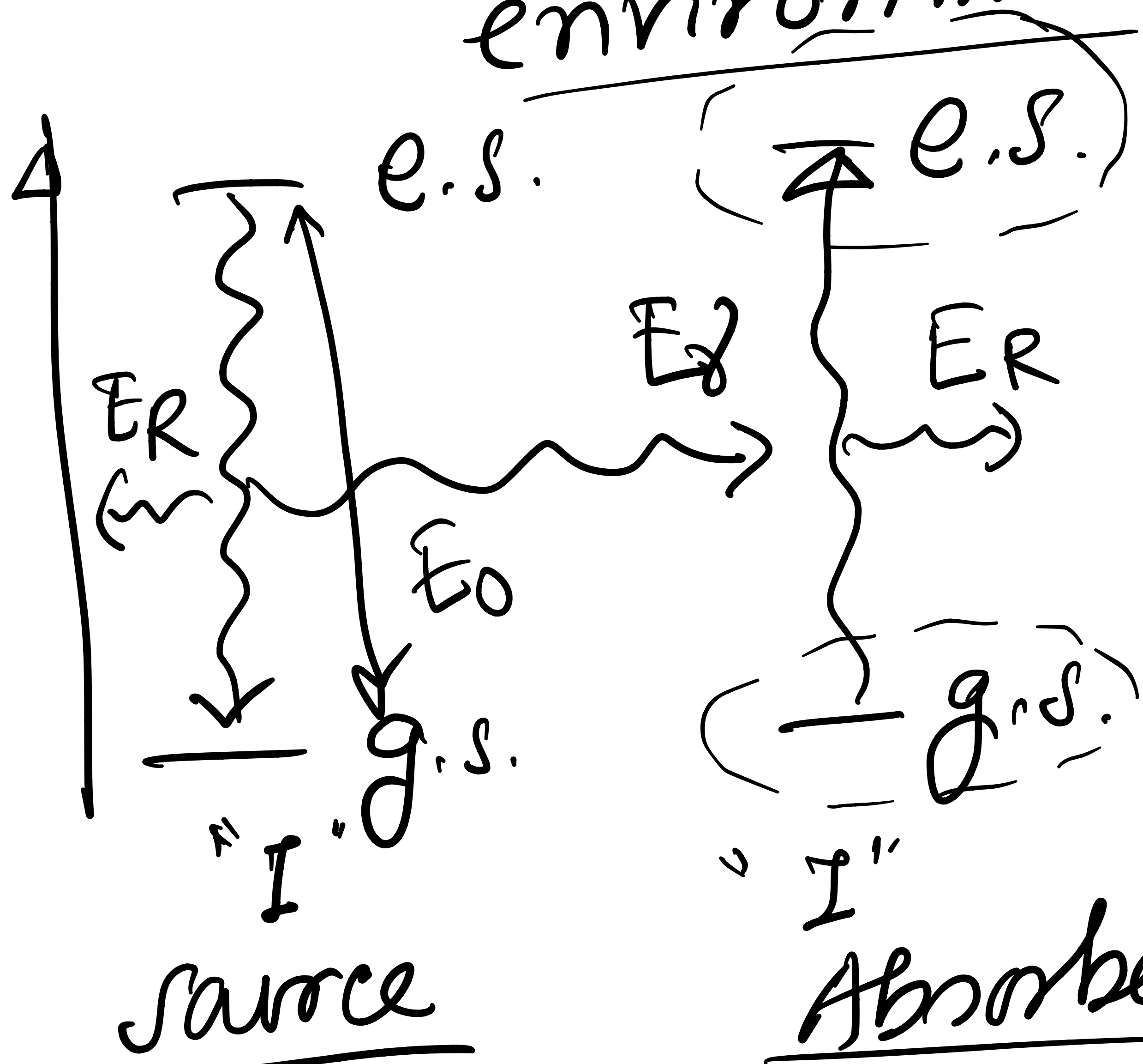
Class 9
CH 827

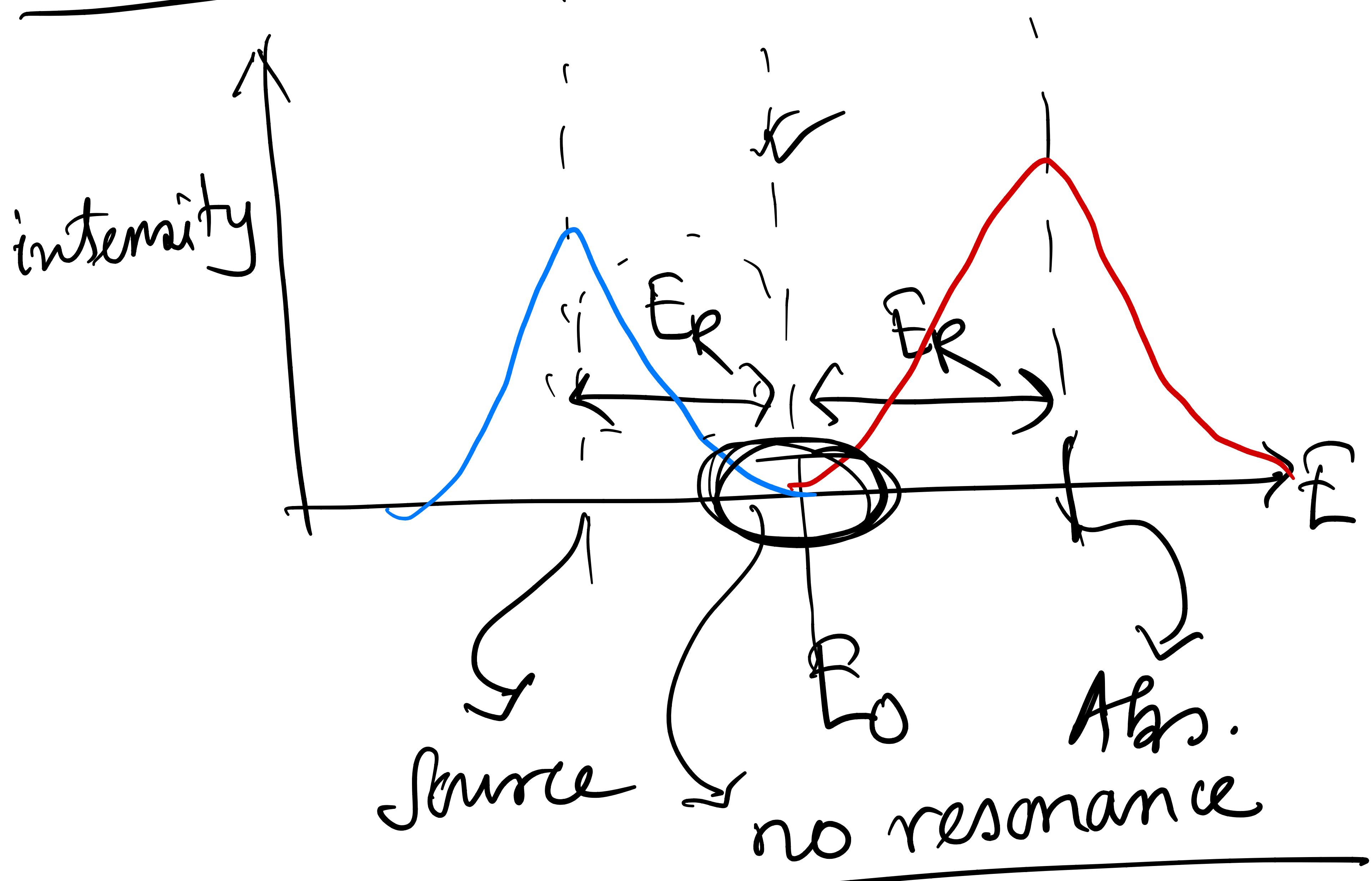
November 12, 2020

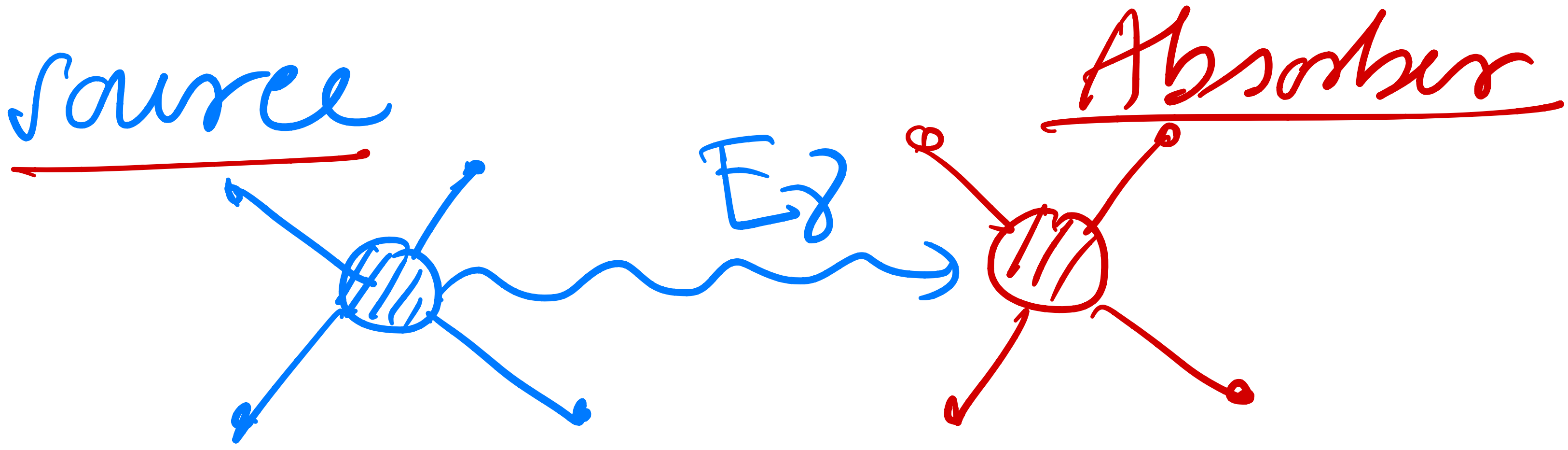
Mössbauer Spectroscopy

surrounding electronic environment ⟷ nucleus



1. Hyperfine interaction (weak)
2. Recoil





solid matrix / lattice

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

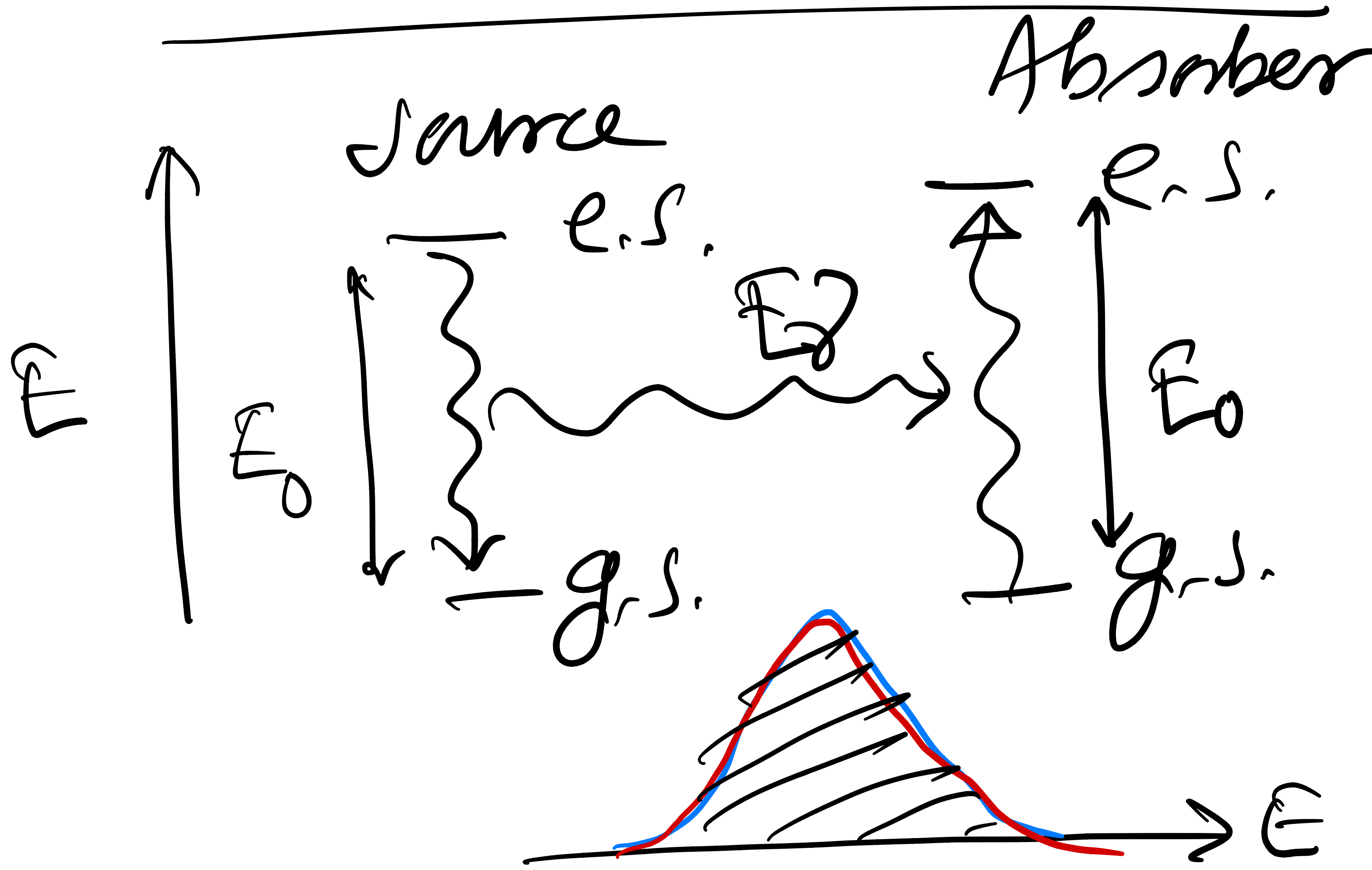
$E_{tr.} \to 0$

$$E_{vib.} = \sum_i{}' \, n\hbar\omega_i \quad \text{(phonon)}$$

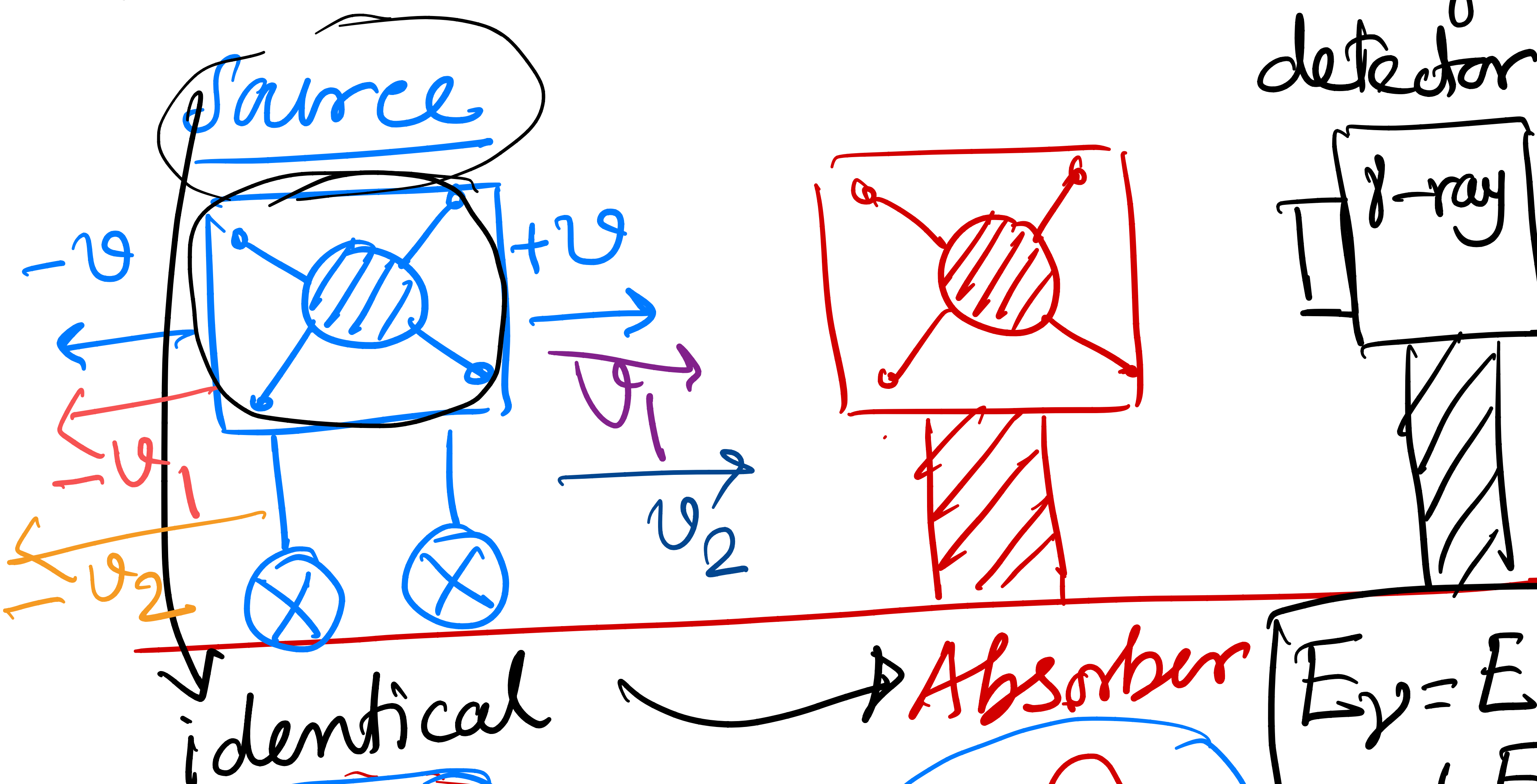
$\boxed{n=0}, 1, 2, 3 \ldots$

recoil-free / recoil-less transition (I)

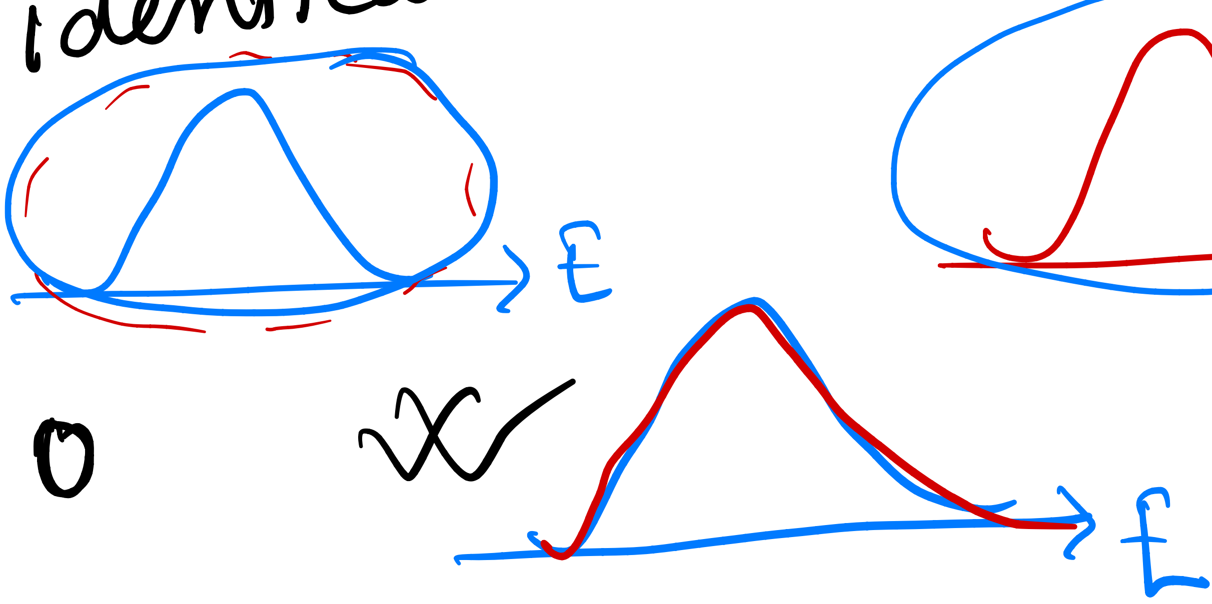
Mössbauer effect



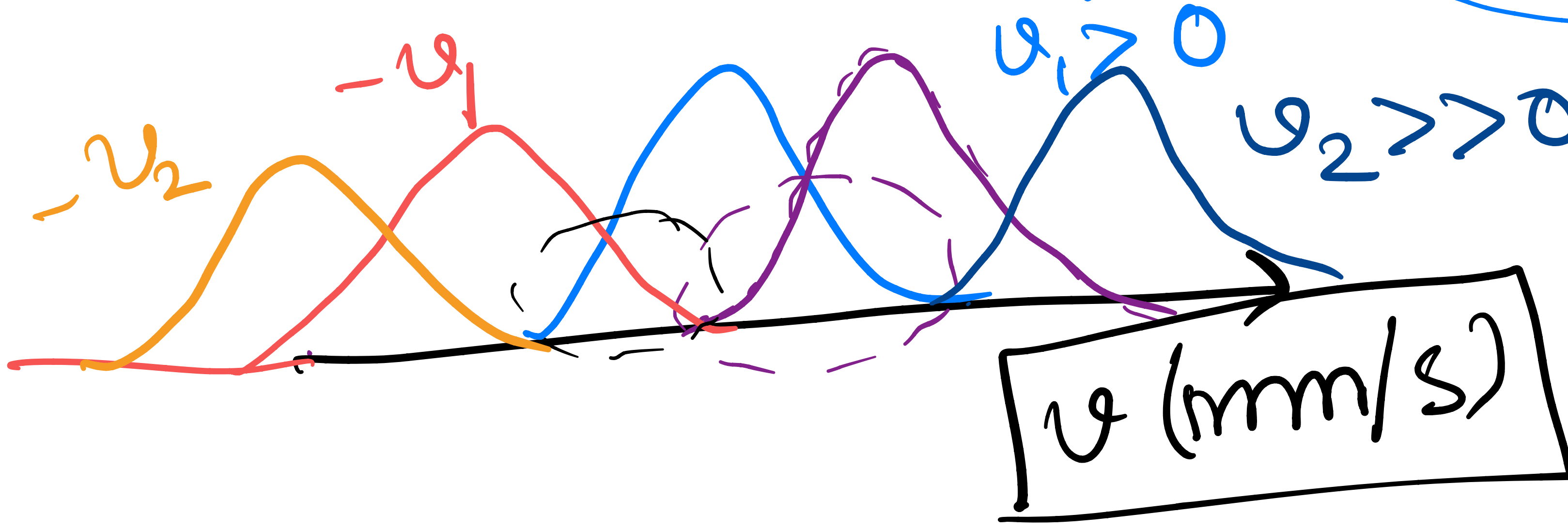
Mössbauer Spectroscopy (expt. design)

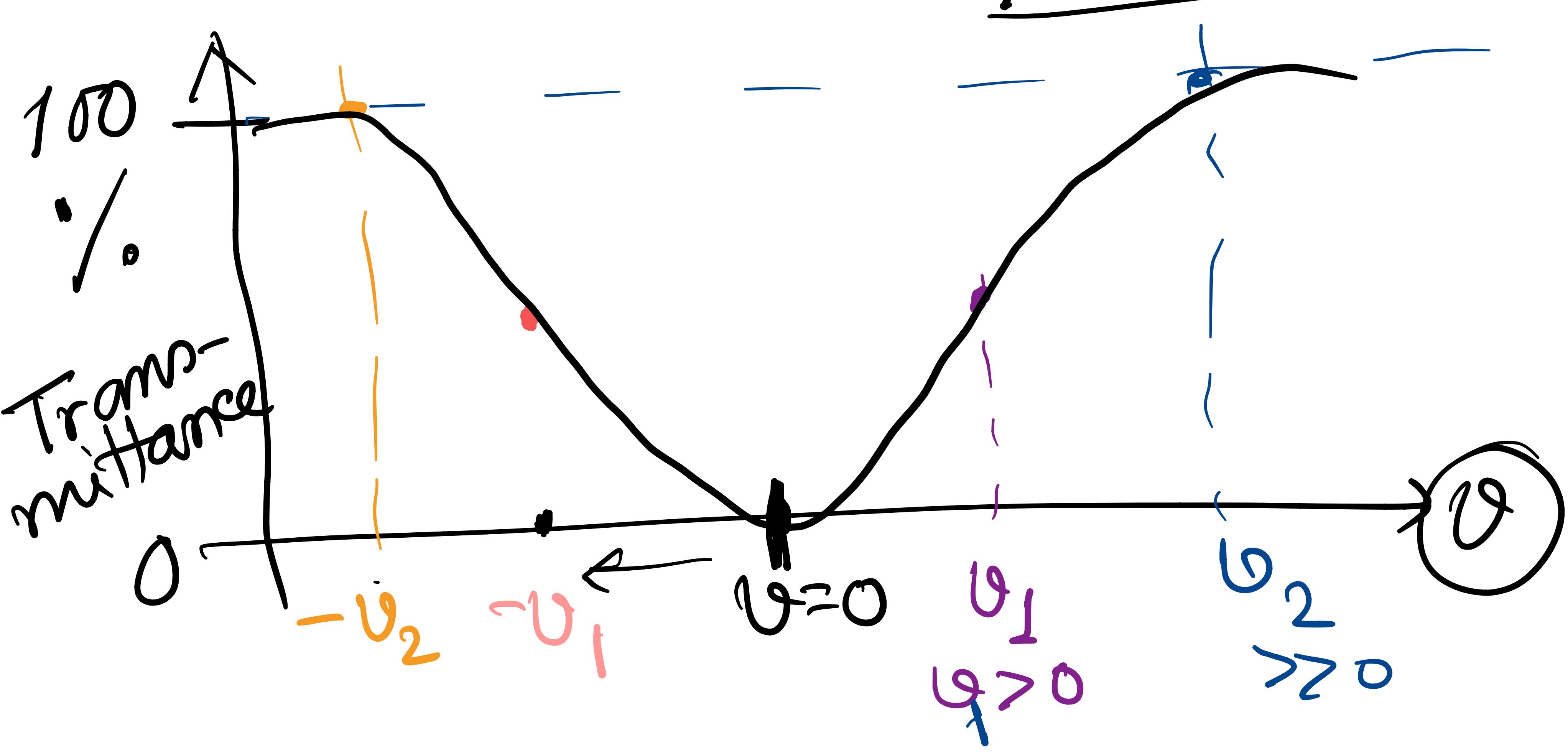


$$\boxed{E_\gamma = E_0 \pm E_D}$$



$$E_\gamma = E_0 (1 \pm v/c)$$





Heisenberg Uncertainty Principle

(tau) $\boxed{\tau \cdot \Gamma \geq \hbar}$

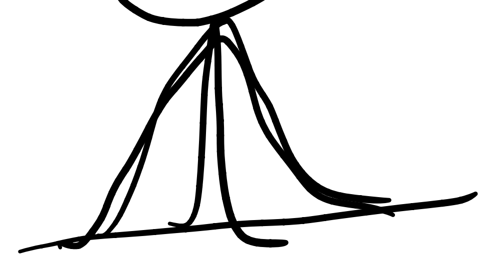
lifetime of the excited state

line-broadening

γ Γ

$\Delta E . \Delta t$

$h \Delta \nu$



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

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

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

<u>resolution</u> $= \Gamma / E_0$

$^{57}Fe \Rightarrow \Gamma = 5.0 \times 10^{-9}\,eV$

$\boxed{\tau = 141\,ns}$

$E_0 = 14.4\,keV = 14400\,eV$

$$\Gamma / E_0 = \frac{5.0 \times 10^{-9}\,eV}{14400\,eV} = \boxed{3.3 \times 10^{-13}}$$

resolution factor $= \frac{\Gamma \uparrow}{E_0 \downarrow}$

Γ (linebroadening) $\uparrow$

τ (lifetime) $\downarrow$ ($\tau \downarrow \Gamma \uparrow \geq \hbar$)

* $\boxed{\text{short-lived excited state}}$

$E_0 \rightarrow$ nuclear transition Energy

* $\boxed{\text{lower value of transition energy}}$

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

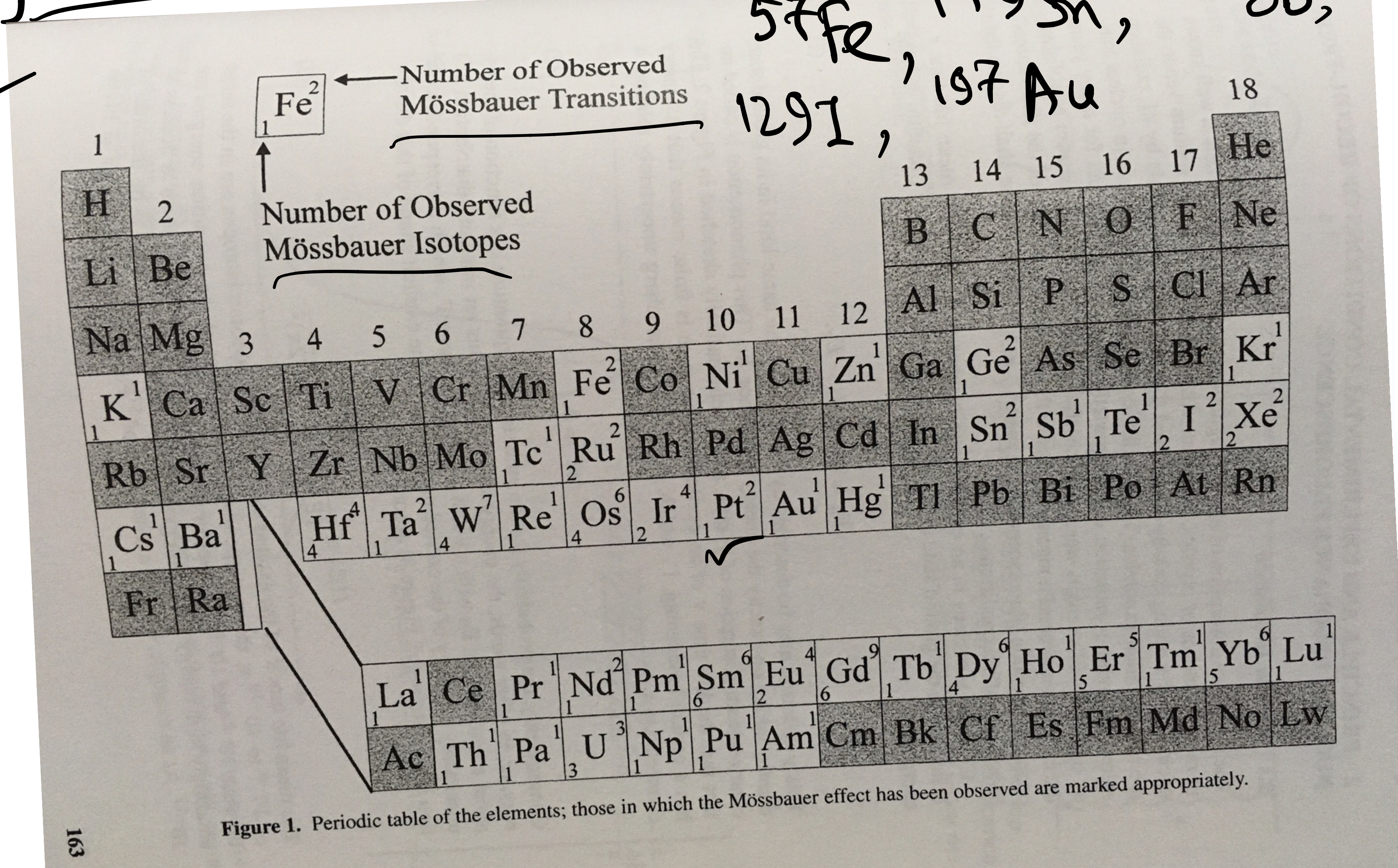
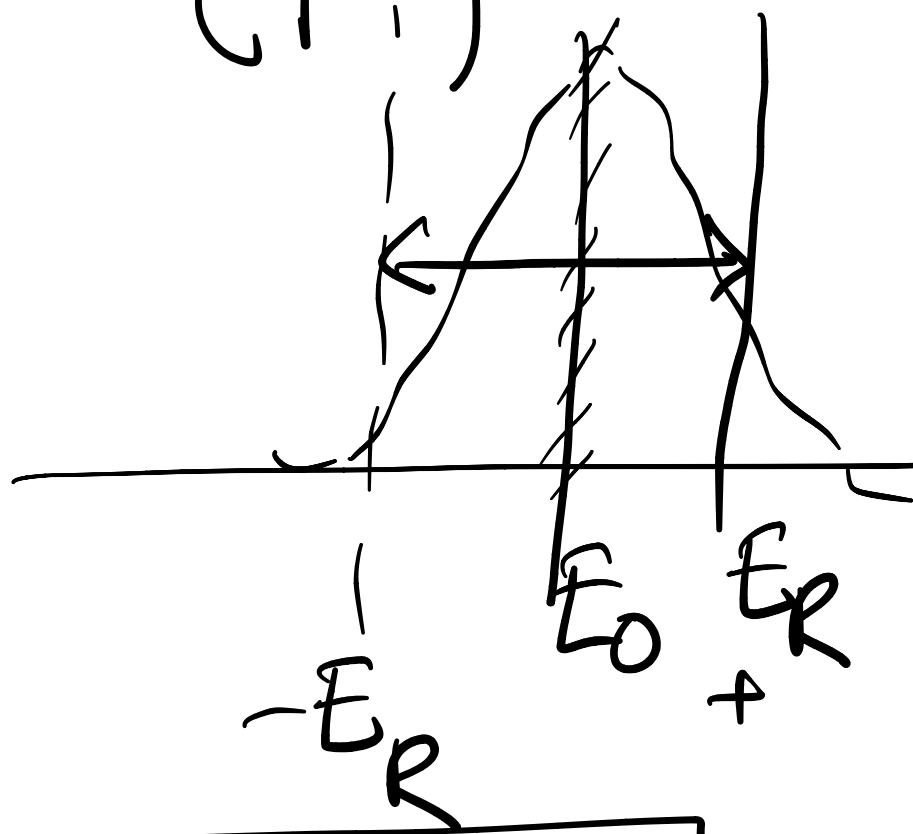


Figure 1. Periodic table of the elements; those in which the Mössbauer effect has been observed are marked appropriately.

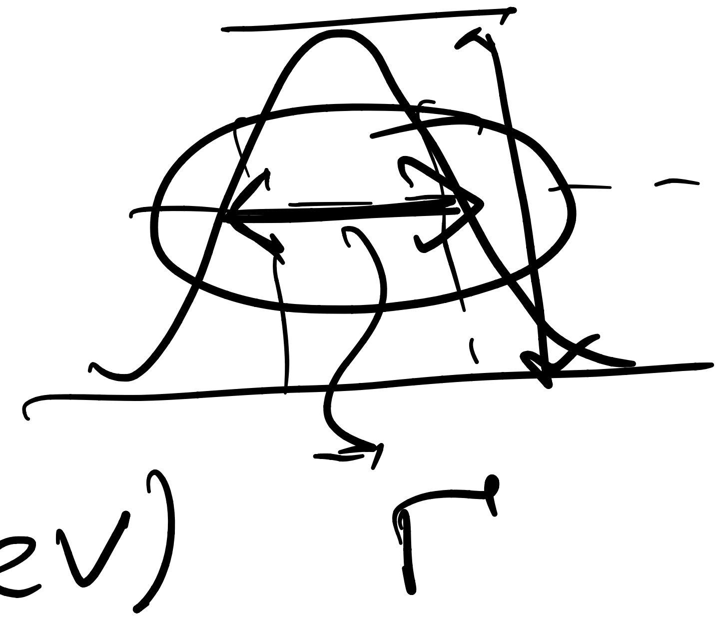
163

line broadening / recoil energy

(Γ) (E_R)

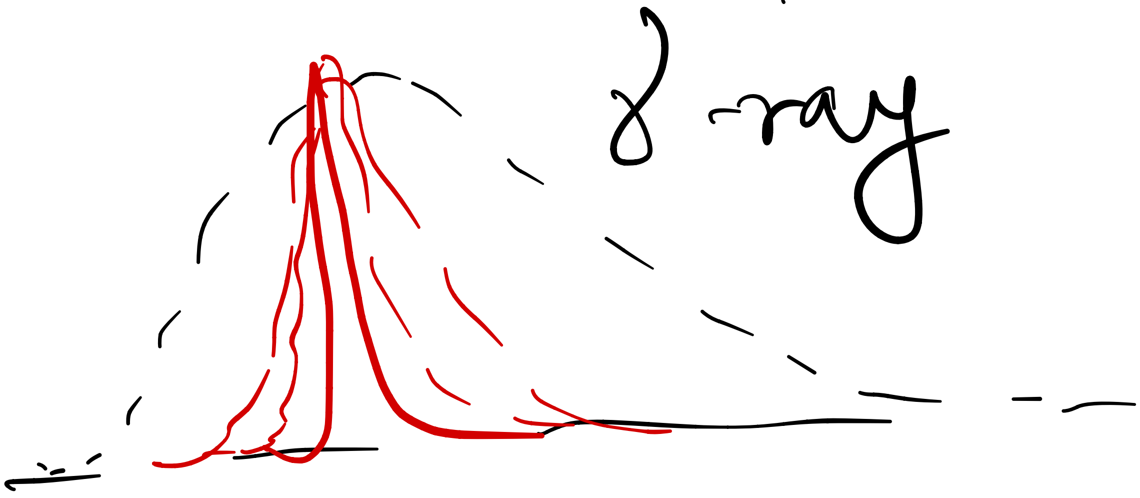


$$\boxed{2E_R \leq \Gamma}$$

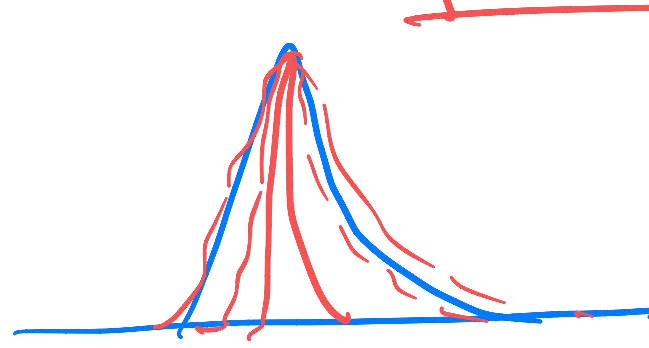


Transition (eV)	Electronic	Nuclear
E_0	~ 2.1	$\boxed{14400}$
Γ	4.4×10^{-8}	5.0×10^{-9}
E_R	10^{-10}	1.95×10^{-3}

γ-ray



Optical



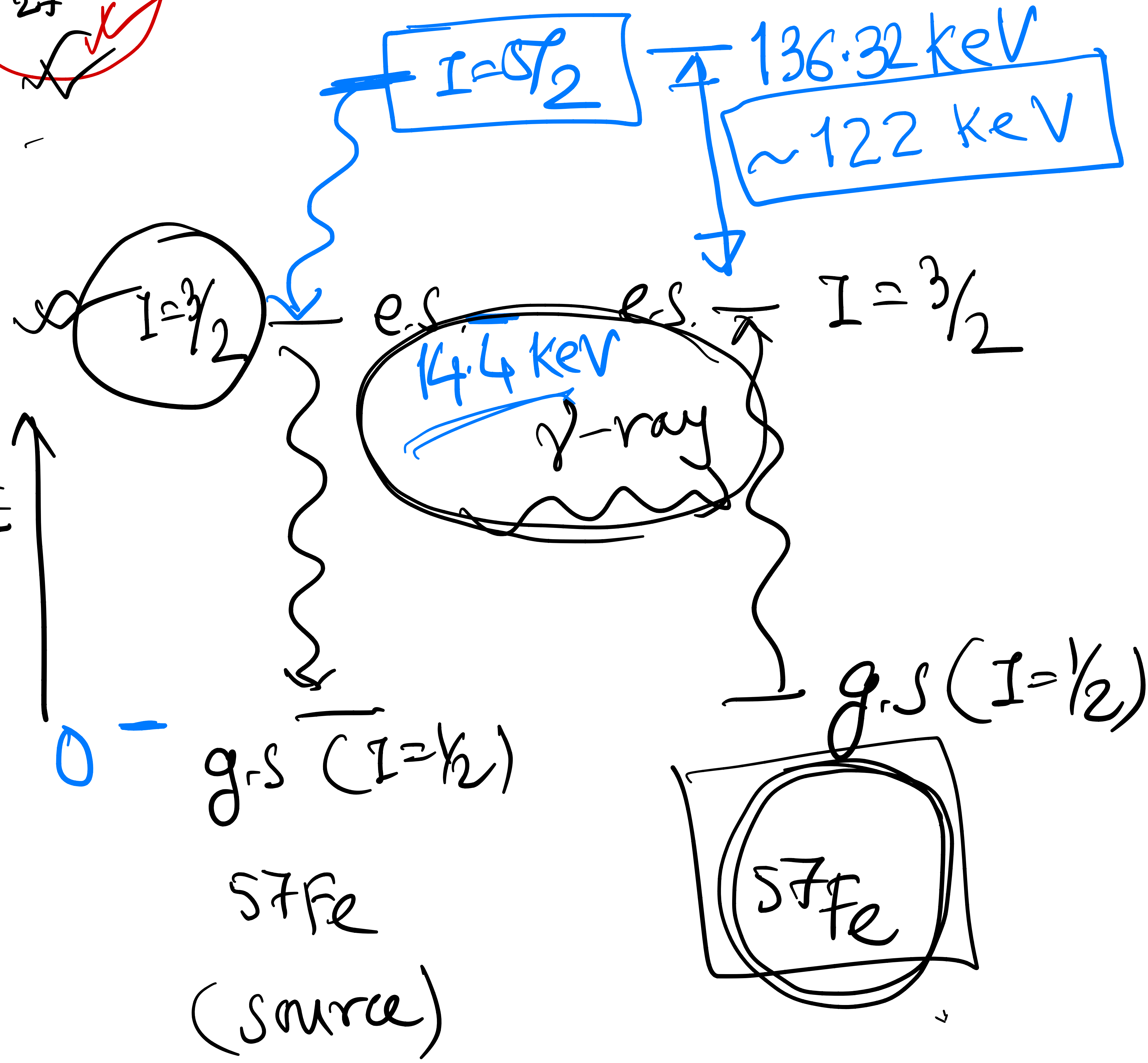
Mössbauer active nuclei

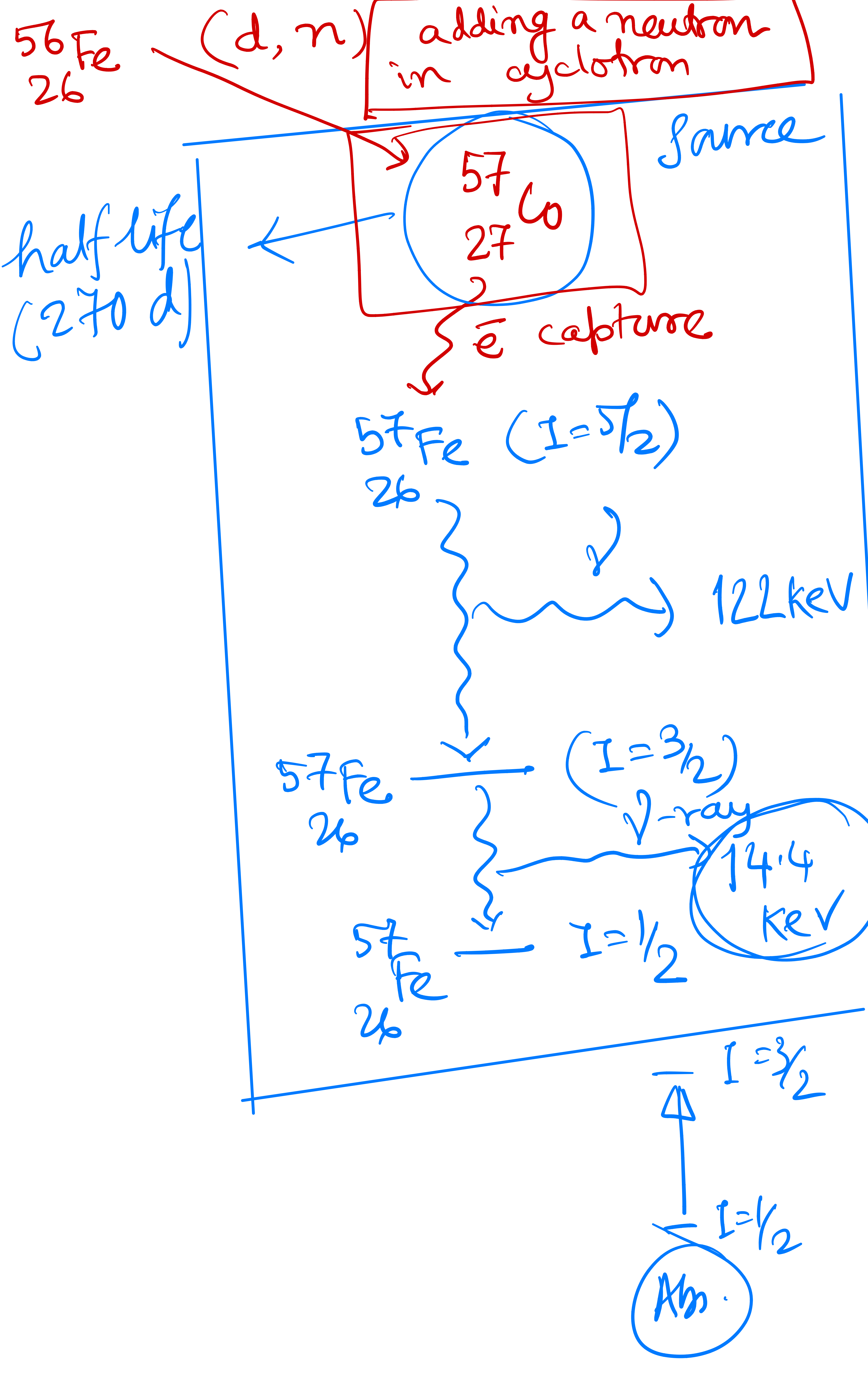
$^{57}_{26}Fe$ natural abundance $\boxed{2.14\%}$

^{57}Fe enriched sample $\rightarrow$ $\boxed{\text{Absorber}}$

parent nuclei $\rightarrow$ $\boxed{^{57}Co}$

$^{57}_{27}Co^{*} \xrightarrow{\bar{e}} {}^{57}Fe\ (I = 7/2)$ $\boxed{(\bar{e}\ \text{capture})}$





$^{56}_{26}Fe$
(d, n)
adding a neutron in cyclotron
Source
$^{57}_{27}Co$
half life (270 d)
$\bar{e}$ capture
$^{57}_{26}Fe$ (I = 5/2)
γ
122 keV
$^{57}_{26}Fe$
(I = 3/2)
γ-ray
14.4 keV
$^{57}_{26}Fe$
I = 1/2
I = 3/2
I = 1/2
Abs.