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Neutron Activation Analysis

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PHYSICAL CONSTANTS

Symbol	*Denomination*	*Magnitude*
a.m.u.	atomic mass unit	931.48 MeV (^{12}C scale) 931.16 MeV (^{16}O scale)
c	light velocity in vacuum	$2.99793.10^{10}$ cm s^{-1}
e	electron charge	$4.803.10^{-10}$ esu
h	Planck's constant	$6.625.10^{-27}$ erg s
$\hbar$	$= h/2\pi$	$1.0544.10^{-27}$ erg s
k	Boltzmann's constant	$1.38047.10^{-16}$ erg deg^{-1}
m_n	neutron mass	1.008665 a.m.u. (^{12}C scale) $1.6757.10^{-24}$ g
m_0	electron rest mass	$5.486.10^{-4}$ a.m.u. (^{12}C scale) $9.107.10^{-28}$ g
m_0c^2	electron rest energy	0.5110 MeV
m_p	proton rest mass	1.007273 (^{12}C scale) $1.6724.10^{-24}$ g
N_A	Avogadro's number	$6.023.10^{23}$ atoms $mole^{-1}$ (^{12}C scale)

LIST OF SYMBOLS

Symbol	Denomination
α	–alpha particle –conversion coefficient –quotient of distribution coefficients –correction factor in the internal standard method
A	–mass number –atomic weight –activity (rate or number of disintegrations, – counts) –ampere
Å	Ångstrom (10^{-8} cm)
β	beta particle
β^-	negatron
β^+	positron
B	background
b	barn = unit of cross section (cm^2)
c	number of counts
cm	centimeter (10^{-2}m)
C	–signal + background –capacity (Farad) –compound nucleus
Ci	Curie ($3.7.10^{10}$ dps)
C_i	convolution integer
CR	cadmium ratio
CR_x	cadmium ratio of element (isotope) x
CT	clock time
δ	–density (g cm^{-3}) –residual standard deviation
D	disintegration rate (dps, . . .)
D_A	distribution coefficient for species A
DT	total dead time
d	–absorption thickness (mg cm^{-2}) –number of disintegrations –distance
ε	energy needed for a hole-electron pair creation (eV)
ε_x	excitation energy of nucleus x (MeV)
E	energy (MeV, keV, eV, erg, . . .)
E_b	Coulomb barrier energy (MeV)
E_{Cd}	cadmium cut-off energy (eV)
E_{eff}	effective threshold energy (MeV)
E_{max}	maximum energy in beta spectrum (MeV)
E_0	energy corresponding to neutron velocity v_0 (0.025 eV)
E_r	energy at the maximum of a resonance peak (eV)
E_T	threshold energy (MeV)
E_x	recoil energy of nucleus x (MeV)
eV	electron volt ($1.60.10^{-12}$ erg)
φ	neutron flux (beam or multidirectional) (n cm^{-2} s^{-1})
$\bar{\varphi}$	equivalent fission flux (n cm^{-2} s^{-1})
$\varphi(E)$	φ at neutron energy E (n cm^{-2} s^{-1})
φ_e	epicadmium neutron flux per unit of lethargy = conventional epicadmium flux (n cm^{-2} s^{-1})
$\varphi_e(E)$	φ_e at neutron energy E (n cm^{-2} s^{-1})

Symbol	Denomination
φ_e^{eff}	φ_e corrected for resonance absorption at finite dilution (n cm^{-2} s^{-1})
φ_0	conventional thermal neutron flux = nv_0 (n cm^{-2} s^{-1})
$\varphi_{reactor}$	conventional reactor neutron flux (n cm^{-2} s^{-1})
φ_{th}	conventional thermal neutron flux below E_{Cd} = $n_{th}\, v_0$ (n cm^{-2} s^{-1})
$\varphi_{th}(E)$	thermal neutron flux at energy E (n cm^{-2} s^{-1})
F	–14 MeV neutron flux (n cm^{-2} s^{-1}) –Fano factor –decay correction factor for measurement of short lived activities (starting point of measuring interval)
FDT	fractional dead time
F_n	fraction of the disintegration of the nuclides of the n^{th} step, producing nuclides of the $(n+1)^{th}$ step in a disintegration chain
FWHM	full width at half maximum of a (photo)peak (eV, keV. . .)
f	–total neutron absorption factor in solids –decay correction factor for the measurement of short lived activities (exact time within the measuring interval) –fission –fraction
f'	total neutron absorption factor in solution
$f(E)$	fission neutron flux at energy E (n cm^{-2} s^{-1})
f_e	epicadmium neutron absorption factor in solids
f_s	self-absorption coefficient for beta rays
ft	comparative half-life of beta decay
f_{th}	thermal neutron absorption factor in solids
Γ	nuclear level width (eV)
Γ_x	partial Γ (eV)
γ	gamma ray
g	gram
h	–photopeak height (cm, activity) –height –hour
I	resonance integral at infinite dilution (barn)
I'	I corrected for $1/v$ contribution (barn)
I_{abs}	absorption resonance integral at infinite dilution (barn)
I_{act}	activation resonance integral at infinite dilution (barn)
IDT	instantaneous dead time
I^{eff}	effective resonance integral = I corrected for resonance absorption = I at finite dilution (barn)
I_n	I for the n^{th} resonance peak (barn)
I_{tot}	$= \sum^{n} I_n$ (barn)
I_x	I for the nuclear reaction of type x (barn)
I'_x	I' for the nuclear reaction of type x (barn)
$I_{1/v}$	resonance integral at infinite dilution obtained by integration of $\sigma_{1/v}$ (barn)
κ	–linear absorption coefficient for pair production (cm^{-1}) –dielectric constant

Symbol	*Denomination*
K_D	distribution constant
k	–reactor reproduction factor –constant
keV	kilo electron volt (10^3 eV)
kg	kilogram (10^3 g)
λ	–radioactive decay constant (s^{-1}) –wave length (mμ, Å)
l	mean free path (cm)
L	–liter –ligand
L_C	critical limit
L_D	detection limit
L_Q	quantitative determination limit
LT	live time
μ	–total mass absorption coefficient ($cm^2\ mg^{-1}$) –micron (10^{-4} cm)
μ'	total linear absorption coefficient (cm^{-1})
μA	micro ampere (10^{-6} A)
μb	microbarn (10^{-6} barn)
μCi	micro Curie (10^{-6} Curie)
μg	micro gram (10^{-6} gram)
μl	micro liter (10^{-6} liter)
μ_n	mobility of electrons in *n*-type semiconductor material ($cm^2\ V^{-1}\ s^{-1}$)
μ_p	mobility of holes in *p*-type semiconductor material ($cm^2\ V^{-1}\ s^{-1}$)
μs	micro second (10^{-6} second)
M	–molarity (mole L^{-1}) –factor of merit of a counter $= S/2\sqrt{B}$
MeV	million electron volt (10^6 eV)
m	–minute –mass –meter
mA	milli ampere
meq	milli equivalent
mb	millibarn (10^{-3} barn)

Symbol	*Denomination*
mCi	milli Curie (10^{-3} Curie)
mg	milligram (10^{-3} gram)
ml	milliliter = 10^{-3} liter
mμ	milli micron = 10^{-7} cm (10^{-3} micron)
mm	millimeter (10^{-3} m)
ms	milli second (10^{-3} second)
mV	–milli electron volt (10^{-3} eV) –millivolt (10^{-3} volt)
ν	–frequency (s^{-1}) –neutrino –number of neutrons liberated per fission
N	–number of neutrons in the nucleus –number of target nuclei per cm^2 –normality (g eq. L^{-1})
n	–thermal neutron density from energy 0 to ∞ (n cm^{-3}) –neutron
n(E)	neutron density at energy E (n cm^{-3})
ng	nano gram (10^{-9} gram)
ns	nano second (10^{-9} second)
n_{th}	thermal neutron density below E_{Cd} (n cm^{-3})
$\bar{n}_{th}$	average n_{th} in the sample at finite dilution (n cm^{-3})
$n(v)$	neutron density at velocity v (n cm^{-3})
P	–probability –peak to total ratio
p	proton
Q	–reaction energy (MeV, a.m.u., . . .) –quality criterion of a counter
q	branching factor
ρ	resistivity (ohm cm^{-1})
R	–reaction rate (s^{-1}) count rate (cps, cpm, ...)

Symbol	*Denomination*
	–particle range –resolution –radius –distance –resistance (ohm)
R_A	–nuclear radius (Fermi unit = 10^{-13} cm) –recovery factor of species A
$R\ (V, E)$	response function of a detector
r	–distance –radius
Σ	macroscopic cross section $= \sigma N$ (cm^{-1})
Σ_R	macroscopic removal cross section of sample for 14 MeV neutrons (cm^{-1})
$\Sigma_{R(i)}$	macroscopic removal cross section of element i for 14 MeV neutrons (cm^{-1})
σ	–effective microscopic target area (cm^2) –cross section (barn) –linear absorption coefficient for Compton effect (cm^{-1}) –standard deviation for an infinite population
$\bar{\sigma}$	average cross section in a fission neutron spectrum (barn)
$\sigma\%$	percentage standard deviation (= percentage coefficient of variation)
σ_{abs}	absorption cross section ($= \sigma_C$) (barn)
σ_{act}	isotopic activation cross section (barn)
$\bar{\sigma}_{act}$	average elemental activation cross section (barn)

Symbol	*Denomination*
σ_C	cross section for compound nucleus formation ($= \sigma_{abs}$) (barn)
σ_{coh}	coherent scatter cross section (barn)
σ_{col}	collision cross section (barn)
$\sigma(D)$	standard deviation for a signal equal to the detection limit
$\sigma(E)$	cross section at neutron energy E (barn)
σ_{eff}	effective cross section (barn)
σ_{el}	elastic scatter cross section (barn)
σ_f	fractional standard deviation (= coefficient of variation) $= \sigma\%/100$
σ_{fa}	free atom scatter cross section (barn)
σ_{inel}	inelastic scatter cross section (barn)
$\sigma_{14\ MeV}$	cross section for 14 MeV neutrons (barn)
$\sigma_{n.e.}$	non elastic scatter cross section (barn)
$\sigma_{n,x}$	reaction cross section (barn)
$\sigma(0)$	standard deviation of background for zero signal
σ_0	cross section at neutron velocity v_0 (barn)
$\bar{\sigma}_0$	average elemental cross section at neutron velocity v_0 (barn)
σ_p	potential scattering cross section ($= 4\pi R_A^2$) (barn)
$\sigma(Q)$	standard deviation for a signal at the quantitative determination limit
σ_r	resonance cross section (barn)

Symbol	Denomination
$\sigma_r(E)$	resonance cross section at neutron energy E (barn)
$\sigma_{reactor}$	cross section for a reactor neutron spectrum (barn)
$\sigma^{eff}_{reactor}$	effective $\sigma_{reactor} = \sigma_{reactor}$ corrected for absorption at finite dilution (barn)
$\sigma_{R(l)}$	microscopic elemental removal cross section for 14 MeV neutrons (cm^2)
$\bar{\sigma}_s$	average scatter cross section (barn)
σ_T	total cross section (barn)
σ_{th}	average cross section for neutron energies up to E_{Cd} (barn)
$\sigma(v)$	cross section at neutron velocity v (barn)
$\sigma(\bar{v})$	cross section at neutron velocity $\bar{v}$ (barn)
$\sigma_{1/v}$	cross section in the epicadmium region, disregarding resonance peaks (barn)
S	–saturation factor –surface, area –signal
$S_{B/A}$	separation factor of species B from A = enrichment factor of A = depletion factor for B
s	–standard deviation for a finite population –second
θ	–isotopic abundance –angle (degree, radian)
τ	–mean life (s, . . .) –dead time (μs, . . .) –resolving time (μs, . . .) –linear absorption coefficient for photoelectric effect (cm^{-1})
T	–absolute temperature (°K) –total time = $\Delta t_c + \Delta t_g$.
$T_{1/2}$	half-life = ln 2/λ (y, h, m, s, . . .)
T_m	Maxwellian temperature (°K)
T_0	293.6 °K
T_R	reactor period
t	–decay time (h, m, s, . . .) –thickness (cm) –temperature (°C)
$t_{1/2}$	time necessary to establish half of the equilibrium distribution in isotopic exchange
t_b	irradiation time (h, m, s, . . .)
t_{eff}	effective thickness for resonance neutron absorption (cm)
u	number of standard deviations
V	–volume (L, ml, μl, . . .) –tension (volt) –volt
$V(d)$	electrical field
v	–neutron velocity ($cm\ s^{-1}$)
$\bar{v}$	average neutron velocity in a Maxwell–Boltzmann distribution ($cm\ s^{-1}$)
v_1	neutron velocity at E_{Cd} ($cm\ s^{-1}$)
v_0	most probable neutron velocity in a Maxwell–Boltzmann distribution (2200m/s at 20°C = 0.025 eV)
W_t	statistical weight
w	weight (g, mg, . . .)
y	–year –fission yield
ζ	Fermi potential in a semiconductor (eV)
Z	–atomic number –residual
z	counting efficiency

CONTENTS