Chemical Engineering 412

Introductory Nuclear Engineering

Lecture 26

Radiation Detection & Measurement II

Spiritual Thought

”The family is ordained of God. Marriage between man and woman is essential to His eternal plan.

Children are entitled to birth within the bonds of matrimony, and to be reared by a father and a mother who honor marital vows with complete fidelity.

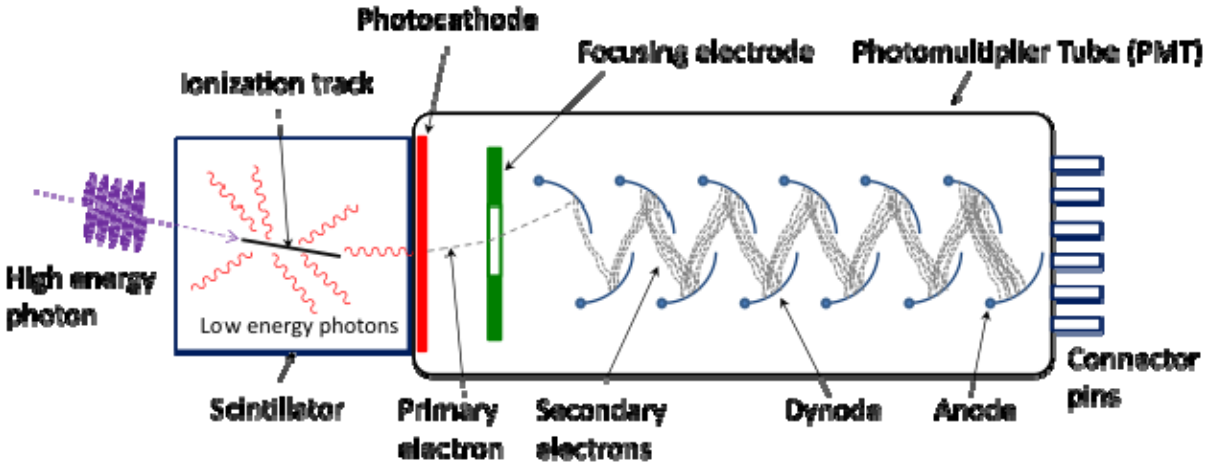
Happiness in family life is most likely to be achieved when founded upon the teachings of the Lord Jesus Christ.”

Quiz!

- Work for 5 minutes on your own
- Then for 3 minutes in groups of 3-4
- Afterward, we'll review together

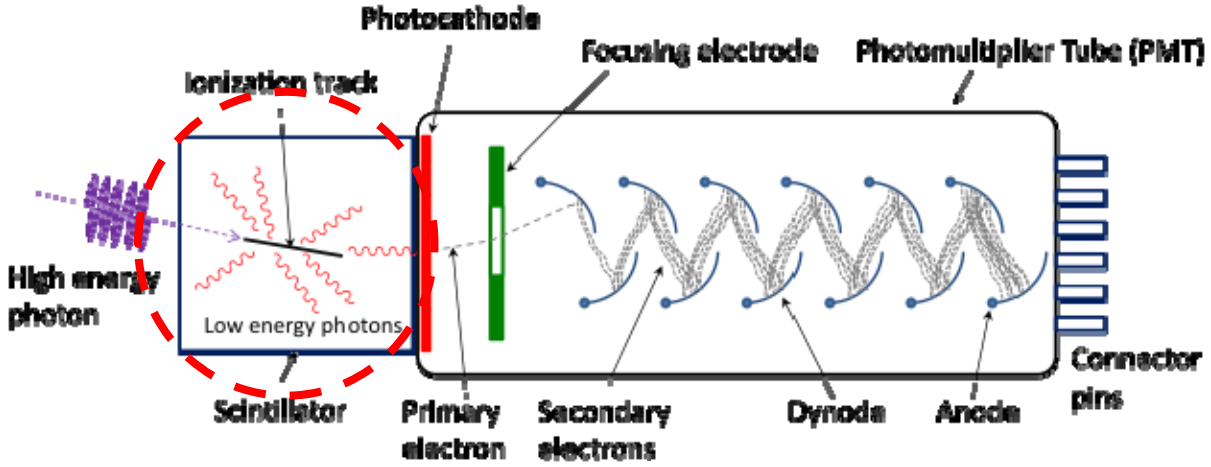
Scintillator

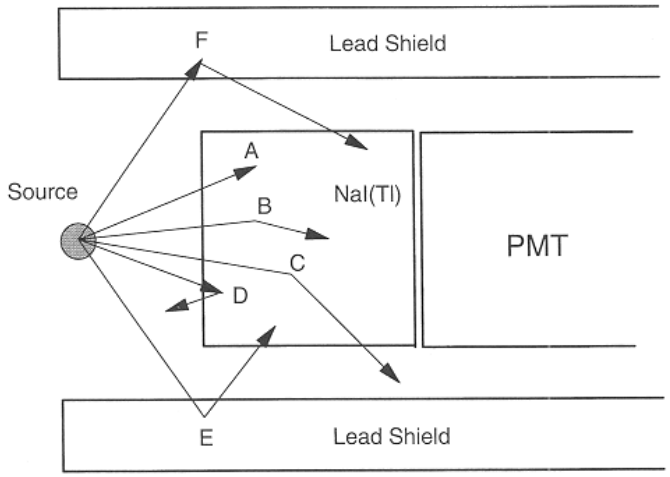
Scintillation crystal



Dynodes

Scintillator Interactions



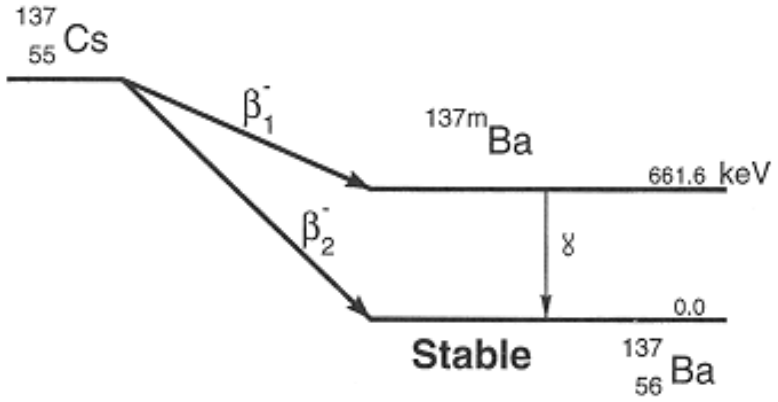


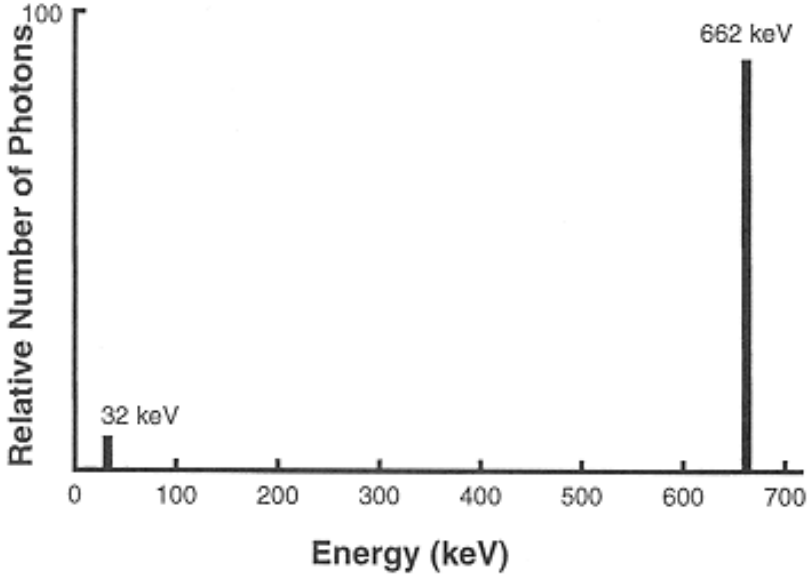
Possible interactions at spectrometer entrance

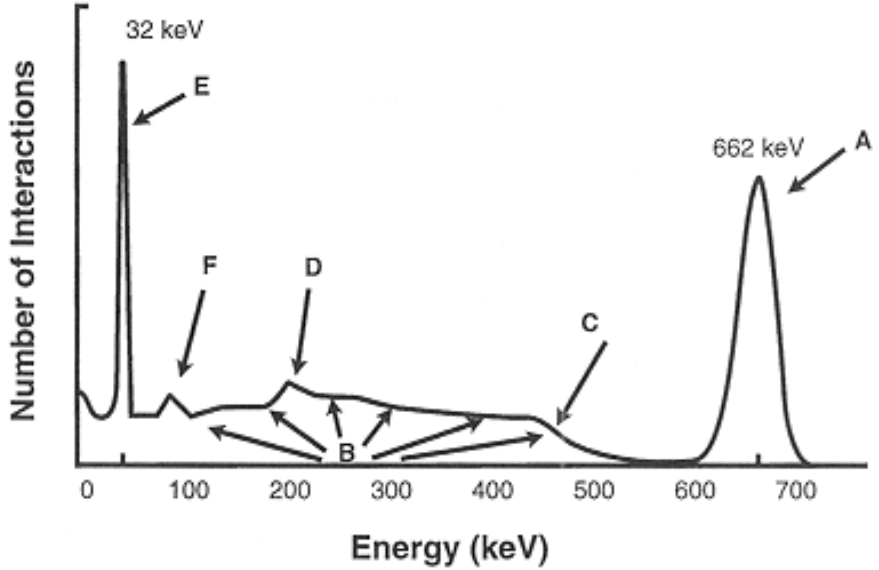
Example: Cs-137 Spectrum

- Cs-137 decays by beta particle emission to Ba-137m, leaving the Ba-137m nucleus in an excited state
- The Ba-137m nucleus attains its ground state by the emission of a 662-keV gamma ray 90% of the time
- In 10% of decays, a conversion electron is emitted instead, followed by a ~32-keV *K*-shell characteristic x-ray

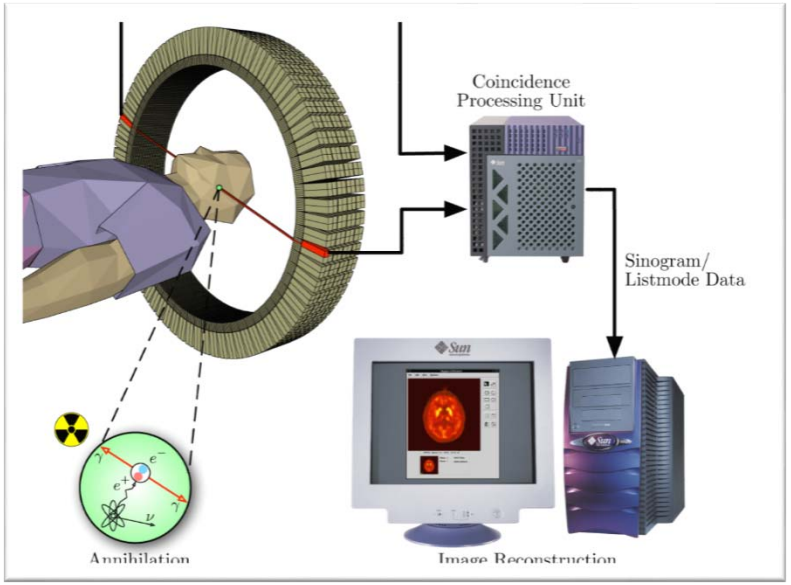
Example Continued







Scintillation Applications

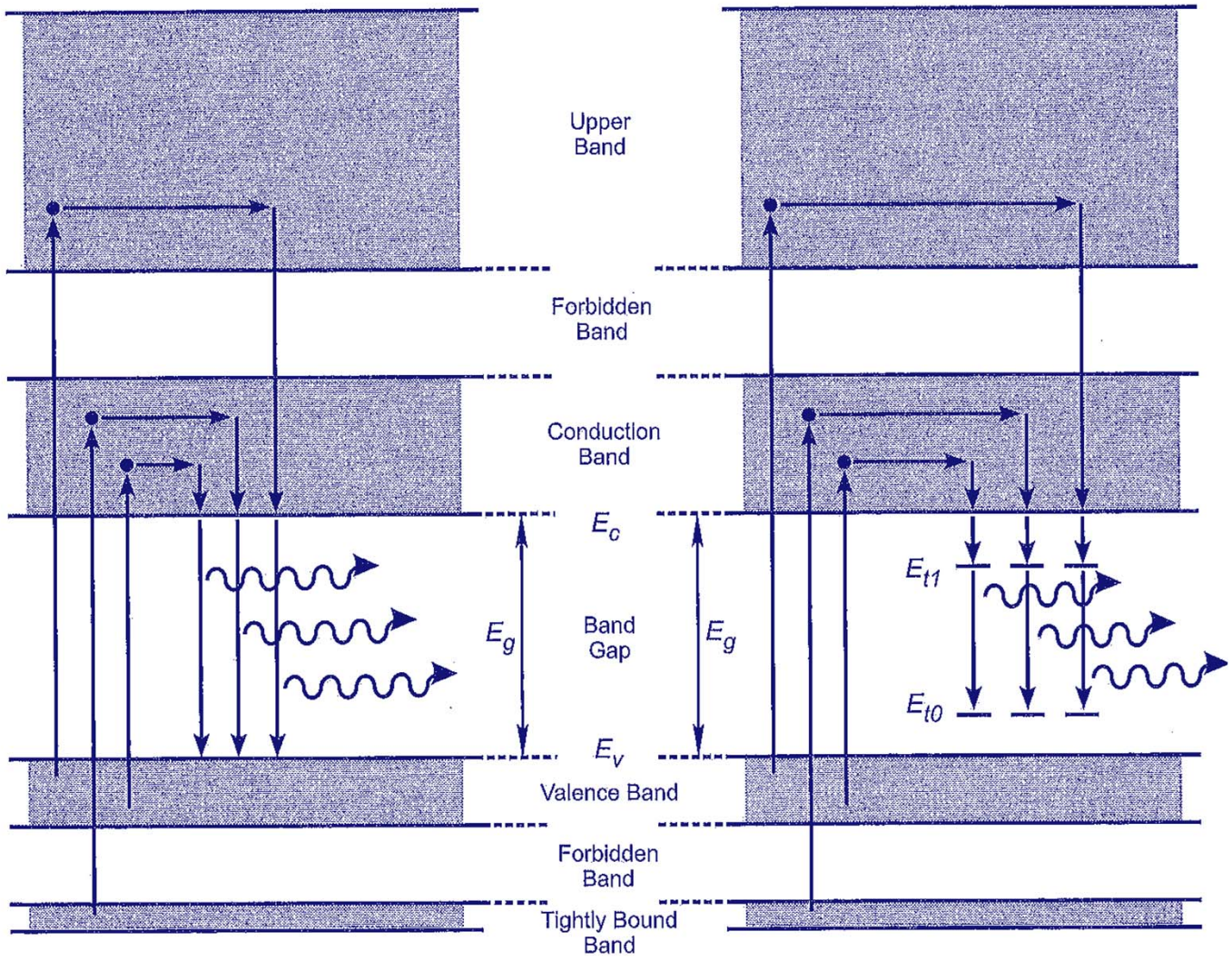


PET scan setup

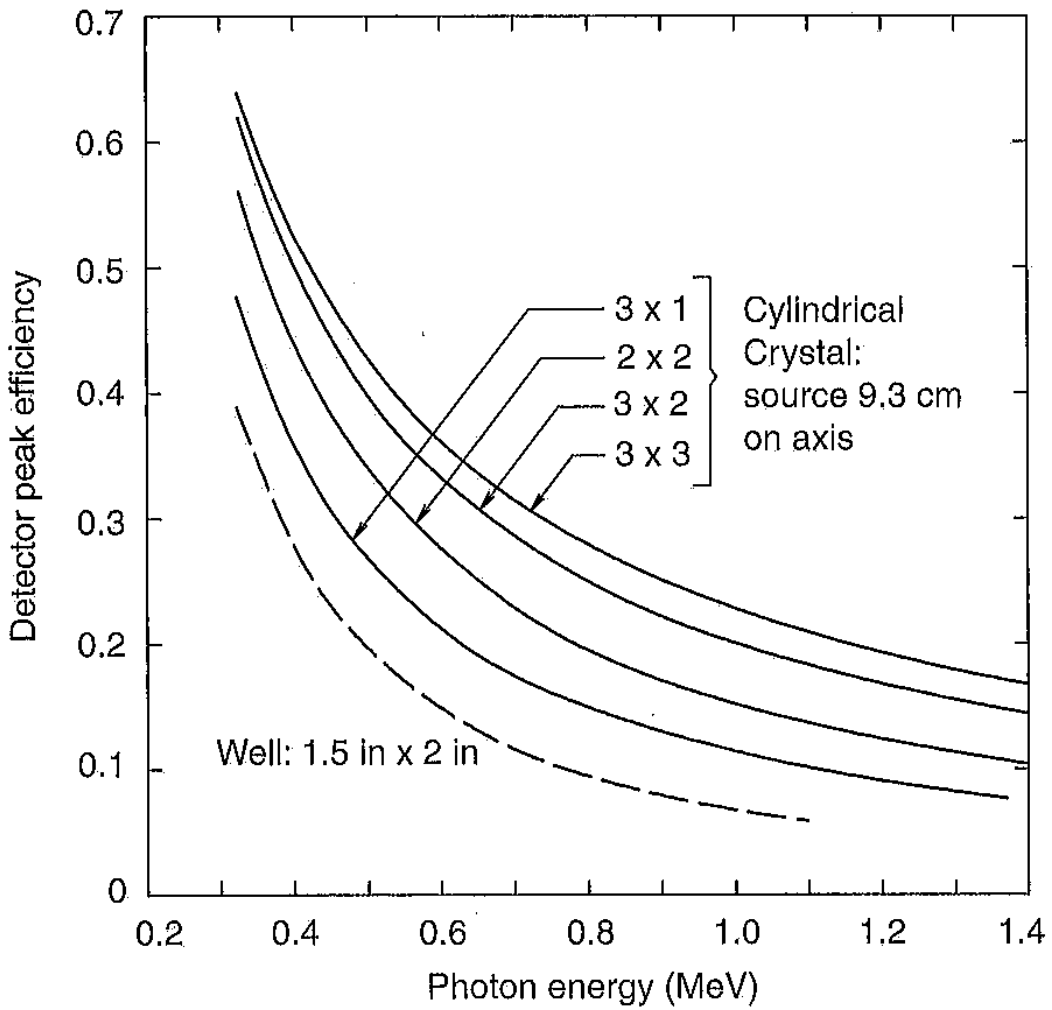
Fluoroscopy

Radiography

Scintillation Mechanism - Inorganic



Absorption Efficiency



Fluorescence Decay Signal

$$N(t) = N_0 exp(-\lambda t) \qquad (1)$$

$$n(t) = \int_0^t \lambda N(t')dt' \qquad (2)$$

$$\lambda = \frac{1}{\tau} \qquad (3)$$

Problem 8.3: quick solution

Quick solution:

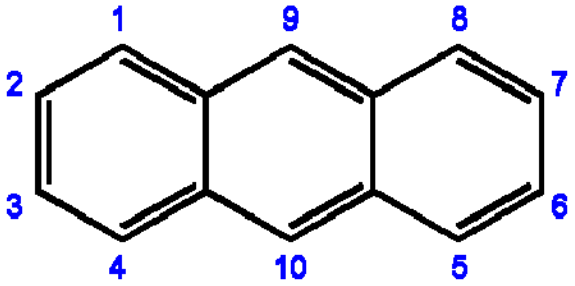
λ=4.35E6/sec

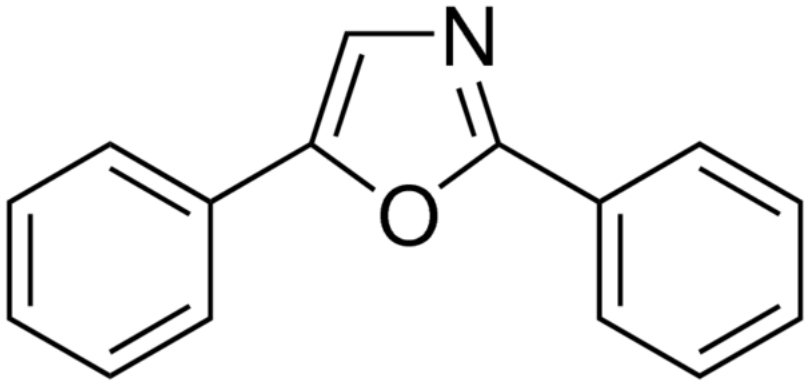
n/N=$\frac{n}{N} = \lambda \int_0^{t_o} e^{-\lambda t}$

$t_o = -\frac{1}{\lambda}\left(1 - \frac{n}{N}\right)$ =529 ns

Organic Scintillators

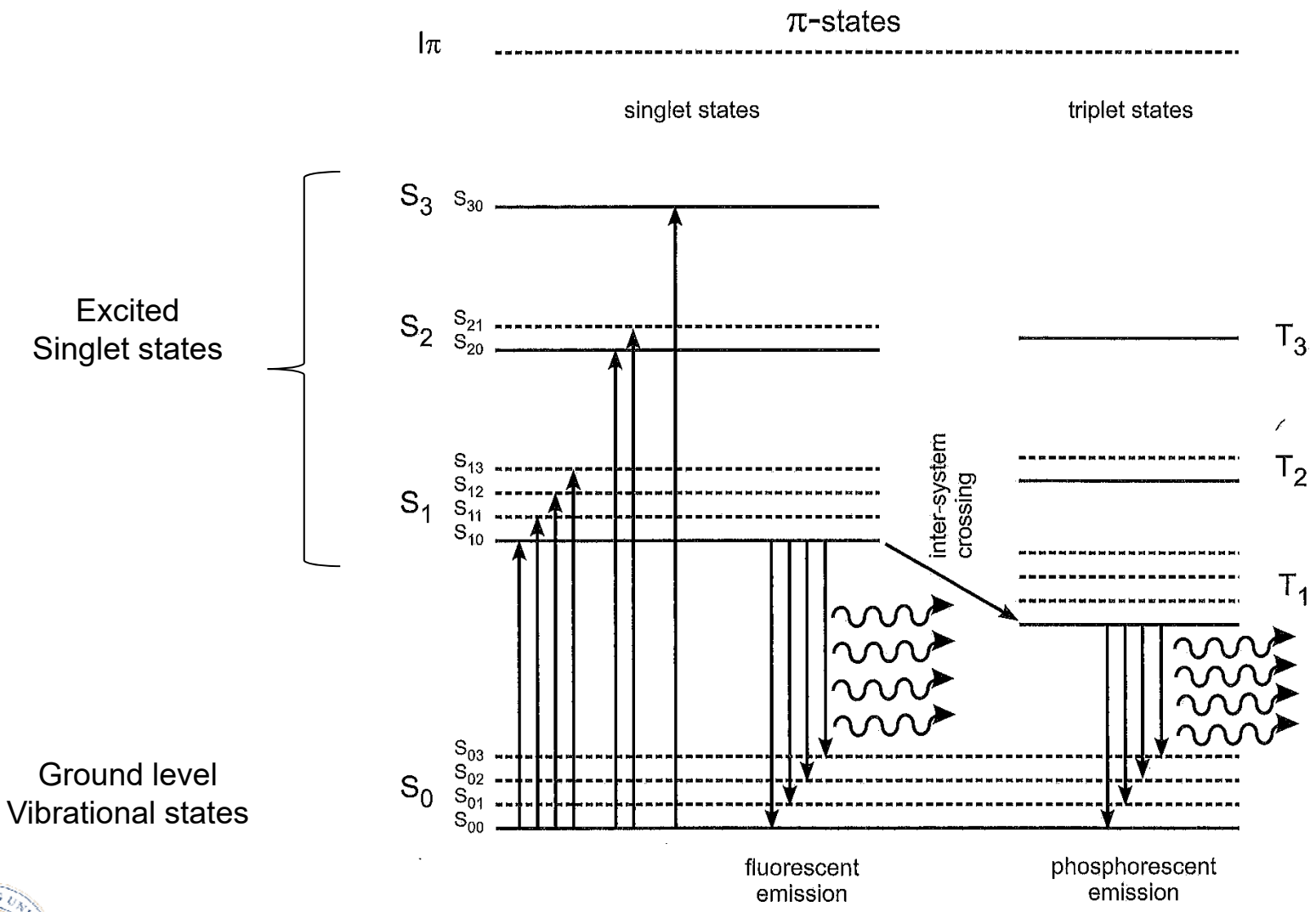
Anthracene: solid organic





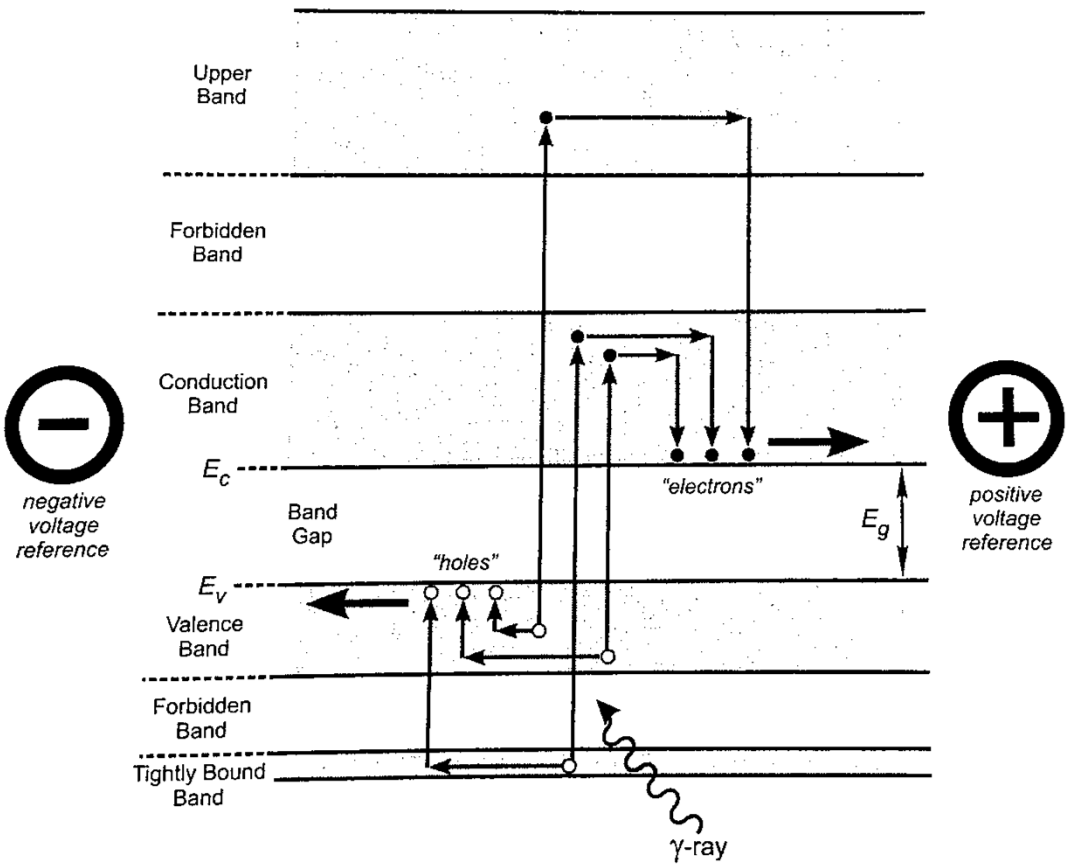
2,5-Diphenyloxazole, or PPO: Liquid organic

Scintillation Mechanism - Organic



Scintillator Desirable Properties

Semiconductor Detectors



Semi-conductor Detectors

Type	Efficiency (Z)	Density (g/cm^3)	Resolution (Band Gap eV)	Ionization Energy (eV/e-h)	Convenience	Notes
Si(Li)	Very Low (14)	2.33	High 1.12	3.61	Low	LN operation
Ge(Li)	Low (32)	5.33	High 0.72	2.98	Very Low	LN always
GaAs	Low (31/33)	5.32	1.42	4.2	modest	
CdTe	Moderate (48/52)	6.06	1.52	4.43	low	polarizes slowly with time
$Cd_5Zn_{45}Te_{50}$	Moderate (48/52)	6.0	1.6	5.0	high	no cooling necessary, stable
HgI_2	Moderate (80/53)	6.4	2.13	4.3	low	polarizes with time

Attributions

- Fluorscopy gif: By Normaler_Schluck-00.jpg (and others): Hellerhoffderivative work: Anka Friedrich (talk) - 34 files:Normaler_Schluck-00.jpg[…]Normaler_Schluck-33.jpg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=15333554
- Photomultiplier schematic: By Qwerty123uiop, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=62426194
- Dynode photo: CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=121682
- Anthracene photo: By Smokefoot - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=40704331
- PPO structure: By Assosiation - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=45249781
- Germanium detector photo: By Sergio.ballestrero at en.wikipedia, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=3131333