Inorganic Scintillators

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Introduction

- Applications
- Desired Properties
- Types
- Mechanism
- Further Reading

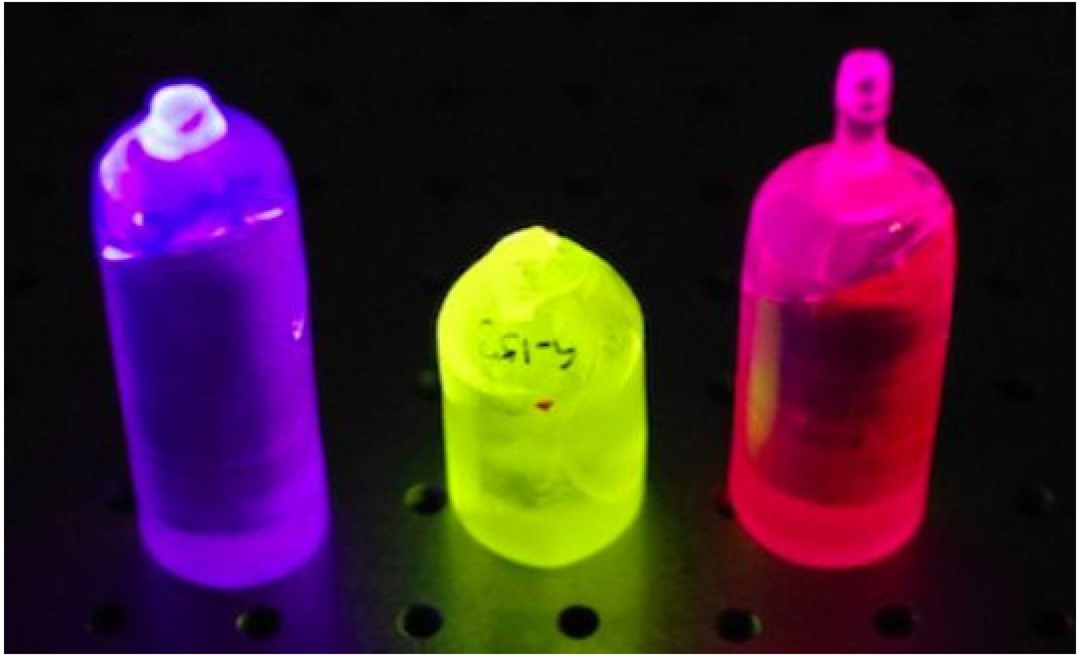
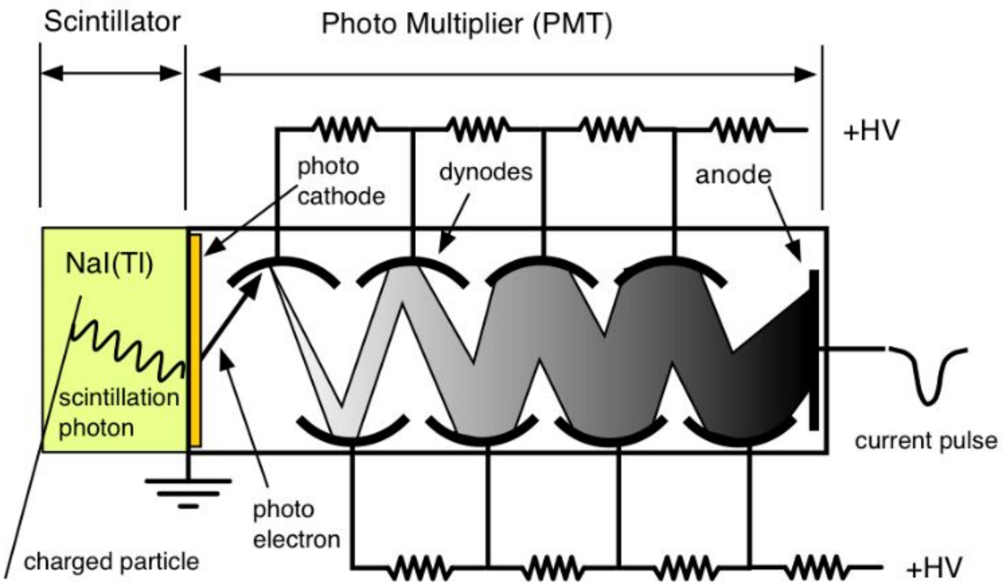


Image from: https://www1.aps.anl.gov/detectors/scintillator-and-visible-light-detectors

Detection systems



- PMT
- SiPM/SSPM (array of Geiger-mode APD’s)
- CCD/CMOS camera

Images from: http://wanda.fiu.edu/teaching/courses/Modern_lab_manual/scintillator.html

Desired Properties

- Luminosity (ph/MeV deposited)
- Density (number of atoms/ sq. cm)
- Atomic number (Zeff)
- Linearity
- Stokes shift (low self-absorption)
- Decay time
- Emission spectrum
- Refractive index
- Energy Resolution
- Cost (ease of growth process)

Image from https://en.wikipedia.org/wiki/Scintillator#/media/File:SGCat24454-scint-gris.noirEtBlanc.jpg

Types

- Organic
  - fast decay time
  - Crystalline (Anthracene, Stilbene)
  - Liquid
  - Plastic
- Inorganic
  - slow but brighter, better energy res.
  - Crystalline (CsI:Tl, NaI:Tl, LSO/LYSO)
  - Ceramic (GLuGAG, GLO)
- Semiconductor
  - CZT, HPGe
- Novel
  - Ion chamber, drift tube, TES, etc.

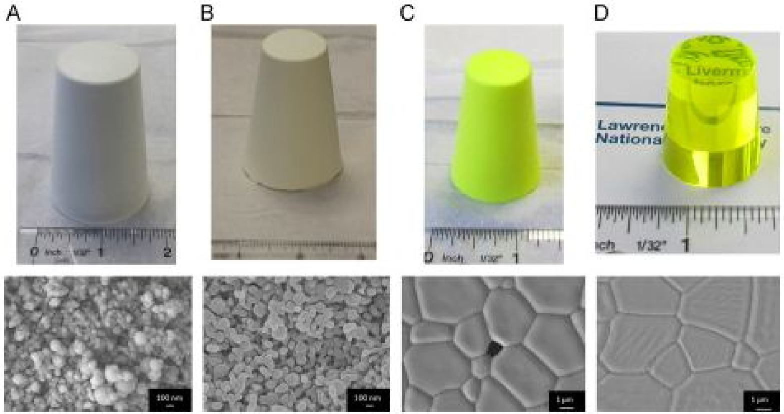


Fig. 2.
Pictures of: (A) gel-cast; (B) calcined; (C) vacuum sintered and (D) HIP'ed (top). Microstructure showing the densification process at each step (bottom).

Figure from Seeley 2013

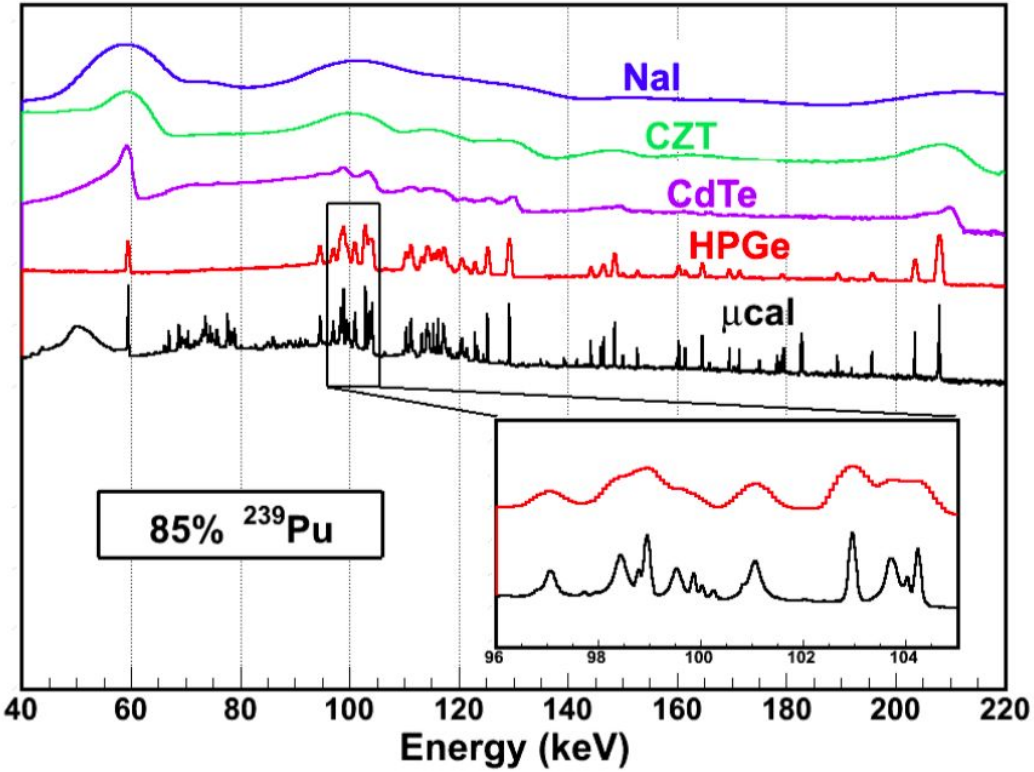
Table 2. A survey of characteristics of selected single crystal scintillators [5, 13, 128, 136, 143].

Crystal	Density ($g\ cm^{-3}$)	Light yield (photon MeV^{-1})	Dominant scintillation decay time (ns)	Emission maximum (nm)	$\Delta E/E$ at 662 keV (%)
CsI:Tl	4.51	66 000	800	550	6.6
NaI:Tl	3.67	41 000	230	410	5.6
$LaBr_3$:Ce	5.3	61 000	35	358	2.9
K_2LaI_5:Ce	4.4	55 000	24	420	4.5
BaF_2 (only cross luminescence)	4.88	1 500	0.6–0.8	180–220	7.7
$Bi_4Ge_3O_{12}$	7.1	8 600	300	480	9.0
$PbWO_4$	8.28	300	2–3	410	30–40
$CdWO_4$	7.9	20 000	5 000	495	6.8
$YAlO_3$:Ce	5.6	21 000	20–30	360	4.6
$LuAlO_3$:Ce	8.34	12 000	18	365	~15
$Y_3Al_5O_{12}$:Ce	4.56	24 000	90–120	550	7.3
$Lu_3Al_5O_{12}$:Ce	6.67	12 500	55	530	11
Gd_2SiO_5:Ce	6.7	8 000	60	420	7.8
Lu_2SiO_5:Ce	7.4	26 000	30	390	7.9

Table from Nikl 2006

Energy resolution for X- and γ-ray spectroscopy

Factor of ten better than conventional semiconductor technology



From "Cryogenic detectors and neutrino mass measurement" by Michael W. Rabin, Los Alamos National Laboratory
http://public.lanl.gov/friedland/info13/info13talks/Rabin-INFO13.pdf

Stokes Shift

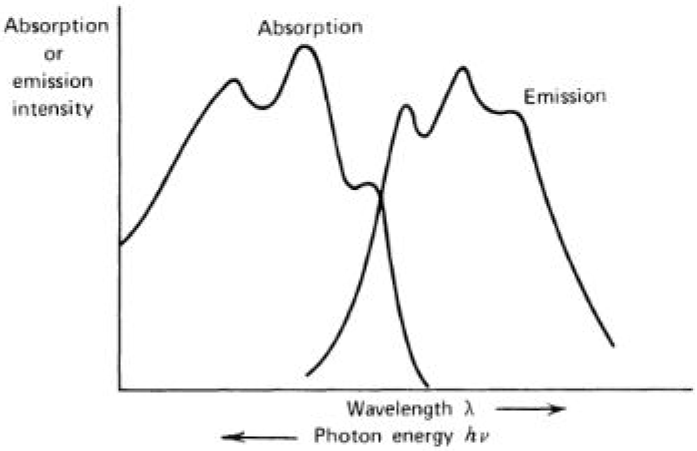


Figure 8.2 The optical absorption and emission spectra for a typical organic scintillator with the level structure shown in Fig. 8.1.

Figure from Knoll 2010

Emission Spectra

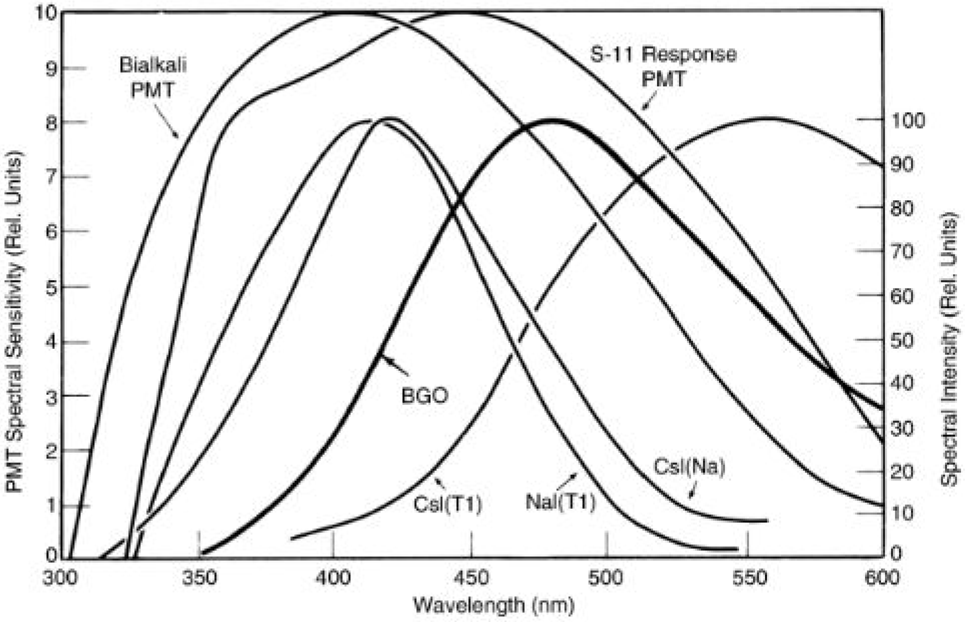


Figure 8.7 The emission spectra of several common inorganic scintillators. Also shown are the response curves for two widely used photocathodes. (Primarily from *Scintillation Phosphor Catalog*, The Harshaw Chemical Company. The emission spectrum for BGO is from Ref. 79.)

Figure from Knoll 2010

Stages of absorption/emission

1. Absorption of the ionizing radiation and creation of primary electrons and holes
2. Relaxation of the primary electrons and holes, i.e., production of numerous secondary electrons, holes, photons, plasmons, and other electronic excitations
3. Thermalization of the low-energy secondary electrons (holes) resulting in a number of e-h pairs with energy roughly equal to the band-gap energy E_g
4. Energy transfer from the e-h pairs to the luminescence centers and their excitation
5. Emission from the luminescence centers

From Rodnyi 1997

Absorption Mechanisms

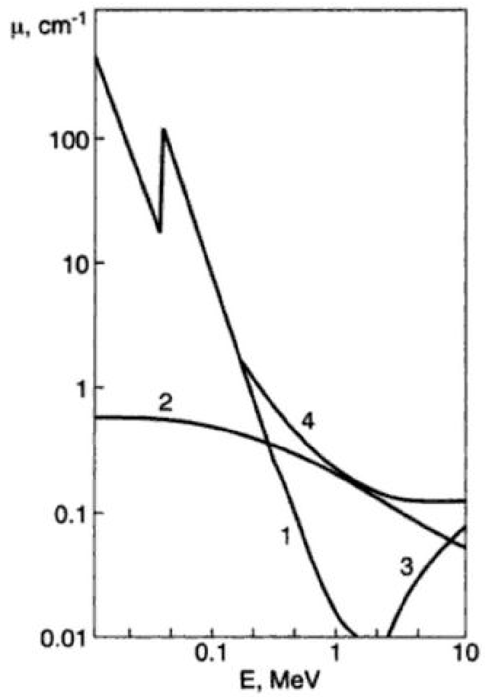


Figure from Rodnyi 1997

FIGURE 1.4 Linear absorption coefficient μ in CsI:Tl as a function of gamma-ray energy for photoelectric effect (1), Compton effect (2), pair production (3), and total absorption (4). (Courtesy of Harshaw Chemical Company.)

Defects

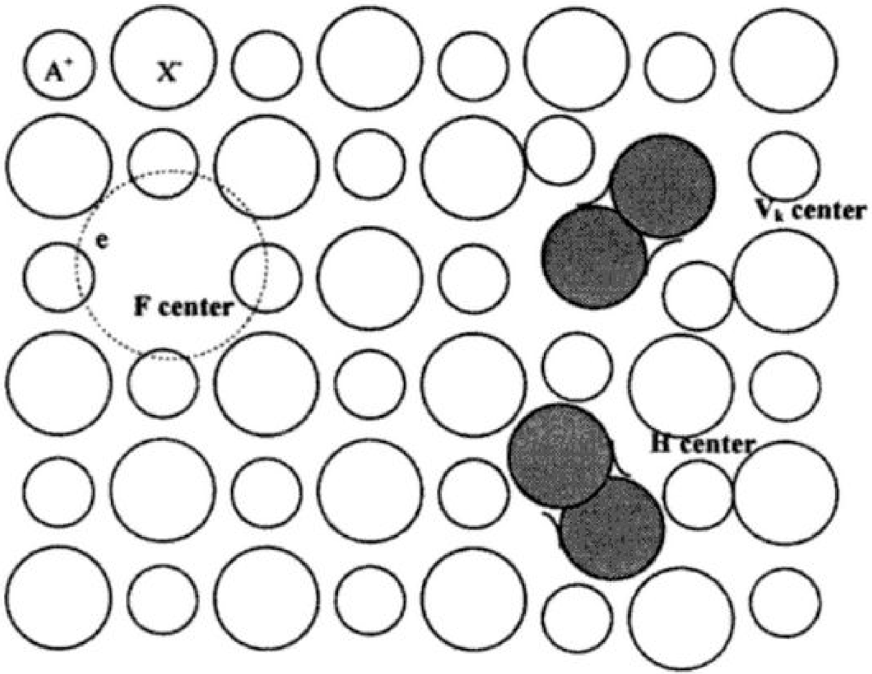


Figure from Rodnyi 1997

FIGURE 1.2 Schematic structure of an F center, a self-trapped hole (V_k center), and an H center in an alkali halide (AX) crystal with the NaCl structure.

Emission

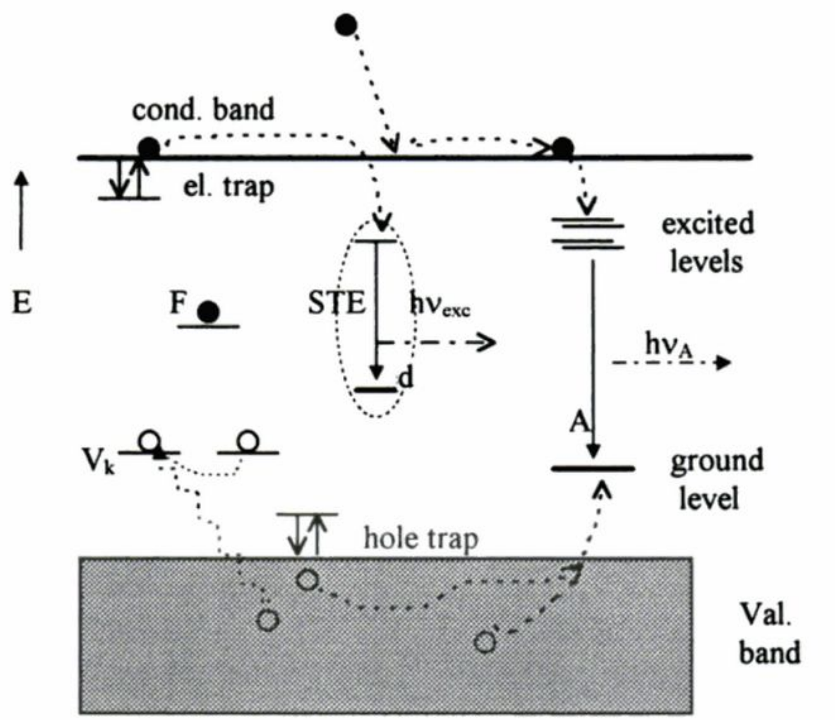
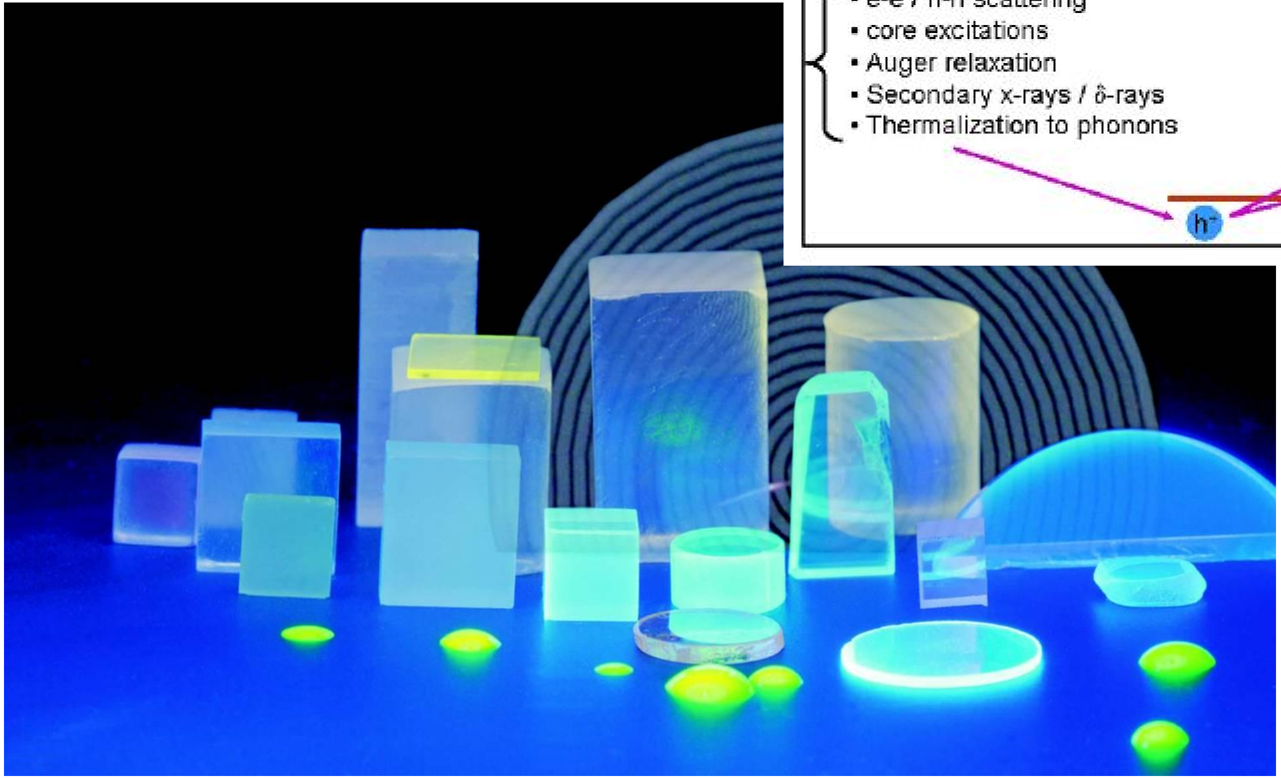


FIGURE 1.3 Final stage of scintillation process in the energy-band scheme of a crystal.

Figure from Rodnyi 1997

Summary



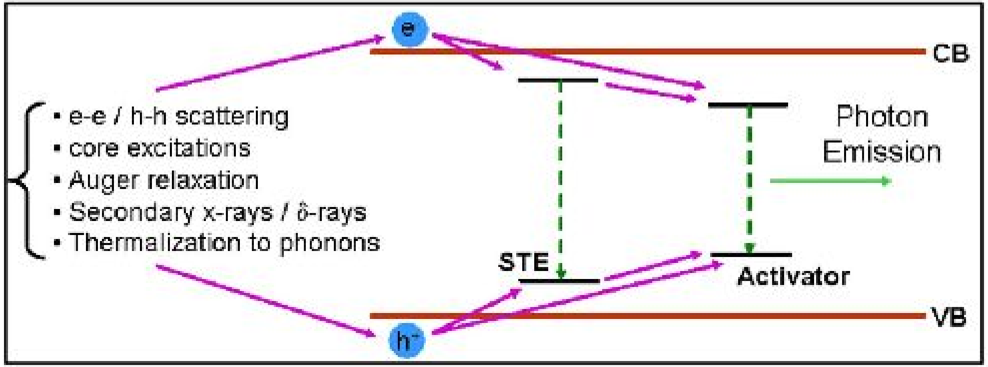


Photo from http://www.tnw.tudelft.nl/index.php?id=34562

References/ Further Reading

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