 1 meter away from my source is 100µSv/hour.
- What is the dose rate 2 meters away?
- Using formula:
  - $D_1R_1^2=D_2R_2^2$ (D=dose R=Radius)
  - $100\mu Sv/h \times (1m)^2 = D_2 \times (2m)^2$
  - $100/4 = D_2$
  - $25\mu Sv/h = D_2$

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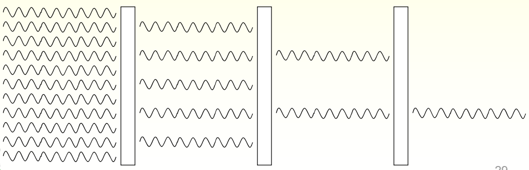
Shielding

- Half value layer
  - The thickness of shield that cuts the dose rate in half.
  - Must specify the shield material
  - Must specify the isotope (or energy)
- Each of the shields below is 1 HVL thick



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Radiation Stores

- Containment
- Shielding/Distance
- Labelling
- Documentation
- Signposting
- Security

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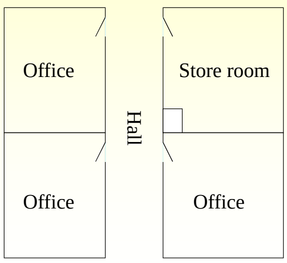
Store Design

- Planned dose rates
- Types of occupants
- Occupancy factors
- Shielding
- Distance
- etc



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Transport of Radioactive Substances

- Aim is to enable safe handling and transport of packaged RS by untrained transport workers as if it was not radioactive
- Based on IAEA transport regulations
- Four key requirements:
  - Adequate containment of the radioactive material
  - Adequate shielding against the radiation emitted by the material
  - The dissipation of the heat generated by high activity radioactive material
  - Prevention of nuclear criticality when the material is fissile

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Containment

- First consider the chemical or biological hazard, it often poses a greater risk than the radiological hazard.
- Then choose the most appropriate package from:
  - Type A
  - Type B (U) or (M)
  - LSA - low specific activity
  - Low level solid
  - Exempt

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Type A (solids)

- Limited total activity - limits in A_1 (special form) and A_2 tables
- Water spray test from all sides simulating 5cm per hour rainfall for at least 1 hour, immediately followed by a
- Drop test from 1.2m to flat surface
- Stacking compression load of 5 × mass of package or 13kPa × vertical area of package for 24 hours
- Penetration test 3.2cm diameter 6kg bar with hemispherical end dropped from 1m onto weakest point of package

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Type A (liquids and gasses)

- All previous Type A tests +
- Drop test from 9m then,
- Penetration test from 1.7m
- and absorbent material inside inner package to absorb twice the volume of liquid

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Type B

- No limit to activity
- All Type A tests then,
- Drop from 9m to flat surface then,
- Drop from 1m to the top of a perpendicular, rigid, circular, 15cm diameter bar then,
- Drop a 500kg flat 1m × 1m plate from 9m onto the package then,
- Fully engulfed 800^{O}C fire for at least 30 minutes with no assisted after-cooling then,
- Immersed under a 15m head of water for at least 8 hours

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Other Types

- LSA - low specific activity
  - Industrial packaging type IP-1, IP-2 or IP-3
- Low level solid
  - LSA + conditions
- Exempt
  - Activity > $A_2 \times 10^{-3}$
  - Any substance with < 70kBq per kg specific activity is not a radioactive substance according to the ADG Code.

Criteria	IP-1	IP-2	IP-3
Design requirements	• General requirements for all packages • Additional pressure and temperature requirements if transported by air	• General requirements for all packages • Additional pressure and temperature requirements if transported by air	• General requirements for all packages • Additional pressure and temperature requirements if transported by air • Type A additional requirements
Test requirements - normal transport conditions		• Free drop (from 0.3 to 1.2 metres, depending on the mass of the package) • Stacking or compression	• Each of the following tests must be preceded by a water spray test: • free drop (from 0.3 to 1.2 metres, depending on the mass of the package) • stacking or compression • Penetration (6kg bar dropped from 1 metre

Transport Index

- TI = The Dose Rate in mSv per hour @ 1m from the surface of the package × 100 (or μSv per hr @ 1m ÷10)
- TI For criticality control = N/50 where N is:
  - one fifth of the no. of packages which would remain sub -critical when stacked in any arrangement and surrounded by water AND
  - one half of the no. of packages which would remain sub -critical when stacked in any way separated by and surrounded by the most effective moderator available

Shielding

- **Category I – White**
  - Radiation level at surface < 5μSv.h^{-1}
  - package not Fissile Class II or Class III
- **Category II – Yellow**
  - Radiation level at surface between 5 and 500μSv.h^{-1}
  - transport index < 1.0
  - package not Fissile Class III
- **Category III – Yellow**
  - Radiation level at surface between 500 and 2000μSv.h^{-1}
  - transport index < 10

Placarding

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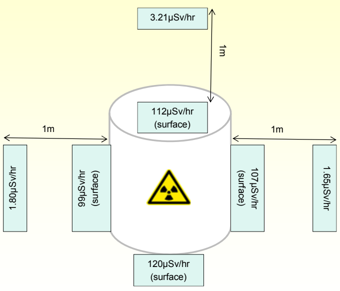
Heat and Criticality

- Heat
  - maximum temperature shall not exceed 82°C in the shade
- Criticality
  - Fissile Class I – safe under all circumstances
  - Fissile Class II – limited numbers are safe under all circumstances TI must be < 50
  - Fissile Class III – safe by reason of special precautions

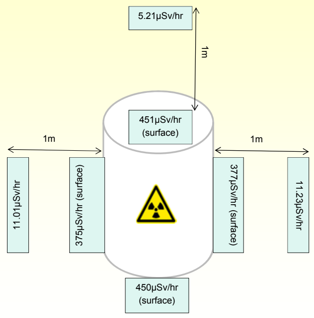
Exercise



Exercise

- TI = The Dose Rate in mSv per hour at 1m from the surface of the package × 100
- $3.21\mu Sv.h^{-1}$ @1m = $0.00321mSv.h^{-1}$
- TI = 0.00321 x 100 = 0.321
- Max surface dose rate = 120 $\mu Sv.h^{-1}$
- Therefore **Category II – Yellow**

Exercise



Exercise

- TI = The Dose Rate in mSv per hour at 1m from the surface of the package × 100
- 11.23µSv.h^{-1} @1m = 0.01123mSv.h^{-1}
- TI = 0.01123 x 100 = 1.123
- Max surface dose rate = 451 µSv.h^{-1}
- Therefore **Category III – Yellow**

Security

- The source container should be;
  - Secured as far away from the driver as possible (usually rear left)
  - Securely restrained with bolts or steel tie downs (not just ropes)
  - Never left unattended

Security

- If the vehicle is to be parked overnight
  - Must be in a secure area (eg a locked garage)
  - Remove source to secure area if carpark is not secure
  - Park rear end in
  - Remove placards if source is removed

Source Security

- A/D = Activity (GBq) / D-Value (GBq)
  - D-Value comes from Table B2

Category 1	**A/D ≥ 1000**
Category 2	**1000 > A/D ≥ 10**
Category 3	**10 > A/D ≥ 1**
Category 4	**1 > A/D ≥ 0.01**
Category 5	**0.01 > A/D**

- Category 1, 2, 3 = Security Enhanced Sources

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Transport Security Plans

- Category 1, 2, 3 sources require a Transport Security Plan
  - particulars of the security enhanced source to be transported;
  - particulars of the transport arrangements for the source;
  - particulars, and an assessment, of all the security risks relating to the transport of the source the transport security plan holder of the plan knows, or ought reasonably to know, exist or might arise;
  - persons who have access to the source and the type of access each person has to the source;
  - other persons to whom the plan applies;
  - the period for which the plan applies;

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Transport Security Plans

- Category 1, 2, 3 sources require a Transport Security Plan
  - the transport security measures for the source;
  - any other measures necessary to deal with risks to the security of the source;
  - how the transport security plan holder proposes to monitor and review the implementation and effectiveness of the measures;
  - particulars of a training program for persons to whom the plan applies;
  - if the transport security plan holder is a corporation—the name of the nominated person for the holder;
  - other particulars prescribed under a regulation

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