(9.4) What is the smallest amount of indium which can be determined in a 100 mg aluminum sample using NAA with a neutron flux of 10^{16} n m^{-2} s^{-1}? Consider neutron captures in ^{27}Al and ^{115}In (95.7% of In): $^{115}In(n,\gamma)^{116}In$ (σ 45 b, $t_{1/2}$ 14 s) and $^{27}Al(n,\gamma)^{28}Al$ (σ 0.23 b, $t_{1/2}$ 2.46 min.) The lowest detectable activity of ^{116}In is assumed to be 10 Bq, and the interference from ^{28}Al not more than 20%.

First the standard definitions:

$Bq := sec^{-1}$ $\qquad N_A := 6.022 \cdot 10^{23} \cdot mole^{-1}$

then the data given in the text:

$m_{tot} := 100 \cdot 10^{-3} \cdot gm$ $\qquad \phi := 10^{16} \cdot m^{-2} \cdot sec^{-1}$ $\qquad \sigma_{27Al} := 0.23 \cdot 10^{-28} \cdot m^2$

$\sigma_{115In} := 45 \cdot 10^{-28} \cdot m^2$ $\qquad R_{116In} := 10 \cdot Bq$ $\qquad R_{28Al} := \frac{20}{100} \cdot R_{116In}$

$t_{half116In} := 14 \cdot sec$ $\qquad t_{half28Al} := 2.46 \cdot 60 \cdot sec$

$\lambda_{116In} := \frac{ln(2)}{t_{half116In}}$ $\qquad \lambda_{28Al} := \frac{ln(2)}{t_{half28Al}}$

$m_{27Al} := m_{tot}$ Neglect the small amount of In

$M_{wAl} := 26.98 \cdot \frac{gm}{mole}$ $\qquad M_{wIn} := 114.82 \cdot \frac{gm}{mole}$ $\qquad x_{In} := \frac{95.7}{100}$

Compute the irradiation time from the requirement that ^{28}Al activity is = 20% of ^{116}In activity.

From § 15.2:

$N_{27Al} := \frac{m_{27Al}}{M_{wAl}} \cdot N_A$ $\qquad t_{irr} := \frac{-ln\left(1 - \frac{R_{28Al}}{\phi \cdot \sigma_{27Al} \cdot N_{27Al}}\right)}{\lambda_{28Al}}$ $\qquad t_{irr} = 8.296 \cdot 10^{-7} \cdot sec$

Then compute the amount of In from the required activity.

$N_{115In} := \frac{R_{116In}}{\phi \cdot \sigma_{115In} \cdot \left(1 - exp\left(-\lambda_{116In} \cdot t_{irr}\right)\right)}$ $\qquad N_{115In} = 5.41 \cdot 10^{18}$

$m_{In} := N_{115In} \cdot \frac{M_{wIn}}{N_A \cdot x_{In}}$ $\qquad m_{In} = 1.078 \cdot 10^{-6} \cdot kg$ $\qquad \frac{m_{In}}{m_{tot}} = 1.078 \cdot \%$

Comment: the irradiation time becomes unrealistically short at the minimum detectable activity and the sensitivity is practically constant up to near 1 second irradiation time, see next page. Thus it is more reasonable to assume 10^7Bq of ^{116}In and calculate a new irradiation time:

$R_{116In} := 10^7 \cdot Bq$ $\qquad R_{28Al} := \frac{20}{100} \cdot R_{116In}$

$t_{irr} := \frac{-ln\left(1 - \frac{R_{28Al}}{\phi \cdot \sigma_{27Al} \cdot N_{27Al}}\right)}{\lambda_{28Al}}$ $\qquad t_{irr} = 0.831 \cdot sec$

This is a practically achievable irradiation time with a rapid rabbit system.

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$$N_{115In} := \frac{R_{116In}}{\phi \cdot \sigma_{115In} \cdot \left(1 - exp\left(-\lambda_{116In} \cdot t_{irr}\right)\right)} \qquad N_{115In} = 5.512 \cdot 10^{18}$$

$$m_{In} := N_{115In} \cdot \frac{M_{wIn}}{N_A \cdot x_{In}} \qquad m_{In} = 1.098 \cdot 10^{-6} \cdot kg \qquad \frac{m_{In}}{m_{tot}} = 1.098 \cdot \%$$

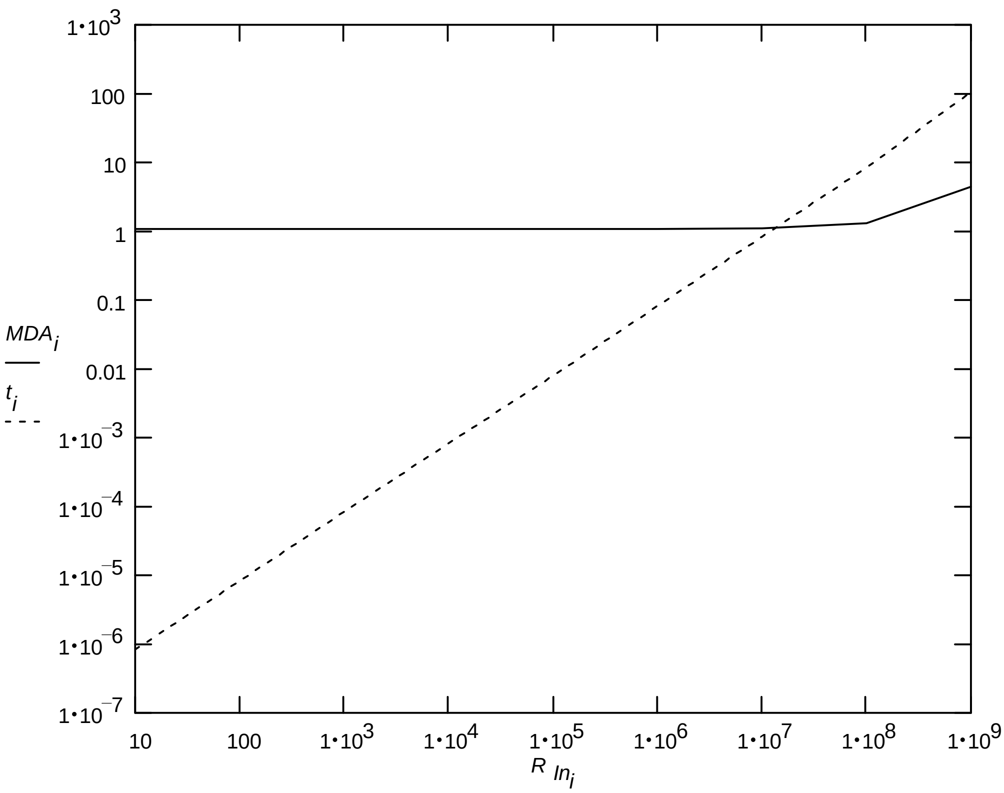
$i := 1 .. 9$

The sensitivity is only marginally worse, but the irratiation time is long enough to be practical.

$R_{In_i} := 10^i$

MDA = Minimum Detectable Amount (%)
R = Indium activity (Bq)
t = Irradiation time (s)

R_{In_i}	$MDA_i :=$	$t_i :=$
10	1.078	$8.296 \cdot 10^{-7}$
100	1.078	$8.296 \cdot 10^{-6}$
$1 \cdot 10^3$	1.078	$8.296 \cdot 10^{-5}$
$1 \cdot 10^4$	1.078	$8.296 \cdot 10^{-4}$
$1 \cdot 10^5$	1.078	0.008
$1 \cdot 10^6$	1.08	0.083
$1 \cdot 10^7$	1.098	0.831
$1 \cdot 10^8$	1.294	8.462
$1 \cdot 10^9$	4.452	105.112



We can now obtain the smallest detectable amount in a 100 mg sample as follows:

$$m_{sample} := 100 \cdot mg \qquad mdm := m_{sample} \cdot \frac{m_{In}}{m_{tot}} \qquad mdm = 1.1 \cdot mg$$