Attachment for Exam Radiation protection expert on the level of coordinating expert

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University of Groningen	RUG
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exam date:
December 9th 2019
exam duration: 13.30 - 16.30 hours

Instructions:

- If you use any data other than the data mentioned in this attachment, state the origin!
- This attachment consists of 14 consecutively numbered pages. Check this!

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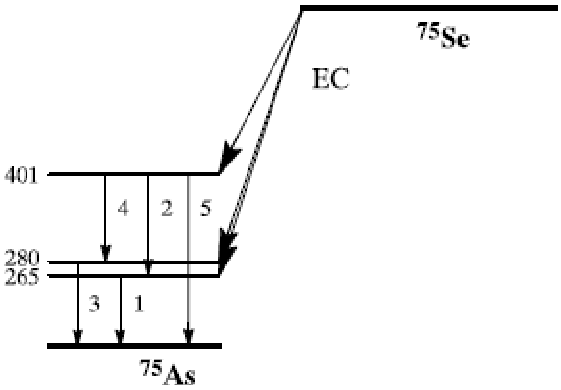
Handboek Radionucliden, A.S. Keverling Buisman (3rd edition 2015), data ^{75}Se

^{75}Se Z = 34

Half-life and decay constant

$T_{1/2}$ = 119,76 d = 1,03×10^7 s λ = 6,70×10^{-8} s^{-1}

Decay scheme (simplified)



Main emitted radiation

Straling	y (Bq·s)$^{-1}$	E (keV)	Straling	y (Bq·s)$^{-1}$	E (keV)
γ_1	0,594	265	K_α	0,481	11
γ_2	0,606	136	K_β	0,047	12
γ_3	0,252	280	KLL	0,315	9
γ_4	0,177	121	KLX	0,099	10
γ_5	0,113	401	LMX	1,309	1

Source constants

Kermatempo in lucht	k = 0,15 µGy/h per MBq/m^2
Omgevingsdosisequivalenttempo	h = 0,072 µSv/h per MBq/m^2

Miscellaneous

Specifieke activiteit	A_{sp} = 5,37×10^{14} Bq/g
Vrijstellingsgrenzen	C_v = 10^2 Bq/g en A_v = 10^6 Bq
Huidbesmetting	H_{huid} = 4×10^{-11} Sv/s per Bq/cm^2
Wondbesmetting; Injectie	$e(50)$ = 2,5×10^{-9} Sv/Bq
Vervoer	A_1 = 3 TBq
	A_2 = 3 TBq

Productie en toepassingen

Het radionuclide ^{75}Se is een activeringsproduct: ^{74}Se(n,γ)^{75}Se. Het wordt gebruikt voor neutronen-activeringsanalyse, in de nucleaire geneeskunde en bij gammagrafie.

N = 41 **^{75}Se**

Metabolic model

Voor stralingshygiënische doeleinden wordt aangenomen dat selenium zich vanuit het bloed als volgt verdeelt:

Fractie	Orgaan	Fractie	Orgaan
0,25	lever	0,005	alvleesklier
0,10	nieren	0,001	gonaden
0,01	milt	0,634	overige

De biologische halveringstijd voor alle organen/weefsels wordt aangenomen te zijn:

Fractie	$T_{1/2}$	Fractie	$T_{1/2}$	Fractie	$T_{1/2}$
0,1	3 d	0,4	30 d	0,5	200 d

N.B. Dit model geldt niet voor patiënten, zie pagina 14.

Ingestion and lung clearance classes

Ingestie		
Elementair Se, selenide	f_1 = 0,05	
Overige verbindingen	f_1 = 0,8	
Inhalatie		
Hydroxide, oxide, carbide	f_1 = 0,8	Klasse M
Elementair Se	f_1 = 0,8	Klasse M
Overige	f_1 = 0,8	Klasse F

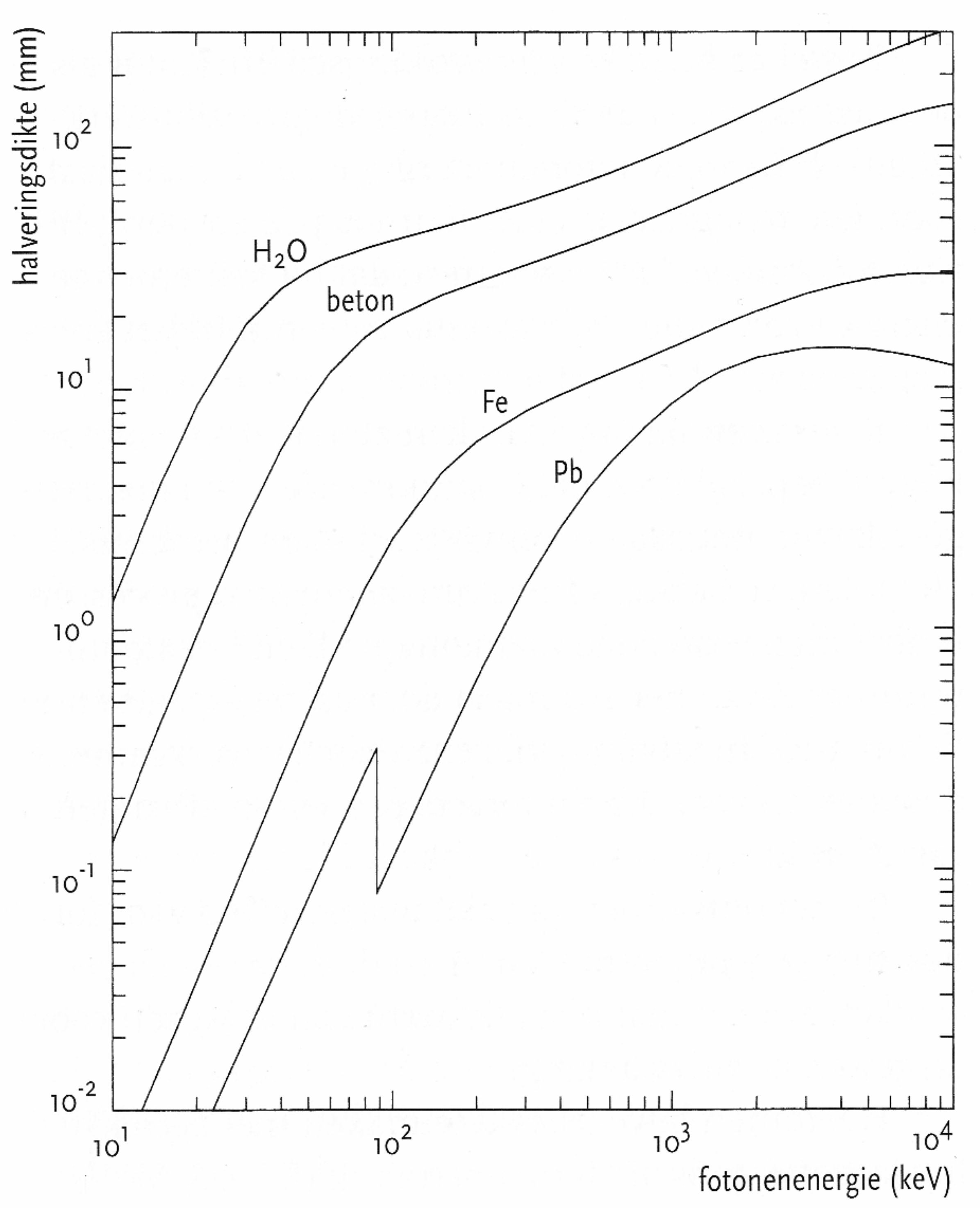
Dose conversion coefficient and radiotoxicity equivalent for workers (w) and members of the public (b)

	Ingestie	Ingestie	Inhalatie	Inhalatie	
	f_1 = 0,05	f_1 = 0,8	F	M	
$e(50)$(w)	4,1×10^{-10}	2,6×10^{-9}	1,4×10^{-9}	1,7×10^{-9}	Sv/Bq
A_{Re}(w)	2,4×10^{9}	3,8×10^{8}	7,1×10^{8}	5,9×10^{8}	Bq
$e(50)$(b)	4,1×10^{-10}	2,6×10^{-9}	1,0×10^{-9}	1,4×10^{-9}	Sv/Bq
A_{Re}(b)	2,4×10^{9}	3,8×10^{8}	1,0×10^{9}	7,1×10^{8}	Bq

Data for total body count count (after single intake)

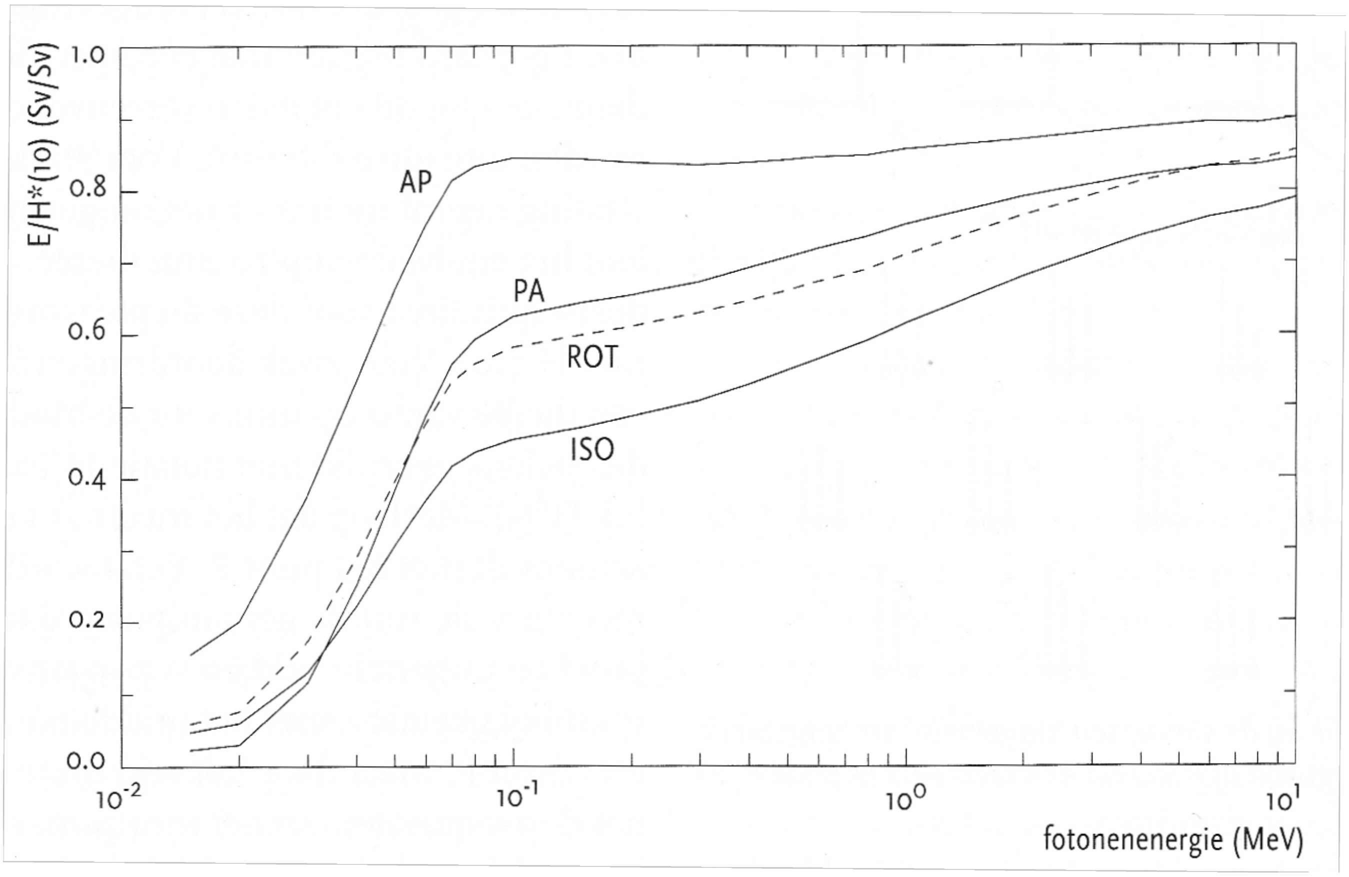
Time (d)	Activity in total body (Bq per Bq intake)			
0,25	9,9×10^{-1}	9,9×10^{-1}	7,4×10^{-1}	7,4×10^{-1}
1	7,2×10^{-1}	9,1×10^{-1}	5,8×10^{-1}	5,7×10^{-1}
2	3,5×10^{-1}	8,1×10^{-1}	4,8×10^{-1}	4,5×10^{-1}
3	1,7×10^{-1}	7,5×10^{-1}	4,3×10^{-1}	4,0×10^{-1}
5	6,0×10^{-2}	6,9×10^{-1}	3,9×10^{-1}	3,6×10^{-1}
7	4,3×10^{-2}	6,5×10^{-1}	3,7×10^{-1}	3,4×10^{-1}

Bos et al., figure 11-1; Half-value layer of some shielding materials for narrow beam photon radiation.



Bos et al., figure 11-1; Half-value layer of some shielding materials for narrow beam photon radiation.

Bos *et al.*, figure 6-7; Ratio of the effective dose E and the ambient dose equivalent H*(10) as function of the photon energy for four different irradiation geometries.



Ratio of the effective dose E and the ambient dose equivalent H*(10) as function of the photon energy for four different irradiation geometries.

Attachment radionuclide laboratories of the KEW-license of the hospital.

2.2 Criteria with regard to internal contamination

2.2.1 Method of defining individual operations

The risk of internal contamination is important for the classification of operations. When operations are classified, it is assumed that internal contamination in a radiological workplace can be caused by radioactive substances that are spread during operations. As previously stated, the possible radiation dose, which the workers present in the workplace receive by inhaling a radioactive substance, determines the risk. If the main risk is expected to be posed by ingestion, this will have to be proven and a different system will have to be chosen.

The amount that can be inhaled depends on the risk of spread for an operation, on the protection that the laboratory area offers, and on the local ventilation facility. The radiotoxicity of the inhaled substance is important for the radiation dose caused by a particular internal contamination. With the risk of internal contamination in mind, the allowed work amounts for B, C and D workplaces are based on the inhalation dose coefficient, which will hereinafter be indicated by $e(g)_{inh}$ for stochastic effects. This $e(g)_{inh}$ is used for the calculations. The values for this formula are shown in table 5 of Appendix 4 of the Radiation Protection Decree (Bulletin of Acts and Decrees 397. 2001). The actual definition is expressed in radiotoxicity equivalents for inhalation [Re_{inh}].

Using formula (2.1), the value can be determined of the maximum permissible amount of applicable activity expressed in the radiotoxicity equivalent for inhalation [Re_{inh}] under certain circumstances or in the event certain measures are taken. This mainly concerns the risk of spread, the protection of the workplace and the local ventilation. Parameters regarding the above-mentioned aspects have been included in this formula:

$$X_{max,\, j} = 0{,}02 \; * \; 10^{p+q+r} \; [Re_{inh}] \tag{2.1}$$

where:

$X_{max,\, j}$	= maximum number of radiotoxicity equivalents [Re_{inh}] that may be used simultaneously per operation j (X is independent of the radionuclide)
0,02	= dose limit for exposed workers [*Sv*]
p	= parameter for the risk of spread
q	= protection parameter of the workspace
r	= parameter for the local ventilation facility.

The maximum amount of radioactivity of a radionuclide i that may be applied under those circumstances is determined using the following formula:

$$A_{max,\; j,\, i} = \frac{X_{max,\, j}}{e(g)_{inh,j}} \qquad [Bq] \tag{2.2}$$

where:

$A_{max,\, j,\, i}$	= maximum applicable activity [Bq] for operation j and radionuclide i.
$X_{max,\, j}$	= number of radiotoxicity equivalents [Re_{inh}] that may be used simultaneously per operation j (X is independent of the radionuclide)
$e(g)_{inh,\, i}$	= inhalation dose coefficient [Sv/ Bq] for stochastic effects of radionuclide i.

The $e(g)_{inh,\, i}$ and the p, q and r parameters will be explained below.
The different parameters from the formula will first be described. Then the calculation of the maximum amounts for use will be discussed.

2.2.2 Inhalation dose coefficient $e(g)_{inh}$

The value of the factor 10^{p+q+r} is the factor that must be taken into account when the maximum amount of radioactivity allowed for work is determined. This factor is a measure of the amount of radioactivity that may cause a radiation dose as a result of contamination.

In order to determine the maximum amount of radioactivity allowed for work, the factor 10^{p+q+r} must be divided by the inhalation dose coefficient $e(g)_{inh}$ and multiplied by the dose limit for exposed workers for stochastic effects (0.02 Sv).

The inhalation dose coefficient $e(g)_{inh}$ is taken from table 5 of Appendix 4 of the Radiation Protection Decree.

2.2.3 Spread parameter *p*

The parameter *p* was introduced to allow the risk of spread of radioactive substances to be determined. The risk of spread not only depends on the form of the substance, but also on the nature of the operations. The parameter *p* is determined here by the risk of spread of radioactive substances during certain operations. This list is shown in table 2.

Table 2: Value of the spread parameter *p* for certain operations within the laboratory

APPLICATION	*p*
Simple operation with gases Using powders in an 'open' system, e.g. mixing or grinding Liquid with temperature approaching the boiling point Operations involving considerable splashing	- 4
Labelling with volatile nuclide (e.g. iodine) Boiling with liquids in a 'closed' system Spinning and mixing on a vortex Simple processing of powders in a ‘closed’ system Storage of noble gas in an administration system	- 3
Labelling with non-volatile nuclide Simple chemical determination with tracers (e.g. RIA)	- 2
Simple operations in ‘closed’ systems, such as: Elution Tc generator Syringe filling Labelling in closed systems Calibration I-131 capsule Measurements of substances in poorly dispersible form (e.g. in ampoules) Storage of radioactive waste in workspaces	- 1

The elution of a Mo/TC generator is a special application. The operations can be regarded as operations with Tc-99m. For storage, Mo-99 should naturally be assumed.

In practice, operations that are not listed will have to be given a *p* value that has been assigned to operations with a similar risk of spread.

2.2.4 Protection parameter *q*

The amount of radioactivity that may be used in a given workspace partly depends on the parameter *q* for the protection that the space offers. This accounts for the effect of the protection provided by the existing facilities, such as ventilation, vacuum and sluice. The expertise of the supervisor, the classification of the exposed worker and a stricter admission regime are also taken into account. The following values may be used for *q*:

$q = 0$ Workspaces outside the laboratory control
$q = 1$ D Laboratory
$q = 2$ C Laboratory
$q = 3$ B Laboratory.

2.2.5 Ventilation parameter *r*

The parameter *r* for the local ventilation facility is assigned as follows:

$r = 0$ For working outside the fume hood without supplementary ventilation facilities
$r = 1$ This value may be used in the case of local exhaust ventilation or a fume hood that has not been tested according to DIN-12924, but for which it has been established that less than 10% of the amount of substance that is released in the fume hood will enter the workspace.
$r = 2$ This applies in the case of a good fume hood, understood as one in which less than 1% of the substance released in the fume hood enters the workspace. Fume hoods that have been qualified according to DIN-12924 and contain no setup that seriously disrupts the airflow, or laminar air flow insulators (Class II safety cabinets), will generally comply with this standard.
$r = 3$ Closed work cabinet. This refers to a Class III cabinet for biological safety with a qualification according to NEN-EN 12469, or a closed laminar air flow insulator that meets these requirements.

The value that may be used to determine the maximum applicable amount must be seen in connection with the value of *q*. In order to ensure that the amounts that may be applied in the different laboratory categories are balanced, the value of *r* must be limited in accordance with that category. In calculations, the value of *r* may therefore never be greater than *q*. Obviously, superior facilities (i.e. with a higher *r*) may be used.

2.2.6 Maximum amount of radioactivity permissible for certain operations

The number of radiotoxicity equivalents $X_{j,i}$, corresponding to an amount of activity $A_{j,i}$ of radionuclide *i* to be applied during an operation *j*, is equal to:

$$X_{j,i} = A_{j,i} * e(g)_{inh,i} \qquad (2.3)$$

where:

$X_{j,i}$ = the number of radiotoxicity equivalents [Re_{inh}] used during operation *j* with radionuclide *i*
$A_{j,i}$ = activity [Bq] that must be applied simultaneously for each operation *j* with radionuclide *i*
$e(g)_{inh,i}$ = inhalation dose coefficient [Sv/ Bq] for stochastic effects of radionuclide *i*.

Main contributors to the calculated absorbed organ dose through injection of the radiopharmaceutical.

Organ	Gy/MBq
Bone surface	1.15
Large intestine (lower part)	0.046
Large intestine (upper part)	0.032
Red bone marrow	0.14

Tissue weighing factors according to ICRP-60

organ		w_T
gonads		0.20
large intestine		0.12
upper part large intestine:	0.07 (ICRP-30)	
lower part large intestine:	0.05 (ICRP-30)	
lungs		0.12
stomach		0.12
red bone marrow		0.12
breast tissue		0.05
bladder		0.05
liver		0.05
thyroid		0.05
esophagus		0.05
bone surface		0.01
skin		0.01

Art.10.3 Decree basic safety standards for radiation protection (Government gazette 2017, nr. 404)

Article 10.3 (exemption discharge ban)

1. A ban as referred to in article 3.5 in conjunction with article 3.8, fourth paragraph, under c, on the acting without authorization through which airborne or liquid radioactive substances are released into the environment, is not applicable when:
   a. for discharge into the air, the activity of the total amount of discharged radioactive substances when leaving the location via a discharge point in a year is lower than 1 radiotoxicity equivalent for inhalation as referred to in attachment 2;
   b. for discharge into the public sewage system, the activity of the total amount of discharged radioactive substances when leaving the location via a discharge point in a year is lower than 10 radiotoxicity equivalent for ingestion as referred to in attachment 2;
   c. for discharge into the surface water, the activity of the total amount of discharged radioactive substances when leaving the location via a discharge point in a year is lower than 0.1 radiotoxicity equivalent for ingestion as referred to in attachment 2.
2. The discharged amounts, expressed in radiotoxicity equivalents, are corrected for physical decay using the correction factors as included in attachment 2.

Correction factors for discharge into water

Table 4.9 Correction factor (CRw) for discharge into water, depending on the physical half-life ($T_{1/2}$, phys) of the discharged nuclide

Physical half-life $T_{1/2, phys}$	Correction factor for discharge into water CR_w
$T_{1/2, phys} \leq$ 5 days	0.001
$T_{1/2, phys} \leq$ 7.5 days	0.01
$T_{1/2, phys} \leq$ 15 days	0.1
$T_{1/2, phys} \leq$ 25 year	1
$T_{1/2, phys} \leq$ 250 year	10
$T_{1/2, phys}$ > 250 year	100

ICRP 33 figure 11, Broad-beam transmission of X-rays through concrete. For the values where the curves cross the y-axis, see caption.

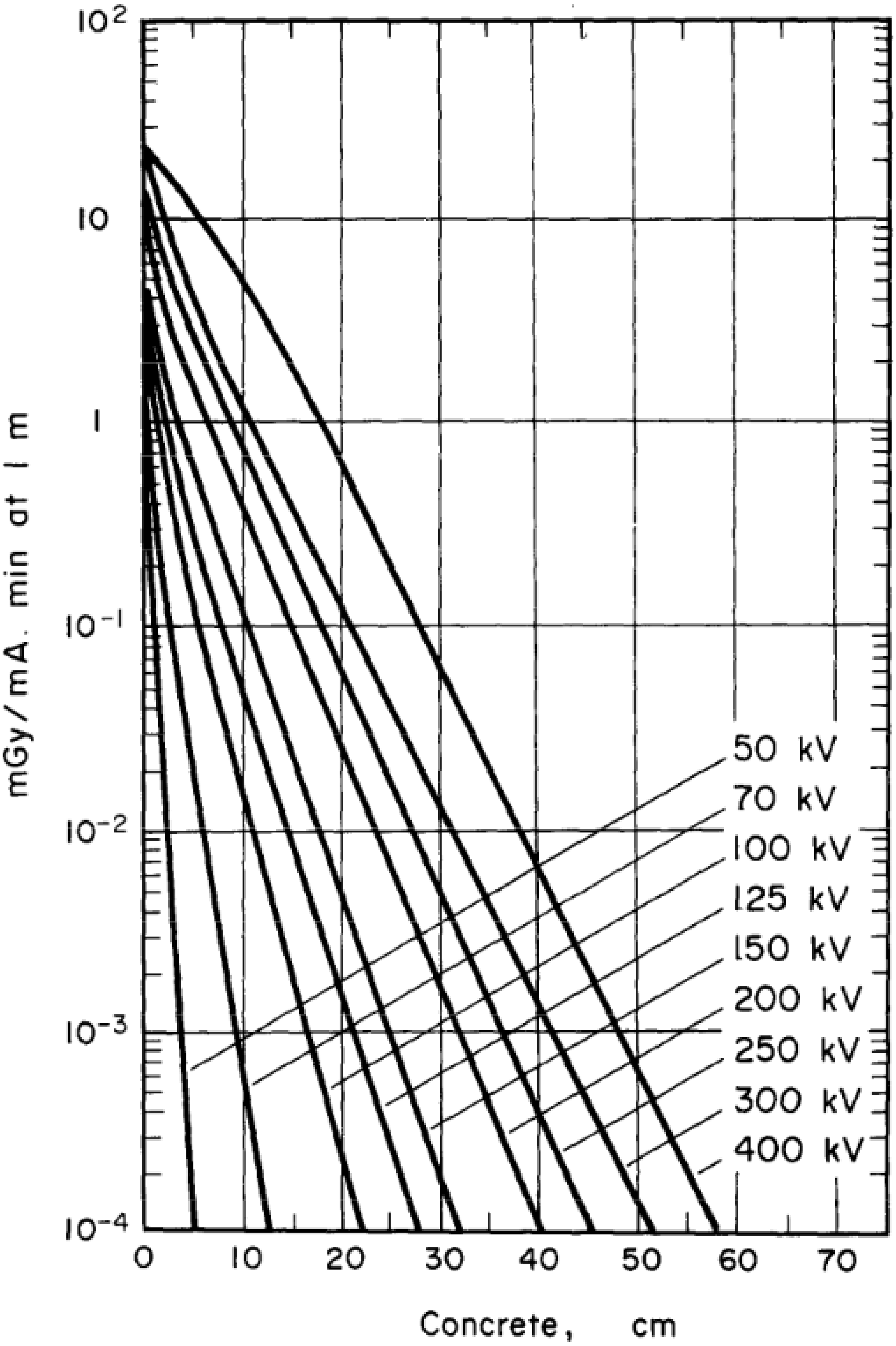


Fig. 11. Broad-beam transmission of x rays through concrete, density 2 350 kg m^{-3}. 50–300 kV: half-wave generator; tungsten reflection target; total beam filtration 1 mm aluminium at 50 kV, 1.5 at 70, 2 at 100, and 3 at 125–300. 400 kV: constant potential generator; gold reflection target; 3 mm copper total beam filtration. Ordinate intercepts are 23.5 at 400 kV, 20.9 at 300, 13.9 at 250, 8.9 at 200, 5.2 at 150, 3.9 at 125, 2.8 at 100, 2.1 at 70, 1.7 at 50.

ICRP 33 figure 22, Scattering patterns of divergent X-ray and gamma ray beams normally incident on a flat concrete wall.

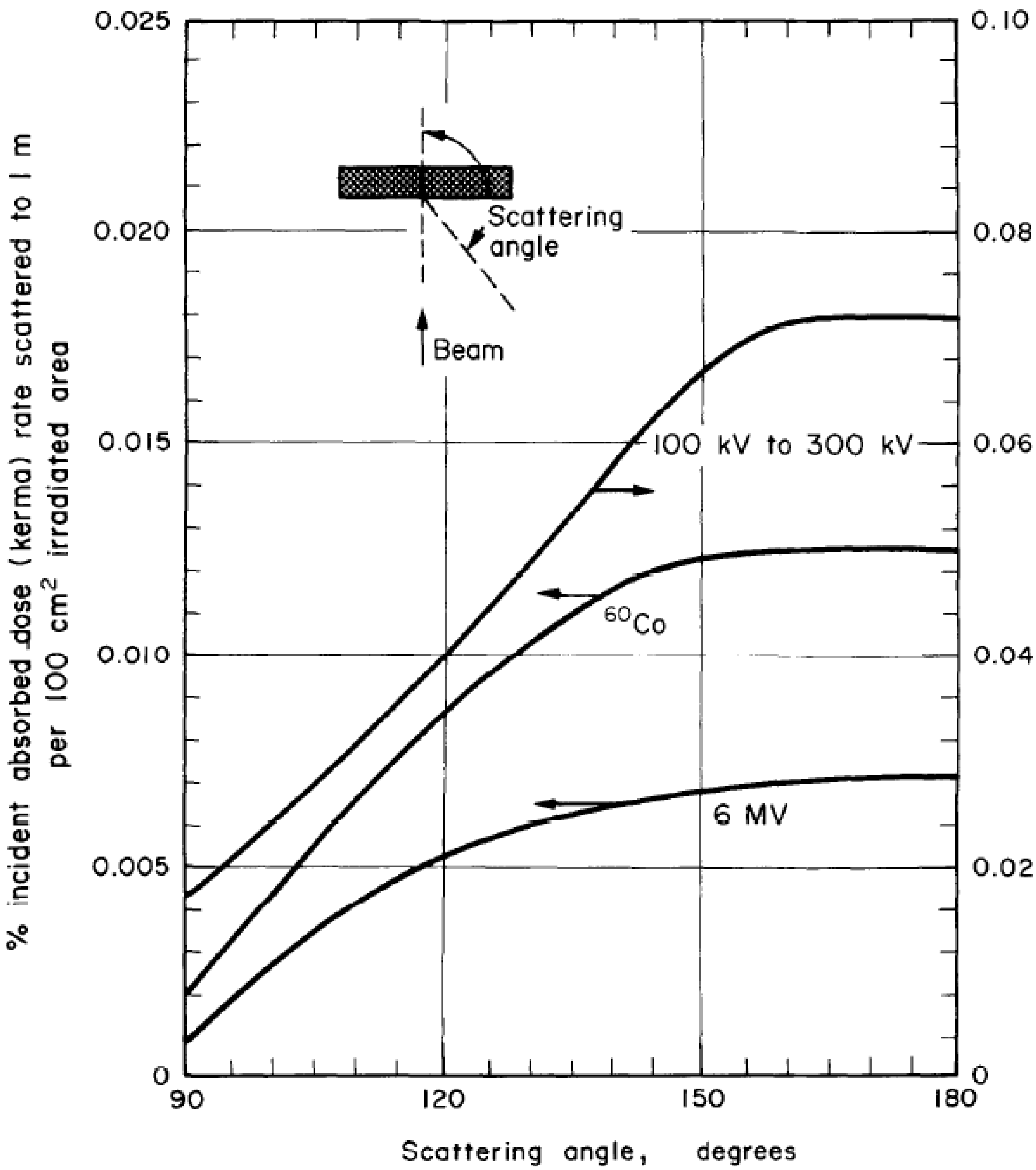


Fig. 22. Scattering patterns of diverging x-ray and gamma-ray beams normally incident on a concrete shield. Per cent scatter is related to primary beam measurements in free air at the point of incidence.

Mass attenuation, energy transfer and energy absorption cross-sections in lead.

Photon energy E (MeV)	μ/ρ (m^2/kg)	μ_{tr}/ρ (m^2/kg)	μ_{en}/ρ (m^2/kg)
0.01	13.66	13.1	13.07
0.02	8.55	6.92	6.91
0.03	2.91	2.46	2.46
0.04	1.38	1.183	1.178
0.05	0.771	0.657	0.654
0.06	0.487	0.411	0.408
0.08	0.237	0.1924	0.1908
0.1	0.578	0.228	0.228
0.15	0.207	0.1164	0.1154
0.2	0.1014	0.0637	0.0629
0.4	0.0233	0.01474	0.01432
0.5	0.01614	0.00984	0.00951
0.6	0.01249	0.00737	0.00710
0.8	0.00886	0.00503	0.00481
1	0.00708	0.00396	0.00377