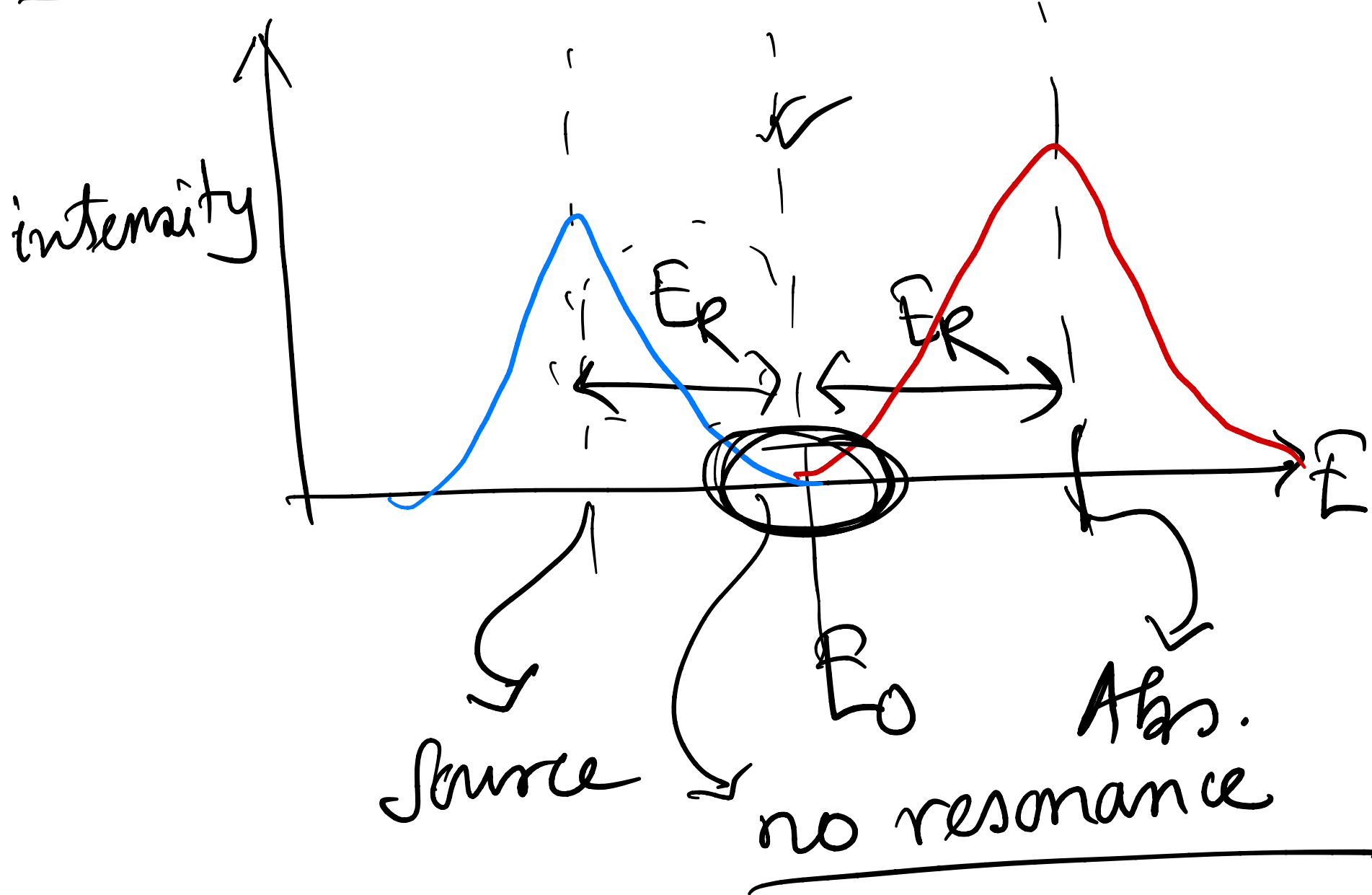
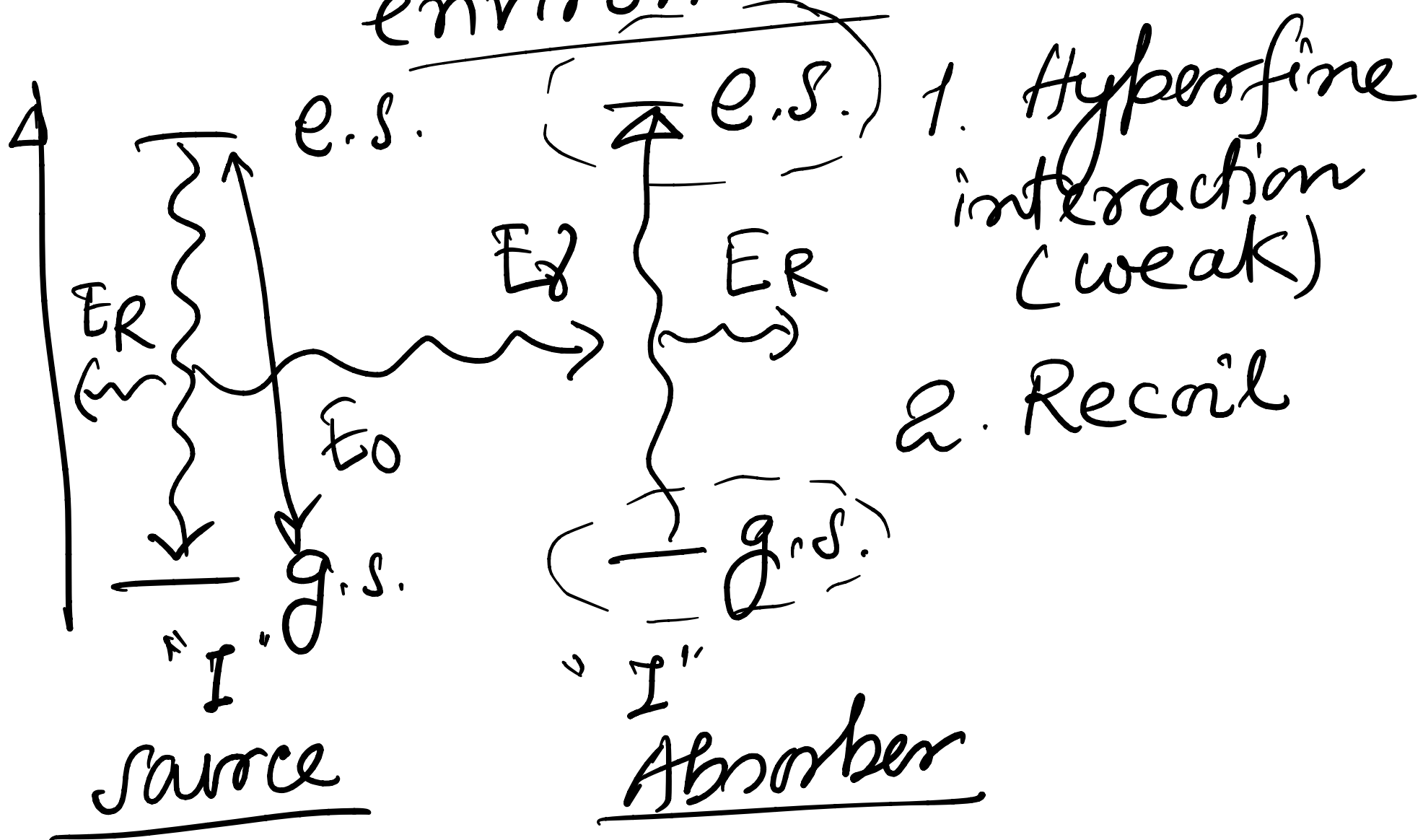


Class 9
CH 82F

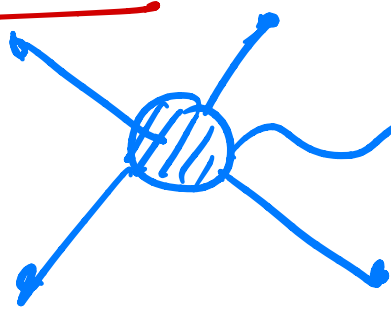
November 12, 2020

Mössbauer Spectroscopy

surrounding electronic environment $\longleftrightarrow$ nucleus

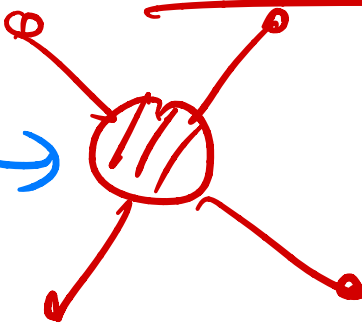


Source



E_γ

Absorber



solid matrix / lattice

$$E_R = E_{tr.} + E_{vib.}$$

$\downarrow$ $\downarrow$

0 (phonon)

$$= \sum_i n \hbar \omega_i$$

$\downarrow$

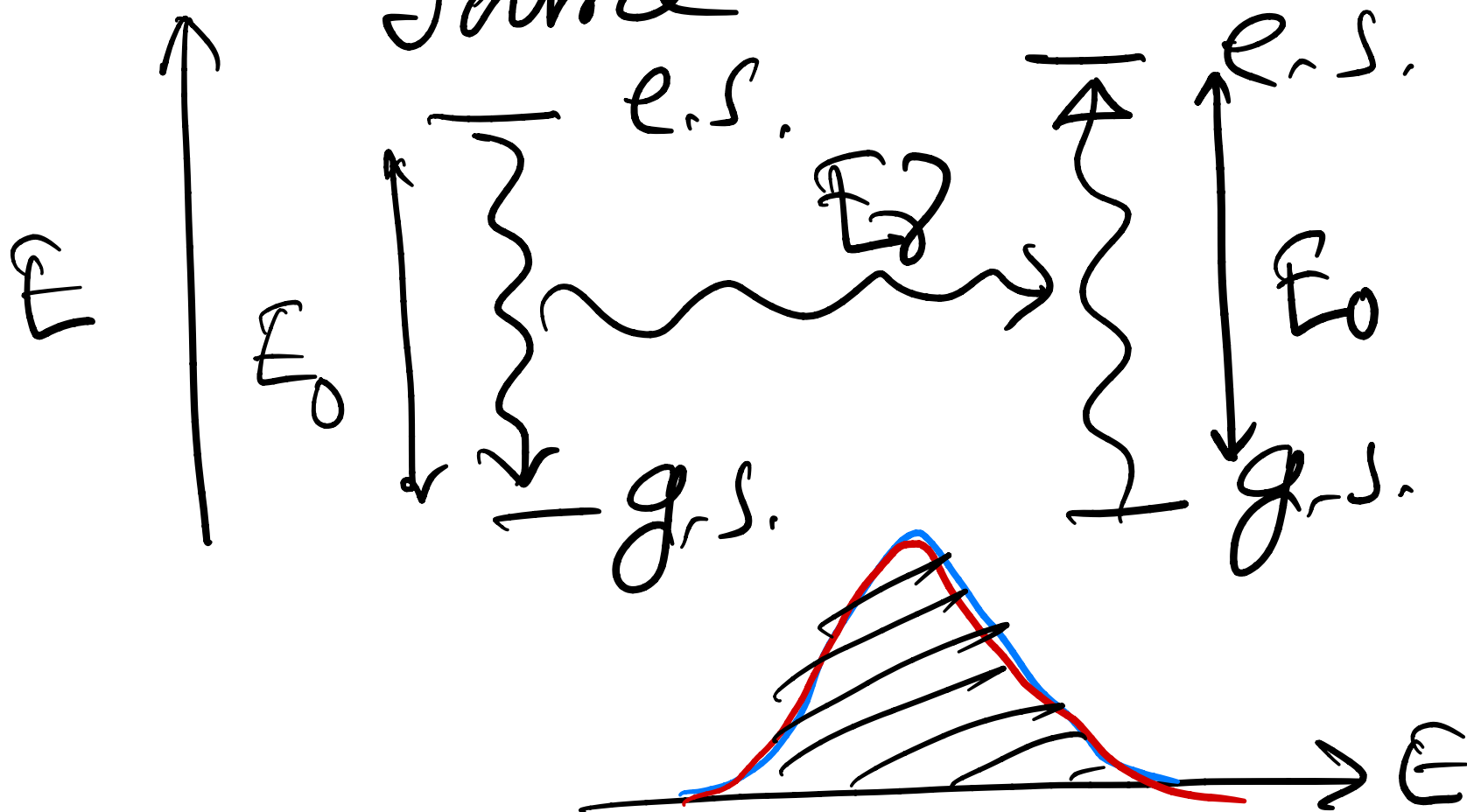
$n=0, 1, 2, 3, \dots$

recoil-free / recoil-less transition (I)

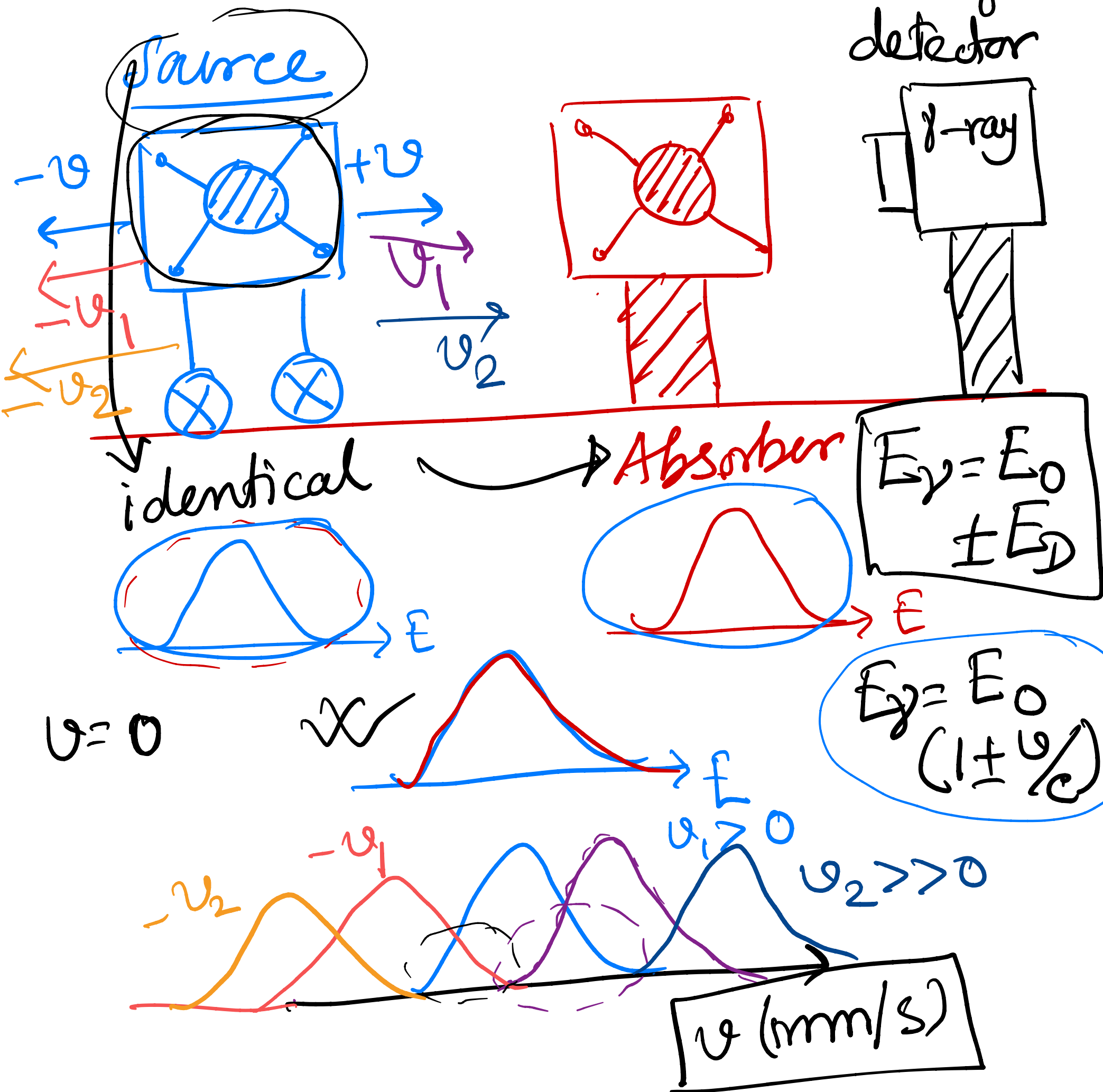
Mössbauer effect

Source

Absorber



Mössbauer Spectroscopy (expt. design)



Heisenberg Uncertainty Principle

(tau) $\tau \cdot \Gamma \geq \hbar$

life time
of the
excited
state

line-
broadening

γ Γ
 $\Delta E \cdot \Delta t$



$\tau = 10^{-6} \text{ s to } 10^{-9} \text{ s}$

$\Gamma = 10^{-9} \text{ eV to } 10^{-5} \text{ eV}$

$E_0/E_\gamma \rightarrow \gamma\text{-ray} > 10^3 \text{ eV}$

resolution = $\frac{\Gamma}{E_0}$



$\Rightarrow \Gamma = 5.0 \times 10^{-9} \text{ eV}$

$\tau = 141 \text{ ns}$

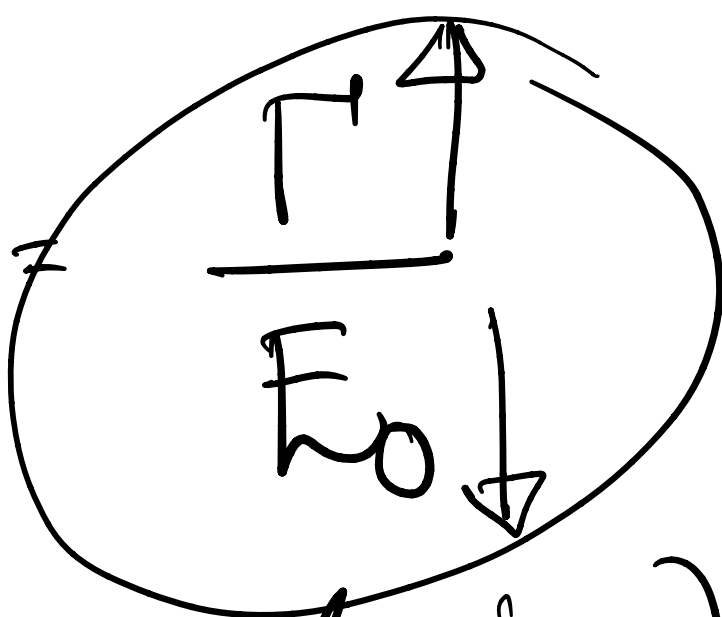
$E_0 = 14.4 \text{ keV} = 14400 \text{ eV}$

$\frac{\Gamma}{E_0}$

$\frac{5.0 \times 10^{-9} \text{ eV}}{14400 \text{ eV}}$

$= 3.3 \times 10^{-13}$

resolution factor



Γ (line broadening) $\uparrow$

τ (life time) $\downarrow$ ($\tau \downarrow \Gamma \geq \hbar$)

* short-lived excited state ✓

$E_0 \rightarrow$ nuclear transition energy

* lower value of transition energy ✓

^{57}Fe , ^{119}Sn , ^{121}Sb ,
 ^{129}I , ^{197}Au

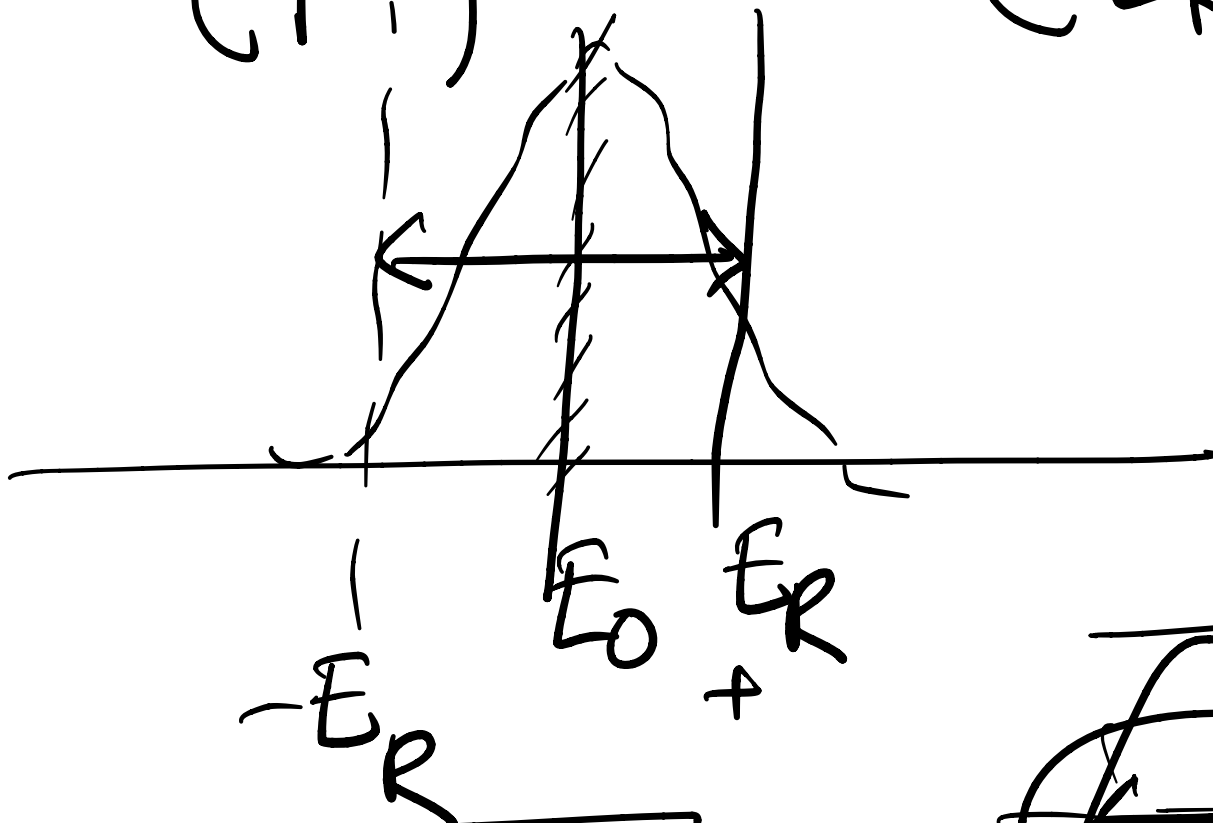
Number of Observed Mössbauer Transitions																																															
Number of Observed Mössbauer Isotopes																																															
1	2											13	14	15	16	17	18																														
H	Li	Be											B	C	N	O	F	Ne																													
Na	Mg											Al	Si	P	S	Cl	Ar																														
K^1	Ca	Sc	Ti	V	Cr	Mn	Fe^2	Co	Ni^1	Cu	Zn^1	Ga	Ge^2	As	Se	Br	Kr^1																														
Rb	Sr	Y	Zr	Nb	Mo	Tc^1	Ru^2	Rh	Pd	Ag	Cd	In	Sn^2	Sb^1	Te^1	I^2	Xe^2																														
Cs^1	Ba^1	Hf^4		Ta^2	W^7	Re^1	Os^6	Ir^4	Pt^2	Au^1	Hg^1	Tl	Pb	Bi	Po	At	Rn																														
Fr	Ra																																														
<table> <tr> <td>La^1</td><td>Ce</td><td>Pr^1</td><td>Nd^2</td><td>Pm^1</td><td>Sm^6</td><td>Eu^4</td><td>Gd^9</td><td>Tb^1</td><td>Dy^6</td><td>Ho^1</td><td>Er^5</td><td>Tm^1</td><td>Yb^6</td><td>Lu^1</td></tr> <tr> <td>Ac</td><td>Th</td><td>Pa</td><td>U</td><td>Np</td><td>Pu</td><td>Am</td><td>Cm</td><td>Bk</td><td>Cf</td><td>Es</td><td>Fm</td><td>Md</td><td>No</td><td>Lw</td></tr> </table>																		La^1	Ce	Pr^1	Nd^2	Pm^1	Sm^6	Eu^4	Gd^9	Tb^1	Dy^6	Ho^1	Er^5	Tm^1	Yb^6	Lu^1	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lw
La^1	Ce	Pr^1	Nd^2	Pm^1	Sm^6	Eu^4	Gd^9	Tb^1	Dy^6	Ho^1	Er^5	Tm^1	Yb^6	Lu^1																																	
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lw																																	

Figure 1. Periodic table of the elements; those in which the Mössbauer effect has been observed are marked appropriately.

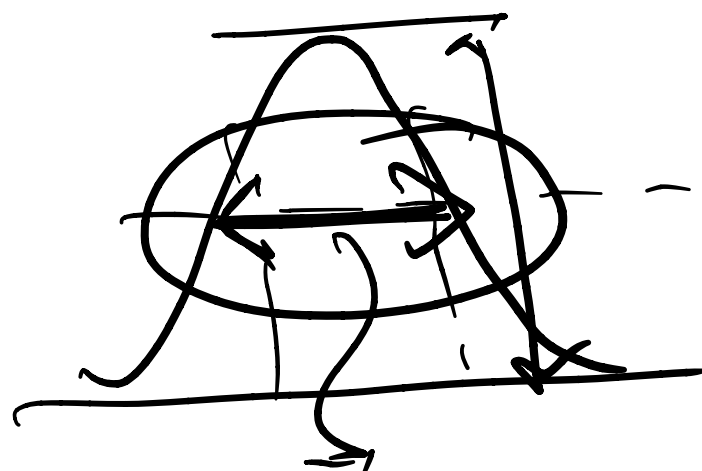
line broadening / recoil energy

(Γ)

(E_R)



✓ $\boxed{2E_R \leq \Gamma}$



(eV)

Γ

Transition

Electronic

Nuclear

E_0

~ 2.1

14400

Γ

4.4×10^{-8}

5.0×10^{-9}

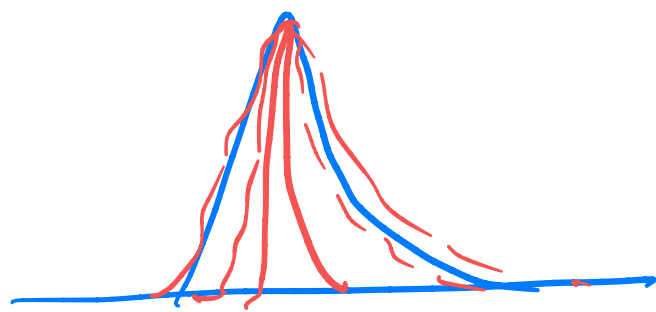
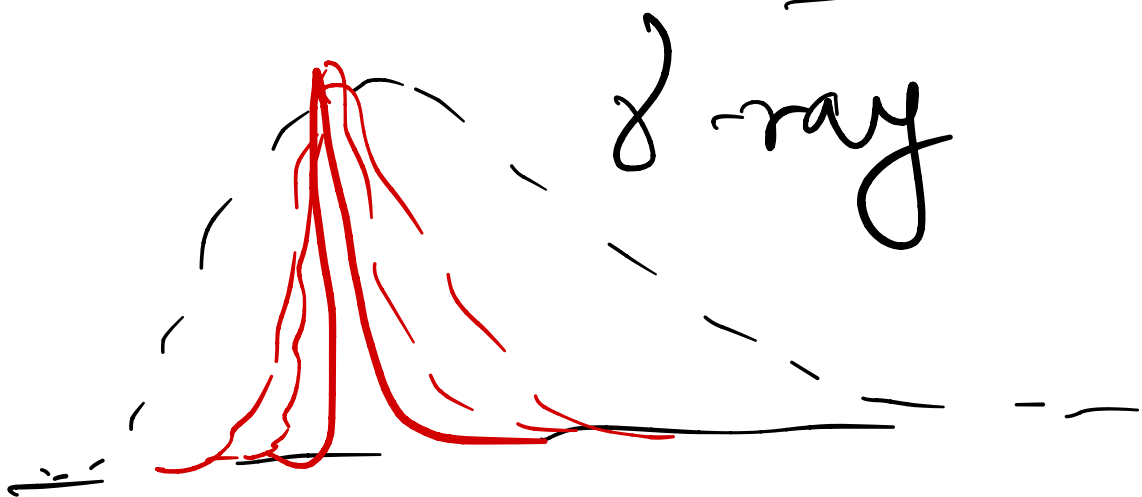
E_R

10^{-10}

1.95×10^{-3}

γ -ray

Optical



Mössbauer active nuclei

$^{57}_{26}\text{Fe}$

natural abundance

2.14%

^{57}Fe enriched sample

Absorber

parent nuclei

^{57}Co

$^{57}_{27}\text{Co}^*$

$\bar{e}$

^{57}Fe

$(I=7/2)$

$(\bar{e} \text{ capture})$

$I=5/2$

136.32 keV

$\sim 122 \text{ keV}$

$I=3/2$

e.s.

14.4 keV

γ -ray

e.s.

$I=3/2$

E

0

g.s. ($I=1/2$)

^{57}Fe

(source)

g.s. ($I=1/2$)

^{57}Fe

$^{56}_{26}\text{Fe}$

(d, n)

adding a neutron
in cyclotron

source

$^{57}_{27}\text{Co}$

$\bar{e}$ capture

half life
(270 d)

$^{57}_{26}\text{Fe}$ ($I = 5/2$)

122 keV

$^{57}_{26}\text{Fe}$

($I = 3/2$)

γ -ray

14.4
keV

$^{57}_{26}\text{Fe}$

$I = 1/2$

$I = 3/2$

$I = 1/2$

Abn.

