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

Nuclear Research and consultancy Group	NRG
Delft University of Technology	TUD
University of Groningen	RUG
Radboudumc	RUMC

exam date:

December 14th 2020

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 12 consecutively numbered pages. Check this!

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Handboek Radionucliden, A.S. Keverling Buisman (3rd edition 2015), ^{60}Co data

^{60}Co

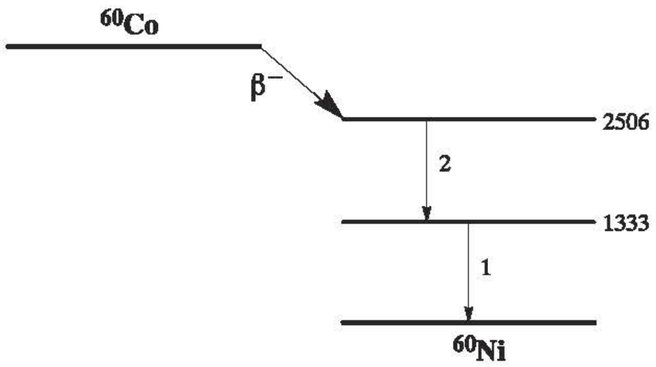
Z = 27

Half-life and decay constant

$T_{1/2} = 5{,}272$ j $= 1{,}66 \times 10^8$ s

$\lambda = 4{,}17 \times 10^{-9}$ s^{-1}

Decay scheme (simplified)



Main emitted radiation

Straling	y (Bq·s)$^{-1}$	E (keV)
β^-	0,999	96 | 318
γ_1	1,000	1333
γ_2	0,999	1173

Source constants

Air kerma rate	k = 0,31 µGy/h per MBq/m^2
Ambient dose equivalent rate	h = 0,36 µSv/h per MBq/m^2

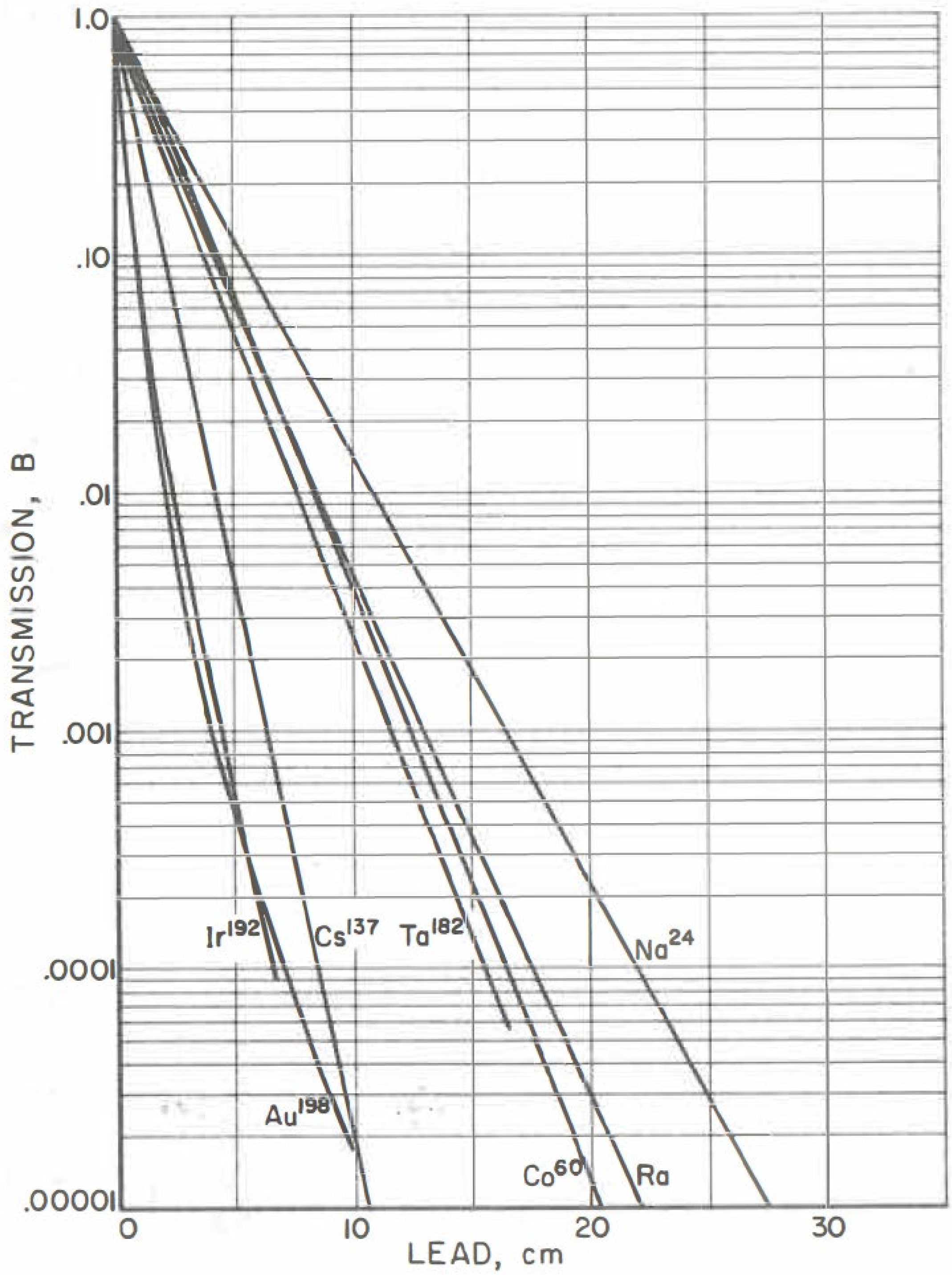
Miscellaneous

Specific activity	A_{sp} = 4,18×10^{13} Bq/g
Exemption levels	C_v = 10^0 = 1 Bq/g !!
Skin contamination	A_v = 10^5 Bq
Wound contamination / injection	H_{huid} = 3×10^{-10} Sv/s per Bq/cm^2
Transport	$e(50)$ = 1,9×10^{-8} Sv/Bq
	A_1 = 0,4 TBq
	A_2 = 0,4 TBq

Productie en toepassingen

Het radionuclide ^{60}Co is een activeringsproduct. Het komt voor als bijproduct in reactoren ten gevolge van de activering van staal. Daarnaast wordt het op velerlei terreinen toegepast. Voorbeelden zijn: radiotherapie, gammagrafie, doorstraling, ijking, demonstratie.

Radiological Health Handbook pg. 148, transmission data of several gamma sources through lead



Transmission through lead of gamma rays from radium [14]; cobalt 60, cesium 137, gold 198 [7]; iridium 192 [15]; tantalum 182 and sodium 24 [29].

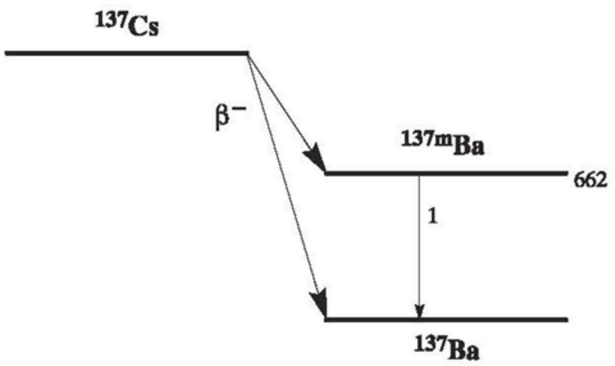
Handboek Radionucliden, A.S. Keverling Buisman (3rd edition 2015), ^{137}Cs data

^{137}Cs   Z = 55

Half-life and decay constant

$T_{1/2} = 30{,}25$ j $= 9{,}55 \times 10^8$ s $\lambda = 7{,}26 \times 10^{-10}$ s^{-1}

Decay scheme (simplified)



Main emitted radiation   **From 137mBa (t1/2 =2.55 min; y =0.946**

Straling	y (Bq·s)$^{-1}$	E (keV)	Straling	y (Bq·s)$^{-1}$	E (keV)
β$^-$	0,946	173 | 512	γ_1	0,898	662
β$^-$	0,054	425 | 1173	ce K γ_1	0,083	624

Source constants (of daughter ^{137m}Ba in equilibrium with ^{137}Cs)

Air kerma rate	k = 0,077 µGy/h per MBq/m^2
Ambient dose equivalent rate	h = 0,093 µSv/h per MBq/m^2

Miscellaneous

Specific activity	A_{sp} = $3{,}19 \times 10^{12}$ Bq/g
Exemption levels	C_v = 10^1 Bq/g en $A_v = 10^4$ Bq
Skin contamination	H_{huid} = 5×10^{-10} Sv/s per Bq/cm^2 (incl. ^{137m}Ba)
Wound contamination / injection	$e(50)$ = $1{,}4 \times 10^{-8}$ Sv/Bq (incl. ^{137m}Ba)
Transport	A_1 = 2 TBq
	A_2 = 0,6 TBq

Productie en toepassingen

Het radionuclide ^{137}Cs is een belangrijk splijtingsproduct. Het wordt onder meer gebruikt als gamma-referentiebron en als bron bij brachytherapie.

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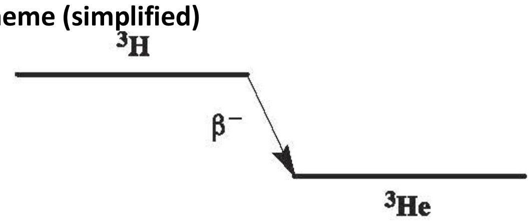
Handboek Radionucliden, A.S. Keverling Buisman (3rd edition 2015), ^{3}H data

^{3}H Z = 1

Half-life and decay constant

$T_{1/2}$ = 12,35 j = 3,90×10^{8} s λ = 1,78×10^{-9} s^{-1}

Decay scheme (simplified)



Main emitted radiation

Straling	y (Bq·s)$^{-1}$	E (keV)
β⁻	1,000	5,7 | 18,6

Miscellaneous

Specific activity	A_{sp} = 3,57×10^{14} Bq/g
Exemption levels	C_v = 10^{6} Bq/g en A_v = 10^{9} Bq
Skin contamination	H_{huid} < 10^{-14} Sv/s per Bq/cm^{2}
Wound contamination / injection	$e(50)$ = 1,8×10^{-11} Sv/Bq (water)
Transport	$e(50)$ = 4,1×10^{-11} Sv/Bq (organisch)
	A_1 = 40 TBq
	A_2 = 40 TBq

Productie en toepassingen

Tritium wordt geproduceerd door bestraling van lithium met neutronen: ^{6}Li(n,α)^{3}H. Tritium ontstaat ook op natuurlijke wijze. Het wordt gevormd in de buitenste lagen van de atmosfeer, door interactie van kosmische straling met stikstof, voornamelijk via de reactie ^{14}N(n,^{3}H)^{12}C. Zodoende komt tritium voor in de biosfeer: de tritium-concentratie in zeewater ten gevolge van het natuurlijke tritium bedraagt 0,1–1 Bq/l. De tritiuminventaris van de gehele aarde wordt geschat op 1–2 EBq. Door proeven met thermonucleaire explosies in de atmosfeer is hieraan inmiddels ongeveer 200 EBq toegevoegd. Elk persoon bevat hierdoor 100 Bq tritium.

Van de vele toepassingen van tritium zijn de volgende het belangrijkst:
– tritium-houdende trefplaat voor neutronengenerator via D,T-reactie;
– als lichtbron (o.a. EXIT-bord en horloge): β-light;
– als grondstof voor thermonucleaire reactie (waterstofbom)
– als merker van biologische verbindingen, o.a. voor geneesmiddelenonderzoek
– als merker bij geologische onderzoekingen, o.a. bij olie-exploratie
– als bron in een electroncapture-detector.

N = 2 ^{3}H

Metabolic Model
For radiation protection purposes, it is assumed that following inhalation and ingestion, all tritium is taken up in the body fully and instantaneously. Furthermore tritium is also taken up via intact skin. The biological half-life for all organs and tissues is set at:

Water T(1/2)		Organic (T1/2)	
97%	10 d	50%	10 d
3%	40 d	50%	40 d

Ingestion and lung clearance classes

Ingestie	
Alle verbindingen	$f_1 = 1$
Inhalatie	
Waterdamp	SR-2
Organisch	SR-2

For watervapour (waterdamp) an extra intake of 0.6 Bq/h per Bq/m^3 applies as a result of uptake via the skin

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

	Ingestie en inhalatie Water(damp)	Ingestie en inhalatie Organisch	
$e(50)$	$1{,}8\times10^{-11}$	$4{,}1\times10^{-11}$	Sv/Bq
A_{Re}	$5{,}6\times10^{10}$	$2{,}4\times10^{10}$	Bq

Data for urine analysis

After single intake

Time (d)	Activity in urine (Bq/l per Bq intake)	urine excretion rate (Bq/d per Bq intake)
1	$2{,}3\times10^{-2}$	$1{,}3\times10^{-2}$
2	$2{,}1\times10^{-2}$	$2{,}3\times10^{-2}$
3	$2{,}0\times10^{-2}$	$2{,}2\times10^{-2}$
5	$1{,}7\times10^{-2}$	$2{,}0\times10^{-2}$
7	$1{,}5\times10^{-2}$	$1{,}8\times10^{-2}$

Percentage radioactivity distribution over the organs after ^{123}I-IBZM administration

Percentage radioactivity distribution in different organs, measured in three time periods after administration of ^{123}I-IBZM. Data are mean ± standard deviation. The data has been corrected for the ^{123}I decay.

	Period 1 15–95 min	Period 2 180–270 min	Period 3 330–360 min
Total body	100[a]	86.7 ± 6.2[a]	75.9[a]
Brain	4.0 ± 0.7	2.0 ± 0.5	0.6
Kidneys	3.6 ± 0.7	2.9 ± 1.0	3.2
Bladder	1.6 ± 0.8	2.9 ± 1.8	10.0
Liver	14.6 ± 3.3	7.7 ± 0.8	5.8
Lungs	13.0 ± 4.2	5.9 ± 0.9	4.1
Spleen	2.7 ± 0.8	1.6 ± 1.0	1.1
Bowel	8.6 ± 3.4	14.0 ± 3.3	10.0
Gall-bladder	1.9 ± 1.0	3.9 ± 2.5	2.5
Heart	4.9 ± 1.5	2.4 ± 0.5	2.1
Thyroid	0.6 ± 0.6	0.5 ± 0.2	0.5
Parotid	0.2 ± 0.0	0.2 ± 0.1	0.1
Submandibular	0.4 ± 0.2	0.2 ± 0.1	0.2
Testes	0.2 ± 0.2	0.6 ± 0.1	0.3
Blood	5.5 ± 1.2	5.9 ± 0.6	5.1
Urine	0	13.3 ± 6.2	24.1

From: Dosimetry of iodine-123 iodobenzamide in healthy volunteers, Nicolaas P.L.G. Verhoeff e.a., European Journal of Nuclear Medicine, September 1993.

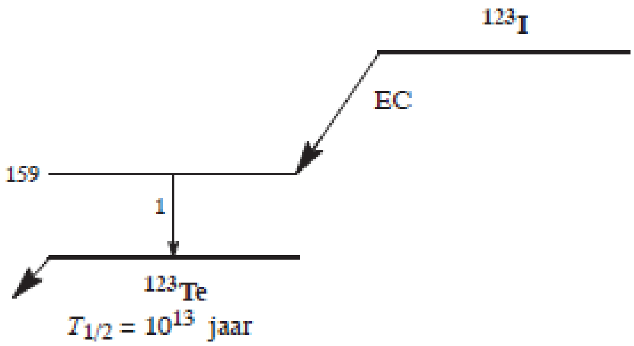
Handboek Radionucliden, A.S. Keverling Buisman (3rd edition 2015), ^{123}I data

^{123}I $Z = 53$

Half-life and decay constant

$T_{1/2} = 13{,}22$ h $= 4{,}76 \times 10^4$ s $\lambda = 1{,}46 \times 10^{-5}$ s^{-1}

Decay scheme (simplified)



Main emitted radiation

Straling	y (Bq·s)$^{-1}$	E (keV)	Straling	y (Bq·s)$^{-1}$	E (keV)
γ_1	0,828	159	KLL	0,082	23
ce K γ_1	0,135	127	LMM	0,606	3
K_α	0,704	27	LMX	0,311	4
K_β	0,158	31			

Source constants

Air kerma rate	k = 0,038 µGy/h per MBq/m^2
Ambient dose equivalent rate	h = 0,046 µSv/h per MBq/m^2

Miscellaneous

Specific activity	A_{sp} = $7{,}13 \times 10^{16}$ Bq/g
Exemption levels	C_v = 10^2 Bq/g en $A_v = 10^7$ Bq
Skin contamination	H_{huid} = 1×10^{-10} Sv/s per Bq/cm^2
Wound contamination / injection	$e(50)$ = $2{,}1 \times 10^{-10}$ Sv/Bq
Transport	A_1 = 6 TBq
	A_2 = 3 TBq

Productie en toepassingen

Het radionuclide ^{123}I is een cyclotronproduct: protonen op xenon. Het wordt toegepast in de nucleaire geneeskunde voor diagnostische doeleinden.

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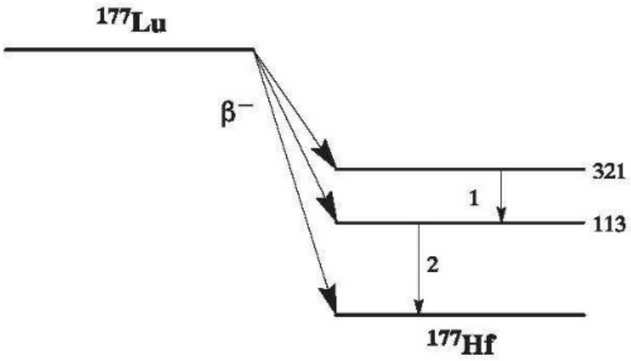
Handboek Radionucliden, A.S. Keverling Buisman (3rd edition 2015), ^{177}Lu data

^{177}Lu Z = 71

Half-life and decay constant

$T_{1/2} = 6{,}71\ \text{d} = 5{,}80\times10^{5}\ \text{s}$ $\lambda = 1{,}20\times10^{-6}\ \text{s}^{-1}$

Decay scheme (simplified)



Main emitted radiation

Straling	y (Bq·s)$^{-1}$	E (keV)
β^-	0,122	47 | 176
β^-	0,091	111 | 384
β^-	0,786	149 | 497
γ_1	0,110	208
γ_2	0,064	113
K_α	0,047	55

Source constants

Air kerma rate	k = 0,0043 µGy/h per MBq/m^2
Ambient dose equivalent rate	h = 0,0063 µSv/h per MBq/m^2

Miscellaneous

Specific activity	A_{sp} = 4,07×10^{15} Bq/g
Exemption levels	C_v = 10^3 Bq/g en A_v = 10^7 Bq
Skin contamination	H_{huid} = 4×10^{-10} Sv/s per Bq/cm^2
Wound contamination / injection	$e(50)$ = 5,0×10^{-10} Sv/Bq
Transport	A_1 = 30 TBq
	A_2 = 0,7 TBq

Mass attenuation coefficients of lead

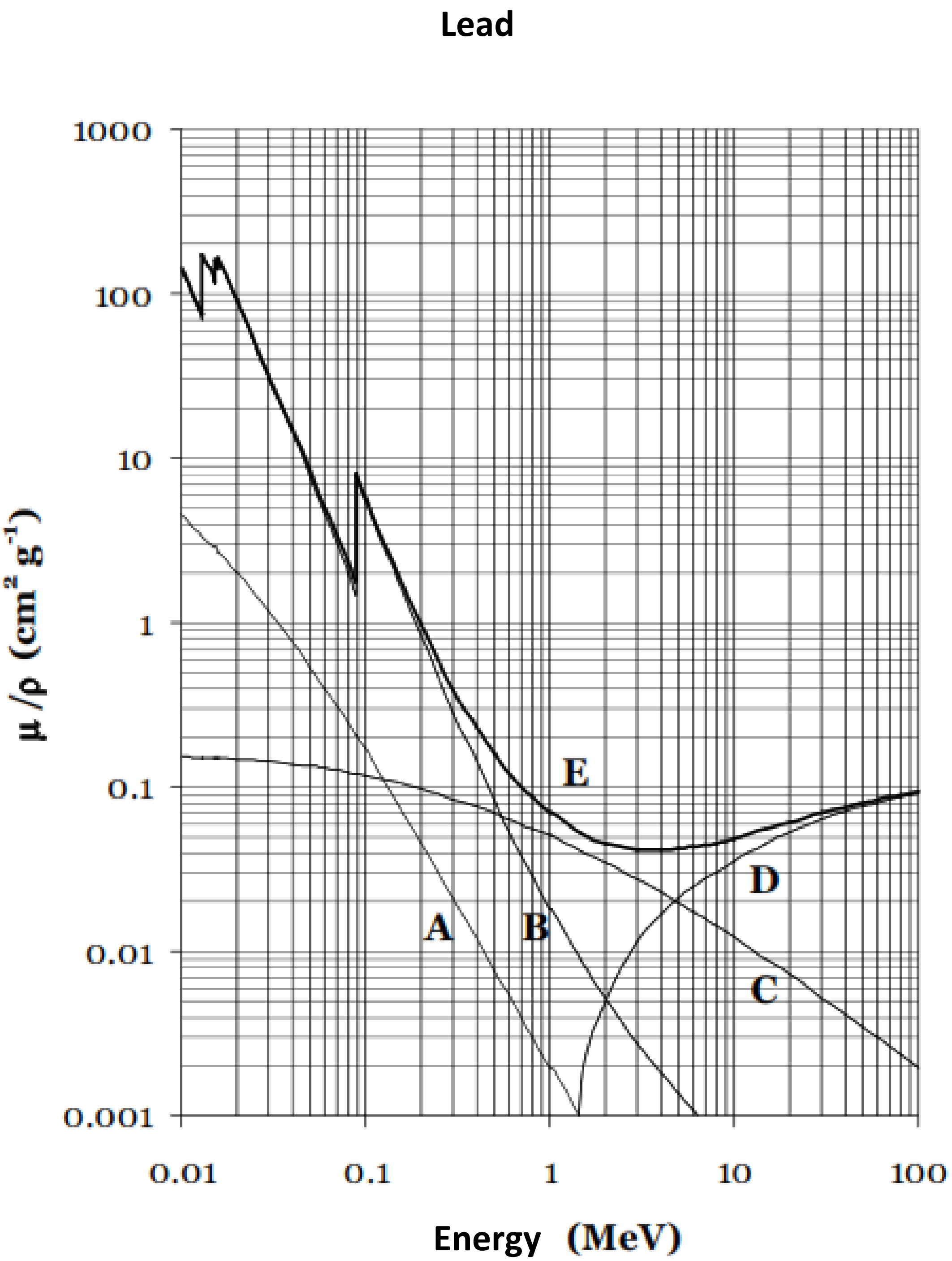
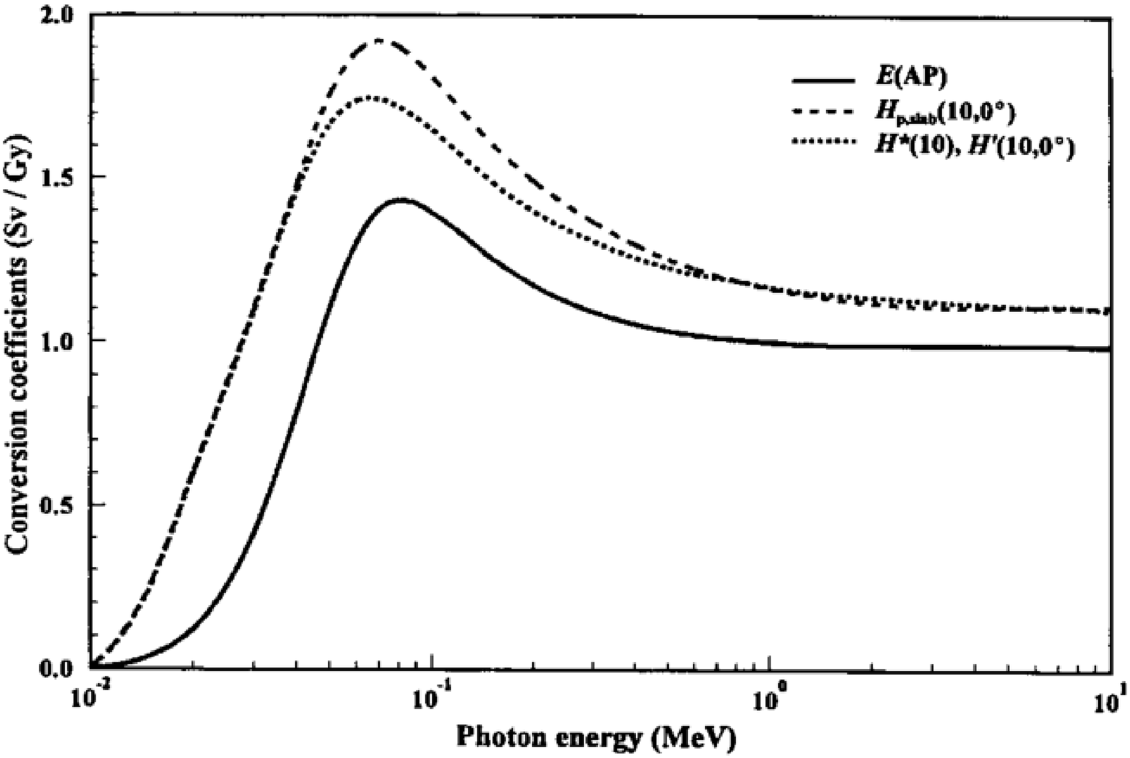


Figure 6.14 Mass attenuation coefficients of lead for (A) Rayleigh scattering, (B) photo electric effect, (C) Compton effect, (D) pair production and (E) the total mass attenuation coefficient μ/ρ

Conversion coefficients of air kerma to ambient dose equivalent as function of the photon energy



Conversion coefficients of air kerma K_a to ambient dose equivalent H(10), effective dose E(AP) in a phantom of an adult in the anterior-posterior geometry, and personal dose equivalent $H_{p,slab}(10)$ in an ICRU-slab.*