Advanced Topics in Condensed Matter

Lecture 7- Mössbauer effect

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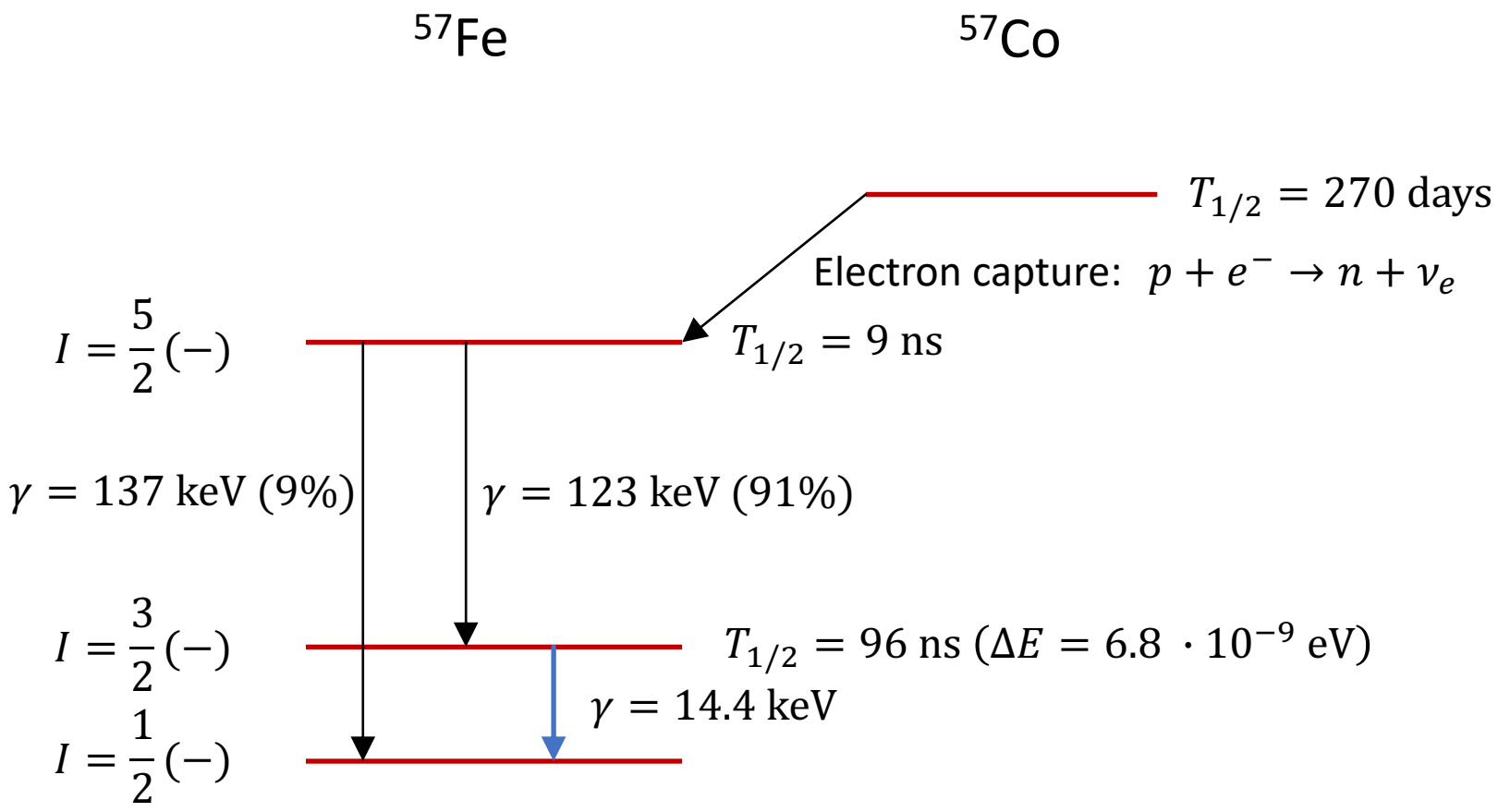
Mössbauer isotopes

White boxes –
Mössbauer isotopes

Handbook of Nuclear Chemistry (Springer, 2004)

Fluorescence in ^{57}Fe



Mössbauer isotopes

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K 40	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe 57	27 Co	28 Ni 61	29 Cu	30 Zn 67	31 Ga	32 Ge 73	33 As	34 Se	35 Br	36 Kr 83
37 Rb	38 Sr	39 Y	40 Zr	41 Np	42 Mo	43 Tc 99	44 Ru 99 101	45 Rh	46 Pd	47 Ag 107	48 Cd 201	49 In	50 Sn 117 119	51 Sb 121	52 Te 125	53 I 127 129	54 Xe 129 131
55 Cs 133	56 Ba 133	57 La 139	72 Hf 178 180*	73 Ta 181	74 W 184 186*	75 Re 187	76 Os 188 190*	77 Ir 191 193	78 Pt 195	79 Au 197	80 Hg 201	81 Ti	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Dm								

58 Ce	59 Pr 141	60 Nd 145	61 Pm 145 147	62 Sm 152 154*	63 Eu 151 153	64 Gd 154– 158*	65 Tb 159	66 Dy 160– 162*	67 Ho 165	68 Er 166 168*	69 Tm 169	70 Yb 172 174*	71 Lu 175
90 Th 232	91 Pa 231	92 U 238*	93 Np 237	94 Pu 239	95 Am 243	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

White boxes –
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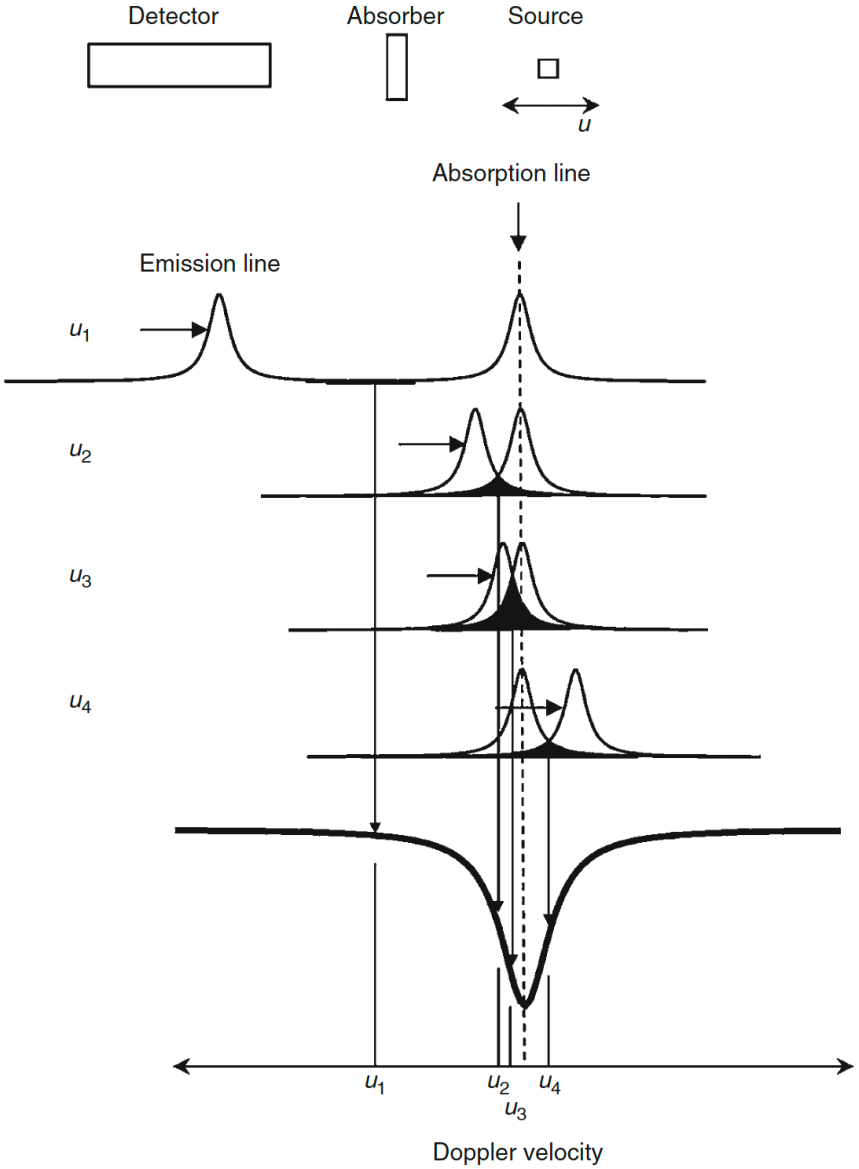
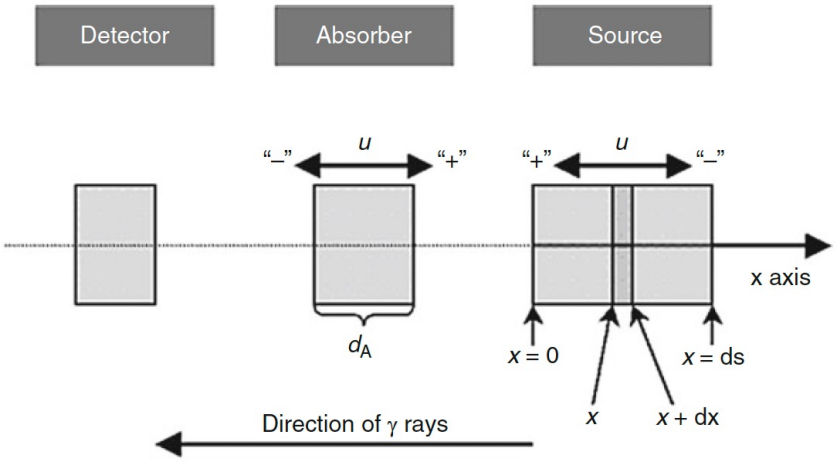
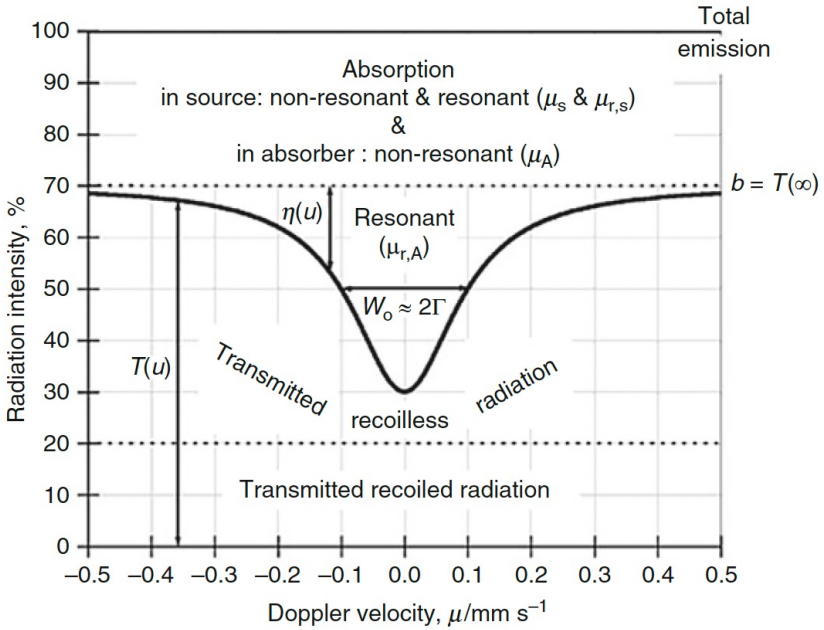
Scheme of the experiment

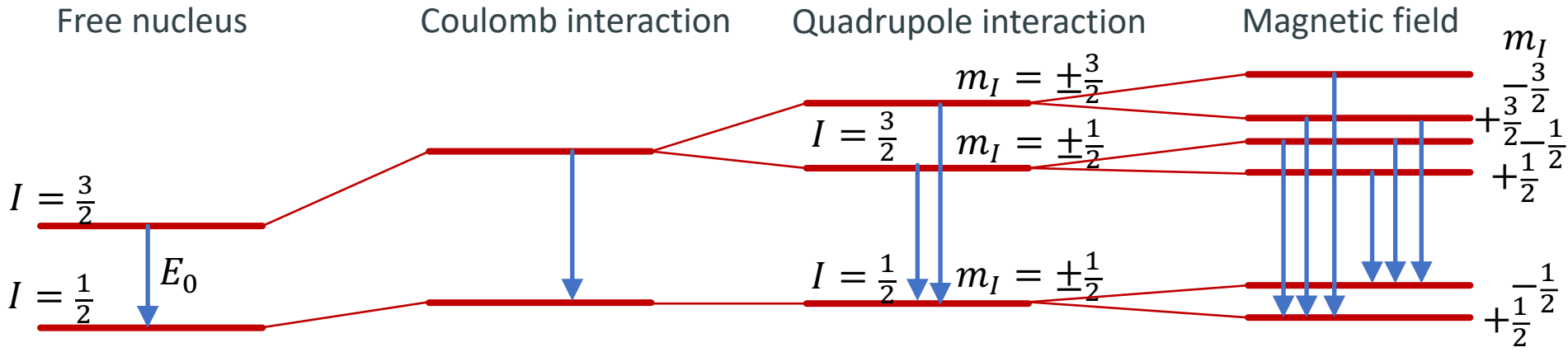




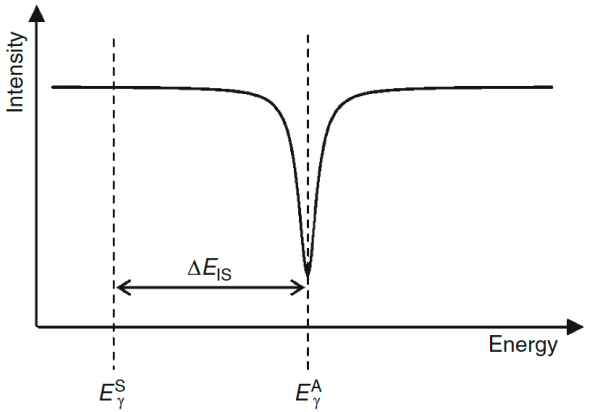


Hyperfine interactions

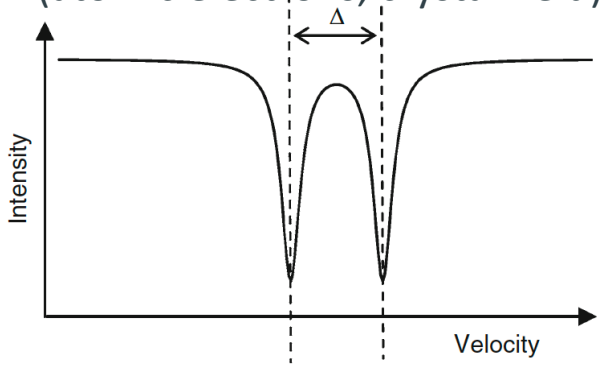
Nucleus interact with the electric field of electrons (Coulomb, quadrupole) and magnetic field of electrons (magnetic dipole).



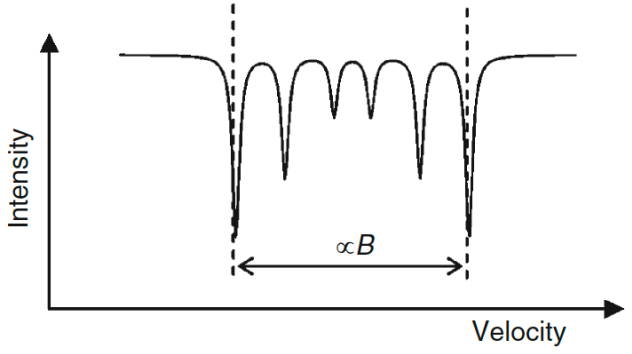
Chemical isomer shift



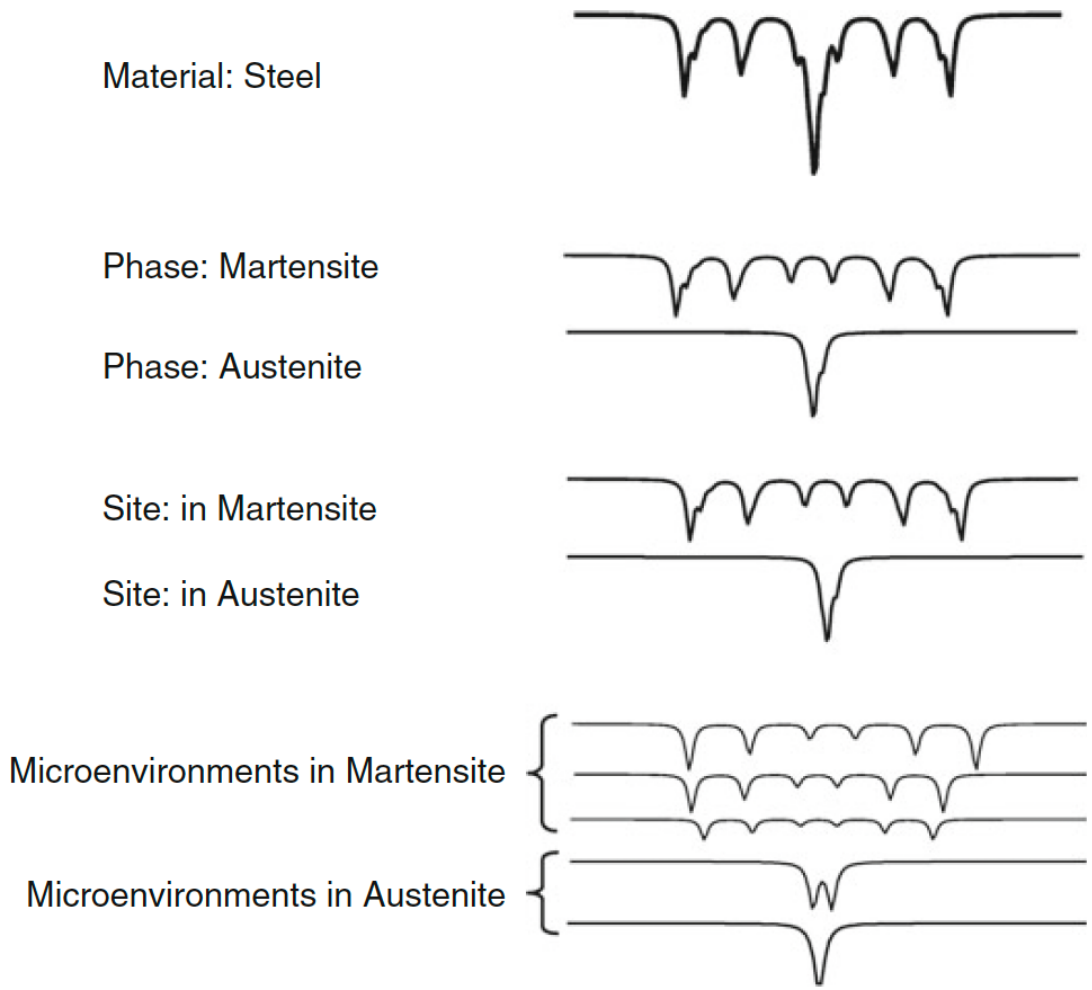
Quadrupole splitting
(atomic electrons, crystal field)



Magnetic splitting
(magnetic ordering)

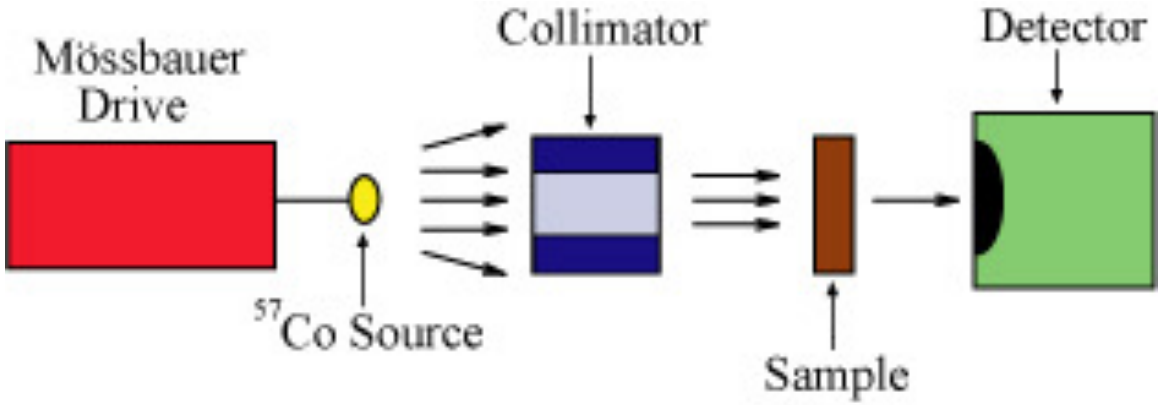


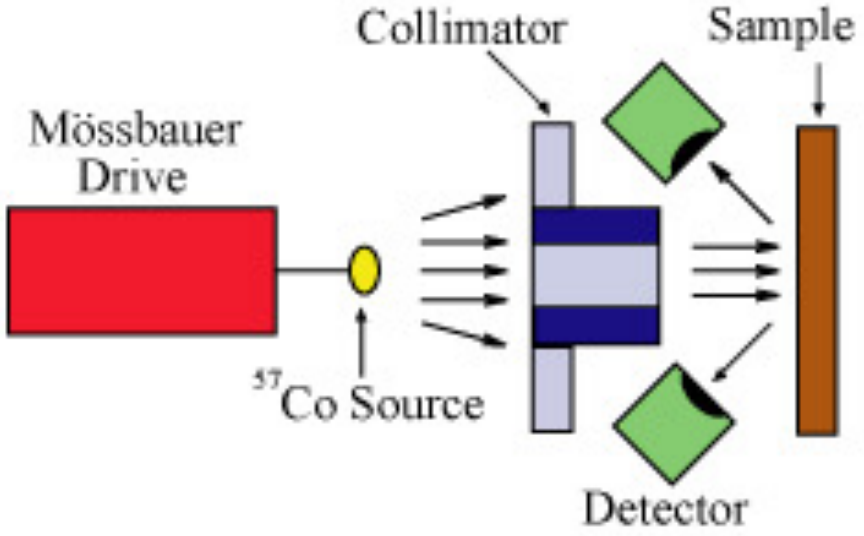
Example: steel



The standard pattern of a steel in which ferrite and austenite phases are present. The ^{57}Fe Mössbauer spectrum of the sample is a complex spectrum that is a sum of subspectra. The subspectra of the ferromagnetic ferrite with bcc lattice and the paramagnetic austenite with fcc lattice are also superimposed from elementary patterns because of the effect of alloying elements, although the Fe atoms can only occupy one single crystallographic site in each phase.

Mössbauer spectrometer

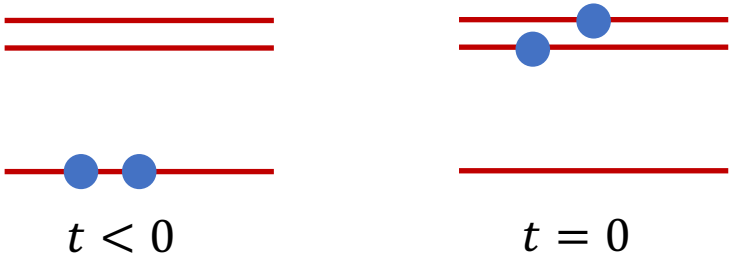




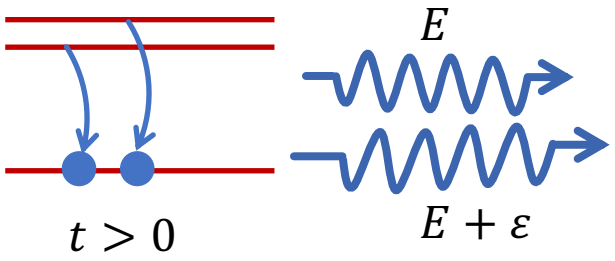
https://serc.carleton.edu/research_education/geochemsheets/techniques/mossbauer.html

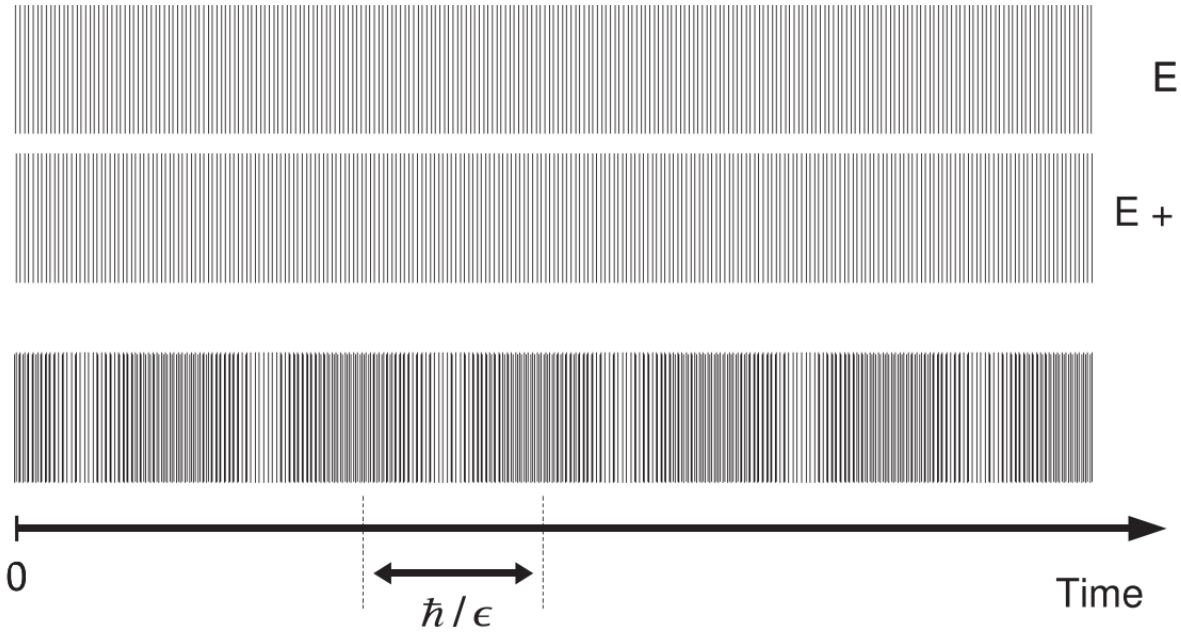
Synchrotron Mössbauer spectroscopy (SMS)

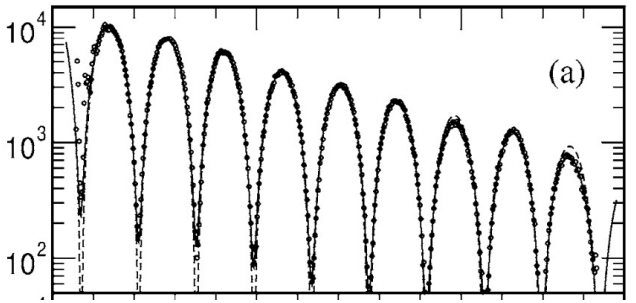
1. Excitation by a short synchrotron pulse (~100 ps)



2. Long nuclear fluorescence (~100 ns)

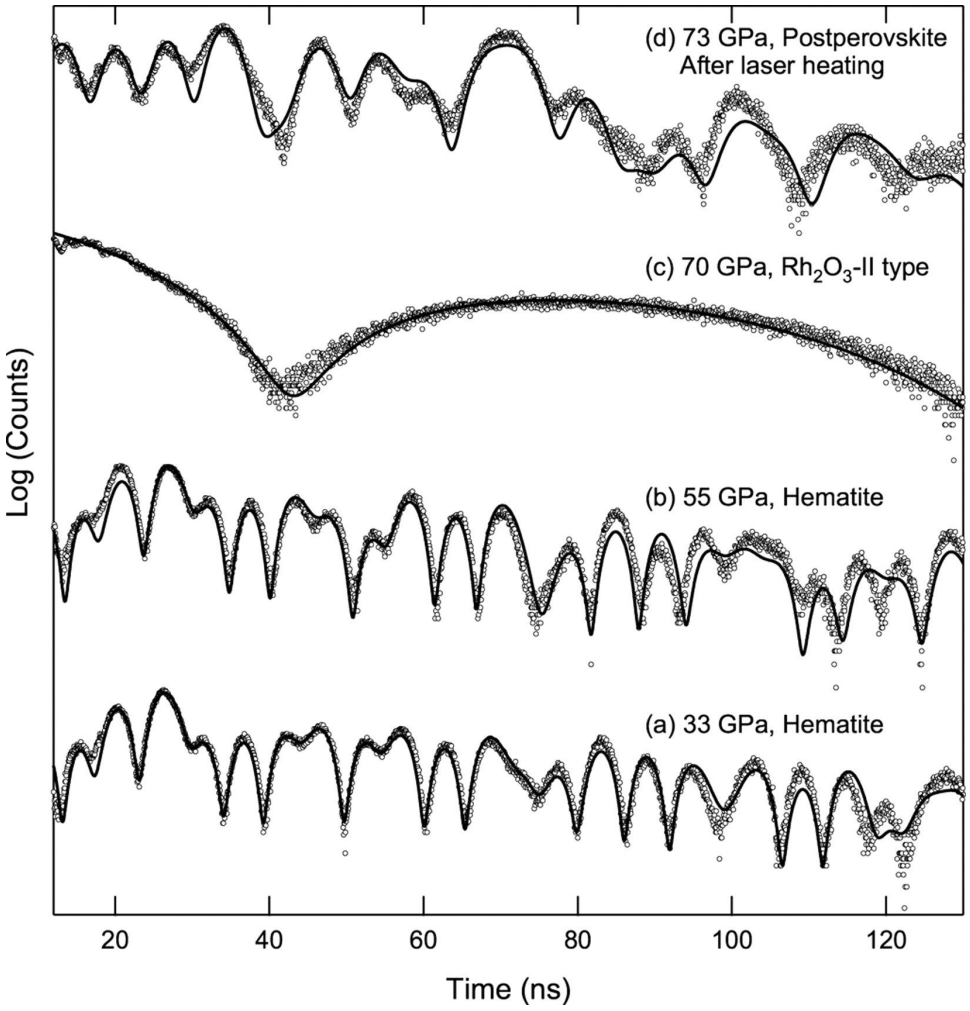


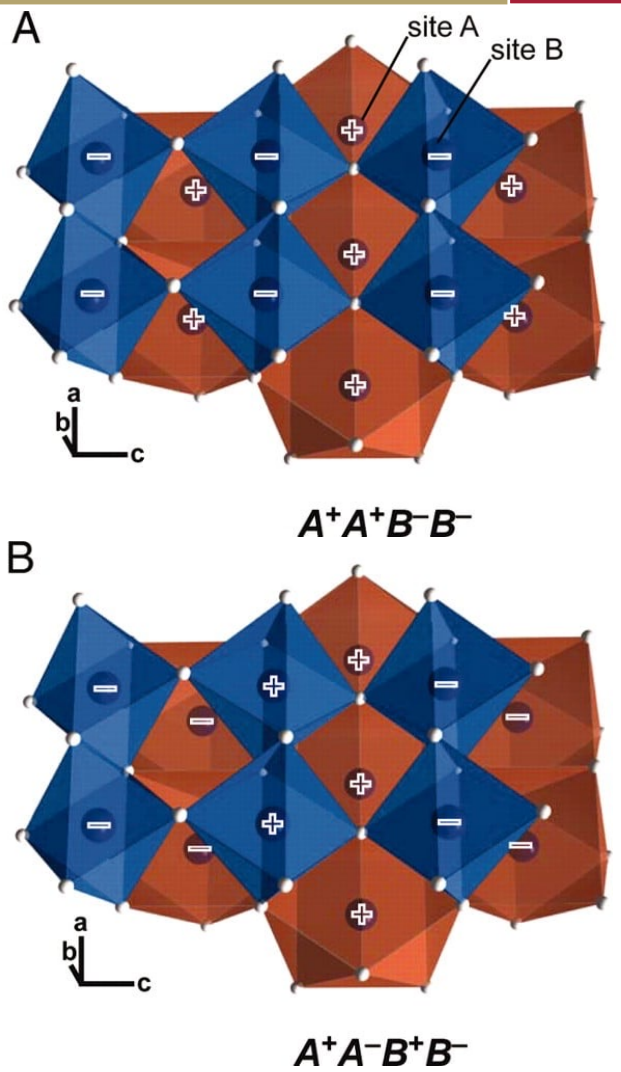




W. Sturhahn, J. Phys.: Condens. Matter 16 S497 (2004)

SMS on Fe_2O_3





S.-M. Shim et al., "Electronic and magnetic structures of the postperovskite-type Fe_2O_3 and implications for planetary magnetic records and deep interiors" PNAS 106 (14) 5508-5512 (2009)

What to remember

- Heisenberg uncertainty for energy resolution and life-time: $\Delta E \cdot \Delta t \geq \frac{\hbar}{2}$
- Mössbauer effect is recoilless absorption/emission of γ-quantum by a nucleus. It is only possible in solid state and at low temperatures
- Mössbauer effect allows to determine local electric and magnetic field at a nucleus
- There are many Mössbauer-active isotopes, including ^{57}Fe
- One can get a Nobel Prize for a PhD thesis