Neutron Source and Research Applications

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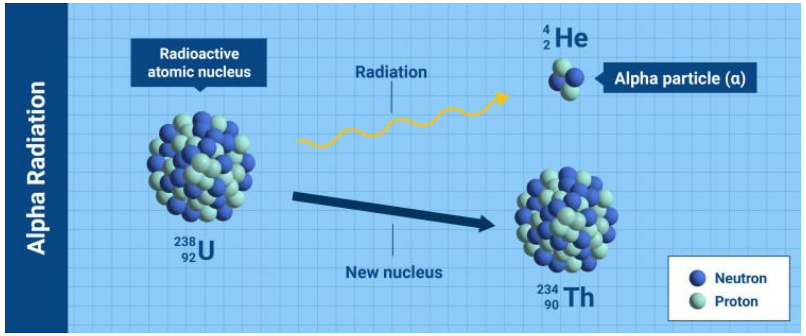
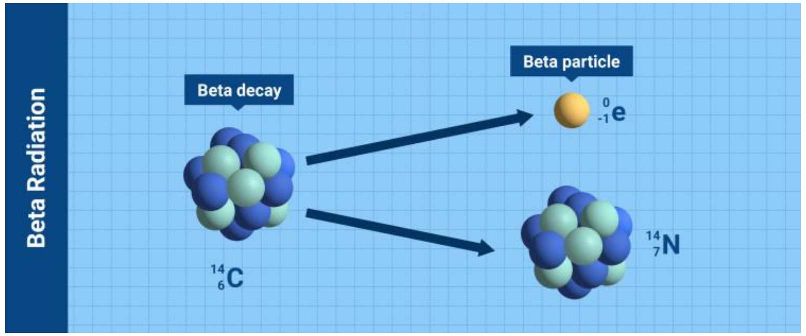
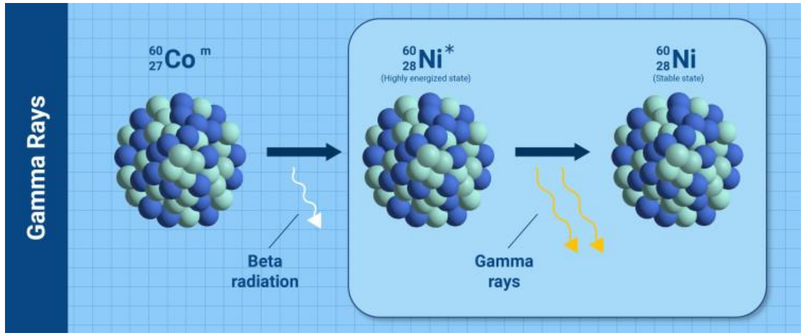
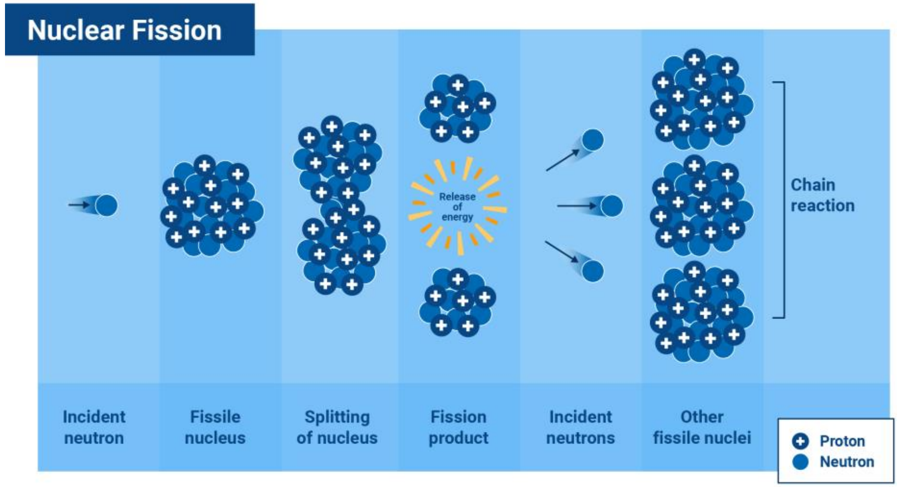
Contents

Radiation sources & Types



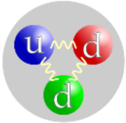




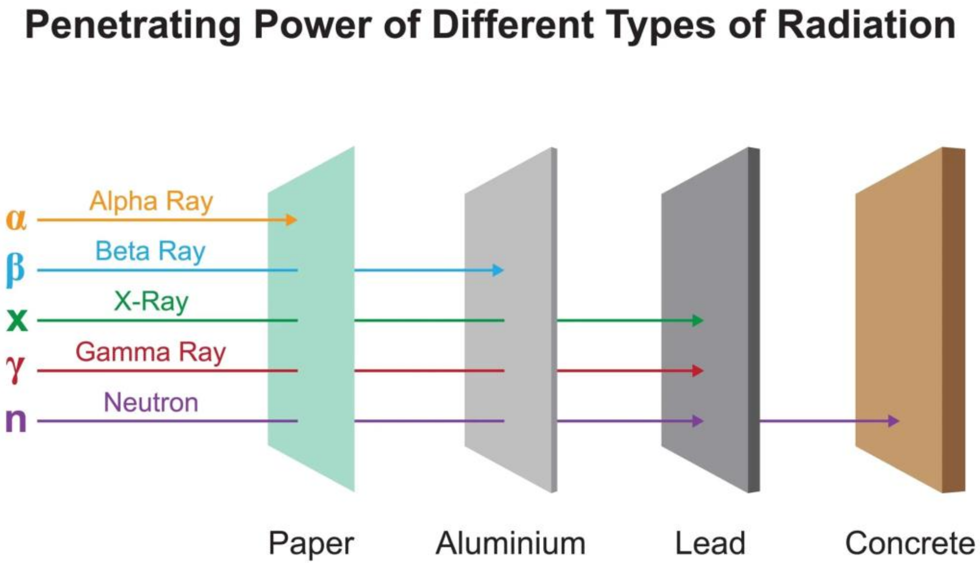


Why they are special.?

Neutrons



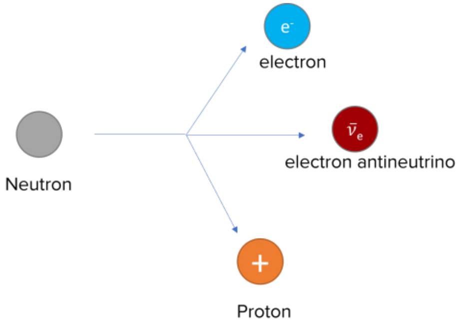
Energy Range: <0.0001 eV (cold neutrons) to >20 MeV (high-energy neutrons)



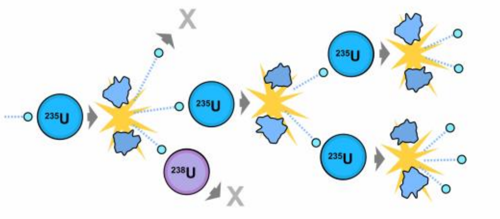
Cold neutrons < 0.003 eV
Slow (thermal) neutrons 0.003–0.4 eV
Slow (epithermal) neutrons 0.4–100 eV
Intermediate neutrons 100 eV–200 keV
Fast neutrons 200 keV-10 MeV
High energy (relativistic) neutrons > 10 MeV

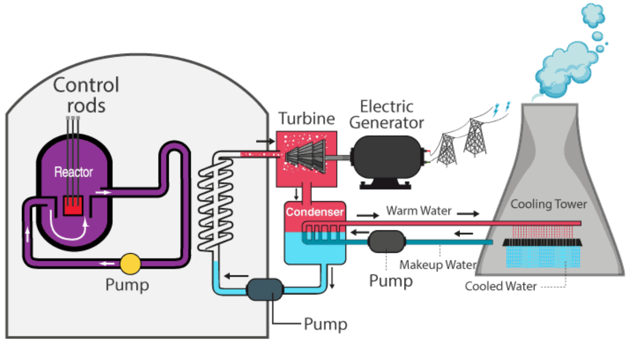
Slow (thermal) neutrons 0.003–0.4 eV **(2.2 km/s)**

Mean life-time: 877.75 ± 0.28 sec

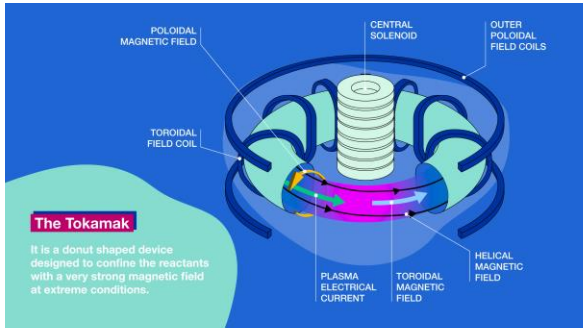


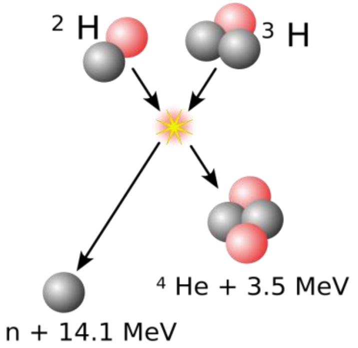
How to produce neutrons



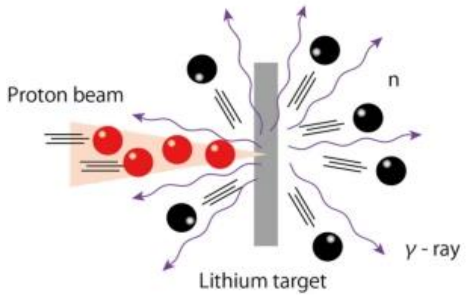


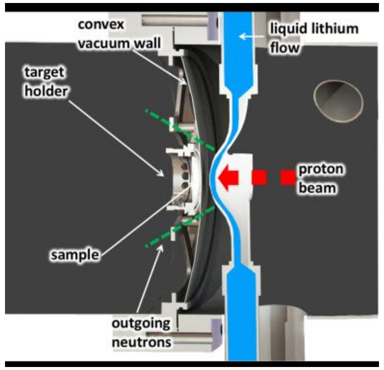
Nuclear Reactor-Based Sources





Fusion-Based Neutron Sources





Accelerator-Based Neutron Sources

$Li + p \rightarrow Be + n$

AmBe

Americium Beryllium

Radioisotope Based neutron Source

Neutron source Facility, MAHE, Manipal

Irradiation chamber | **Source room** | **Neutron source facility**

Bhabha Atomic Resear

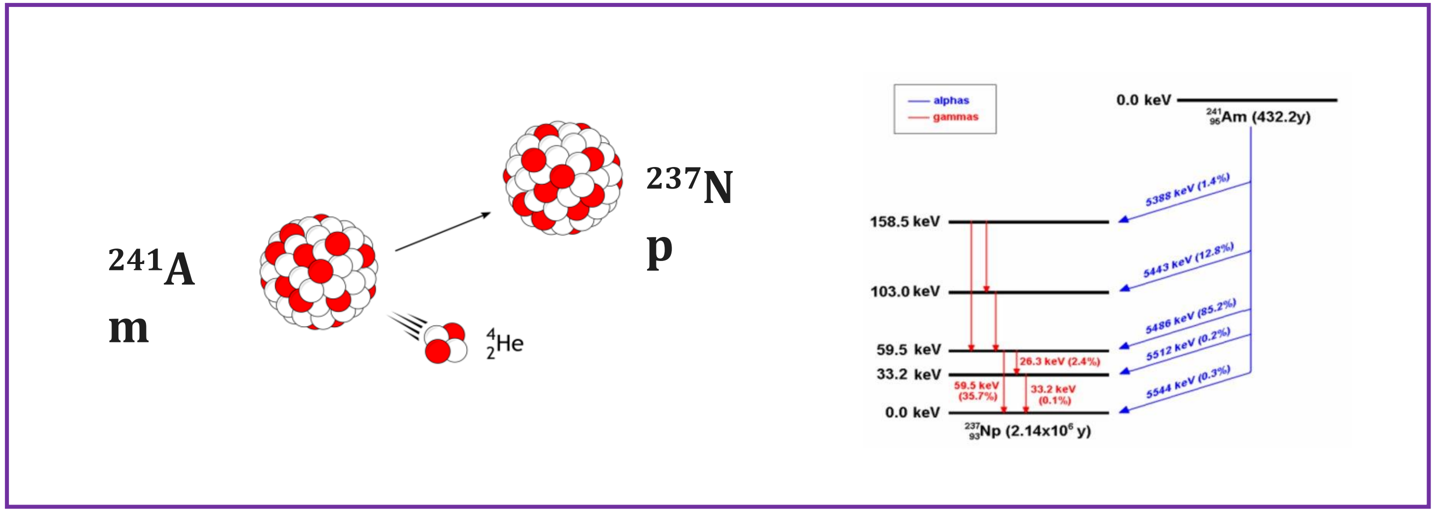
Few images removed

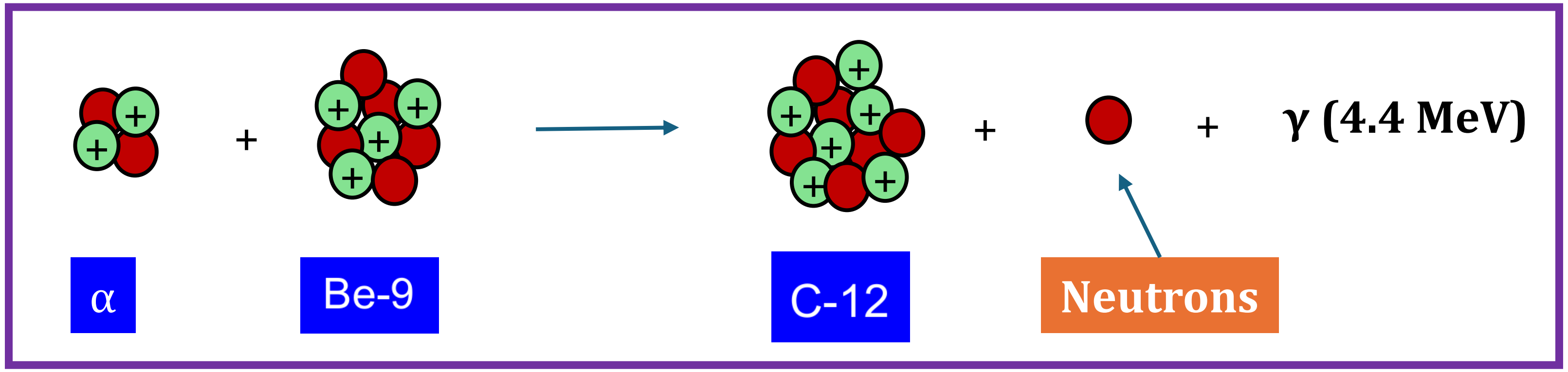
Dr. K. V. Subbaiah, MCNS, Manipal

How to produce neutrons

Radioisotope-Based Sources - These rely on spontaneous neutron emission from radioactive materials.

Americium Beryllium Neutron source

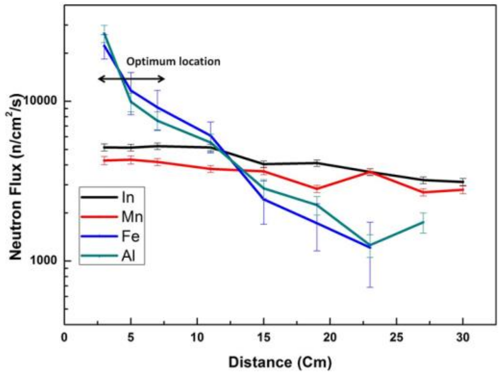




Neutron source Facility, MAHE, Manipal

16 Curie Radioisotopes of **Am-241**

$16 \times 3.7 \times 10^{10}$

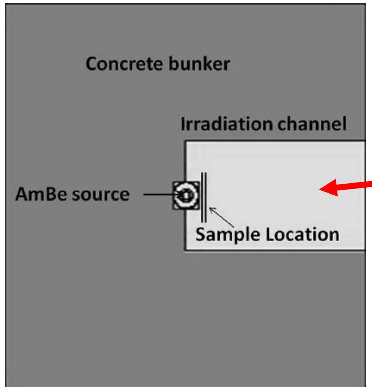


Spatial neutron flux mapping

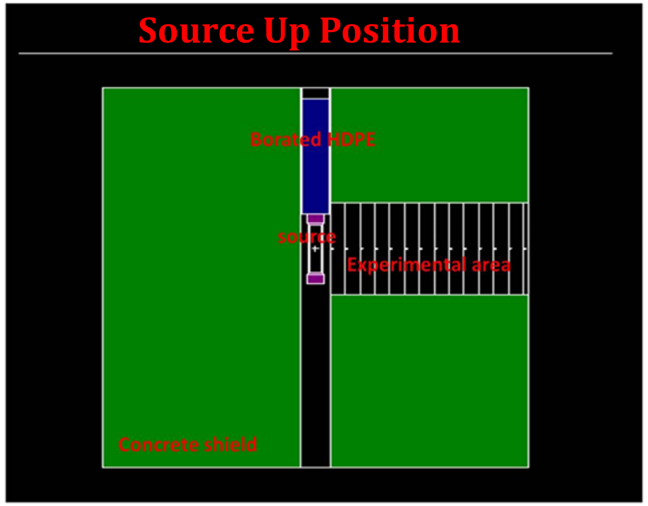
At 5 cm in our irradiation facility, we have flux around, 10^4 neutron/cm2/second

neutron housing schematic

1.5 x 1.5 x 1.3 m Concrete bunker

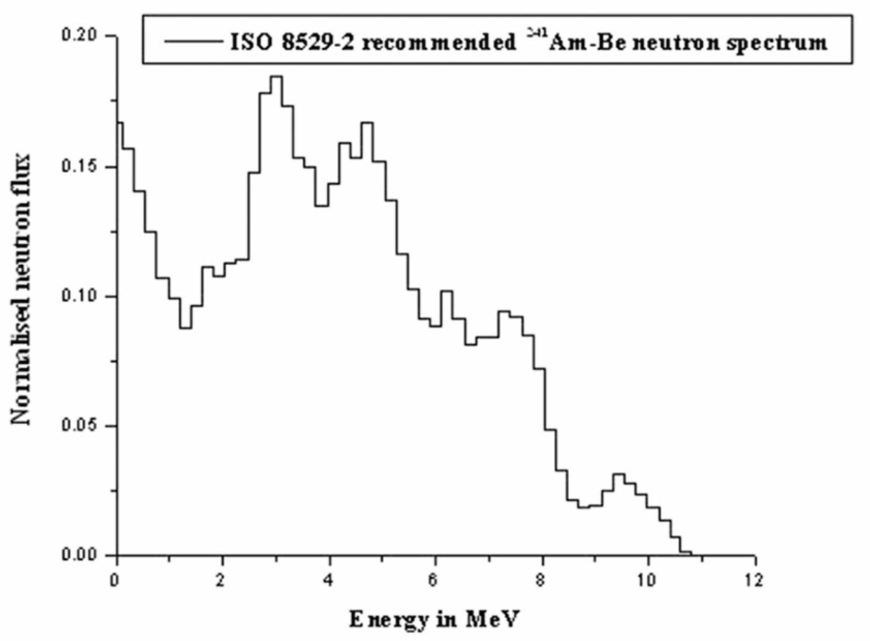


40x70x70 cm

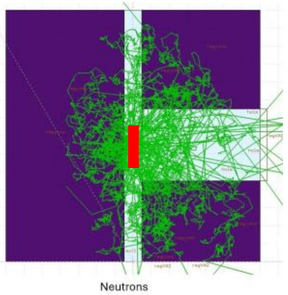


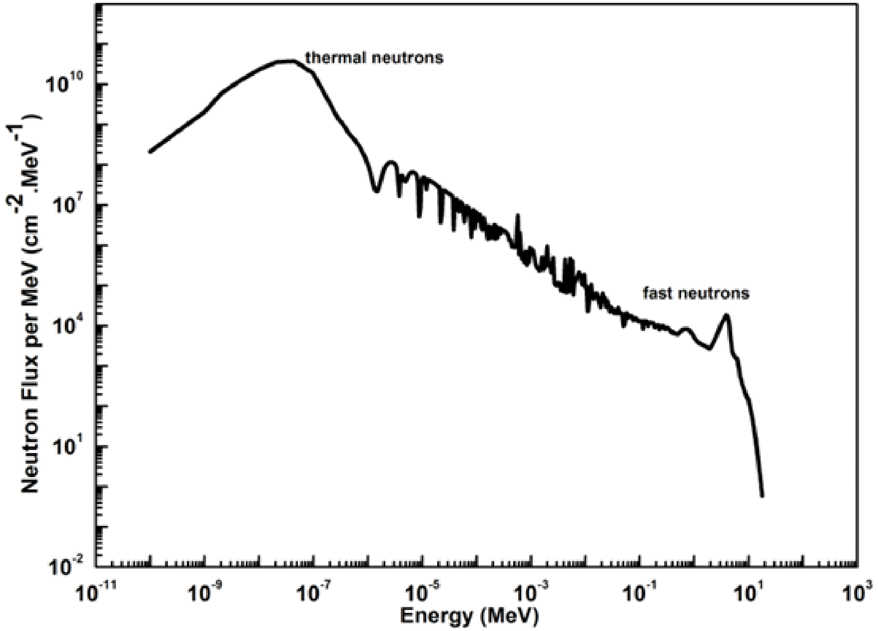
Neutron Yield = 3.5×10^7 neutrons/sec

Neutron source Facility, MAHE, Manipal



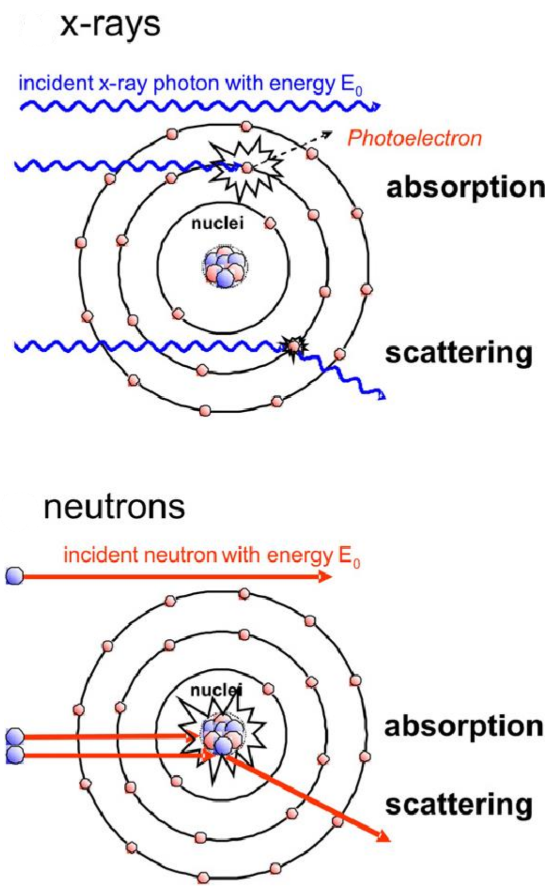
AmBe ISO-8529 spectrum

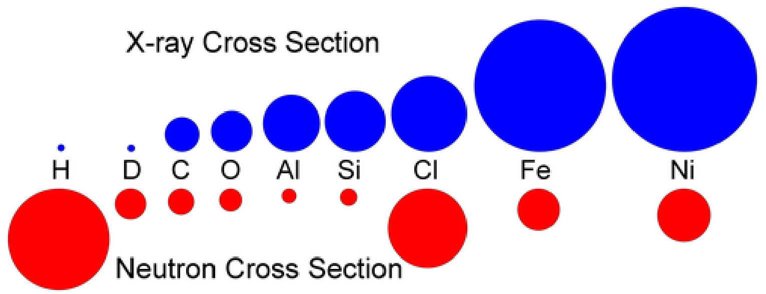


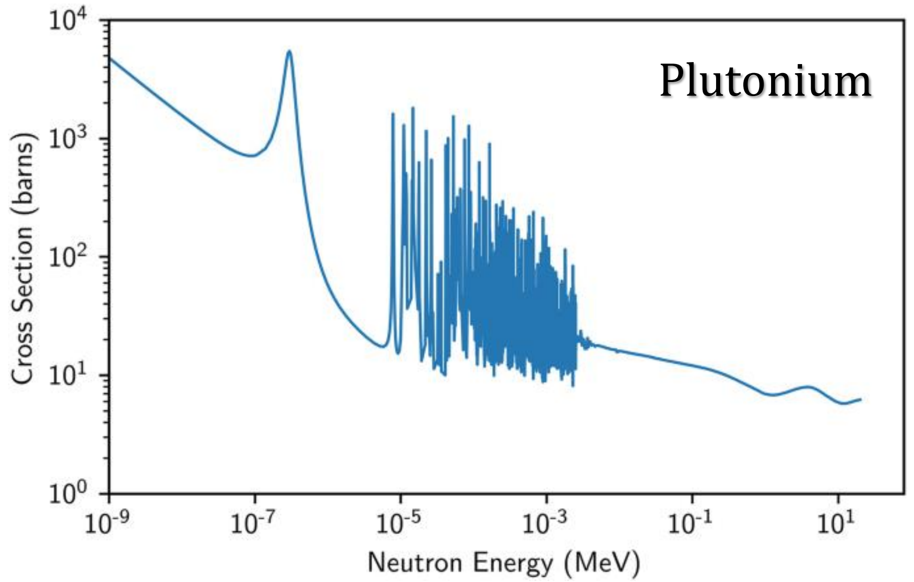


Spectra at irradiation location

Neutron interaction with Atomic Nucleus



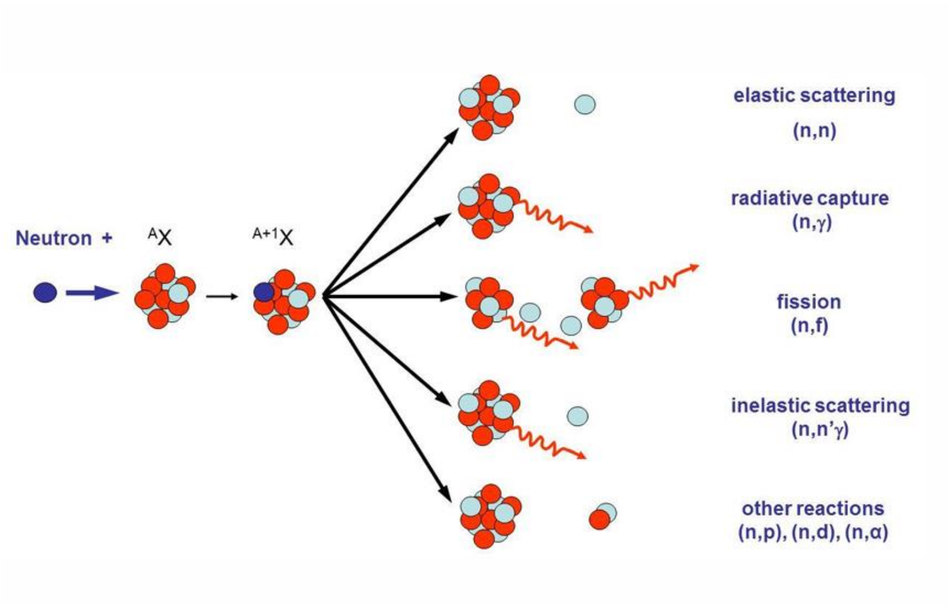


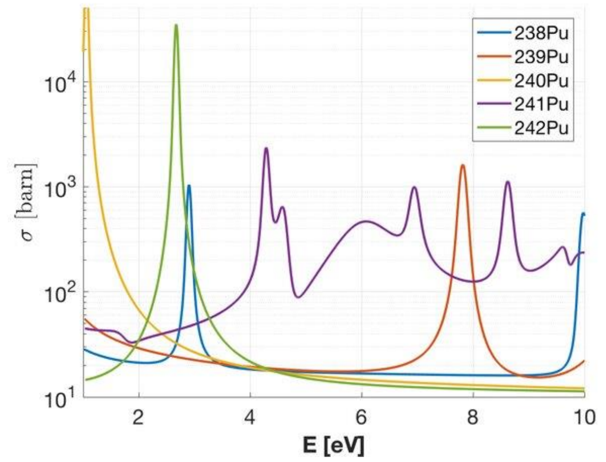


Neutron Cross section (Interaction probability)
varies with incoming neutron energy

Neutron interaction with Atomic Nucleus

Neutron Cross section (Interaction probability) varies with incoming neutron energy



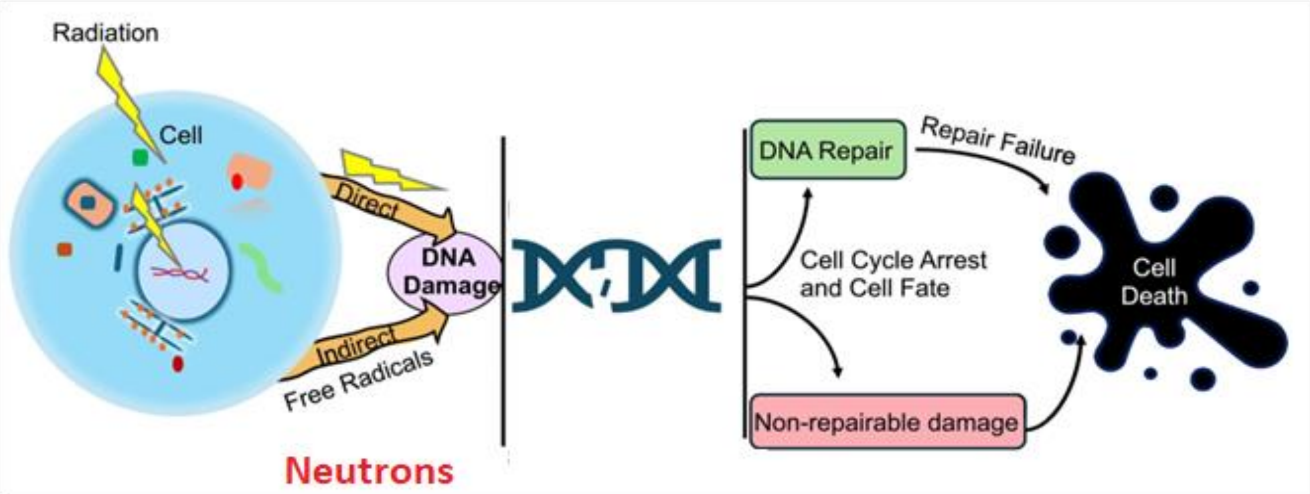


Total interaction cross sections for epithermal neutrons for various plutonium isotopes

Scientific Research | Medical Applications
Industrial Uses | Security, Detection & Defence

Biological Effects

Neutron source



DNA Damage & Mutations
Neutron irradiation of water in cells produces **free radicals (OH, H, O_2)**, which cause oxidative stress and DNA damage.

Cell Death High neutron doses trigger programmed cell death

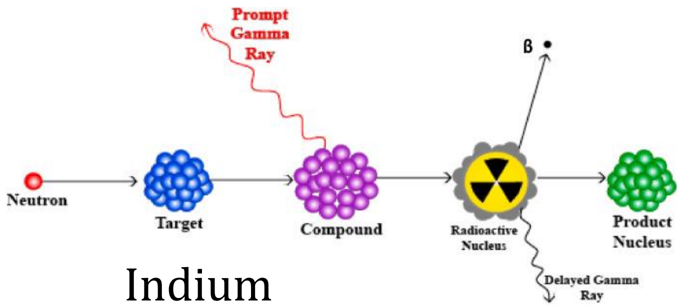
Changes in Cell Cycle
Neutron irradiation alters cell division rates, leading to delayed growth or uncontrolled proliferation (cancer risk).

Inducing genetic mutations for crop improvement.

Mutation Breeding in Plants

Neutron transmutation doping (NTD)

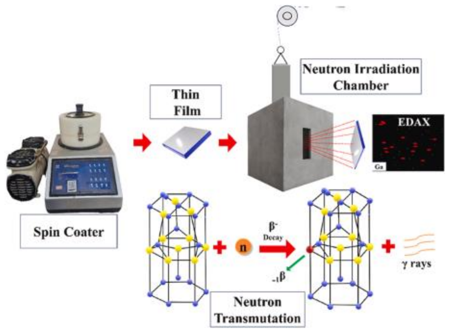
Semiconductor (InSe)



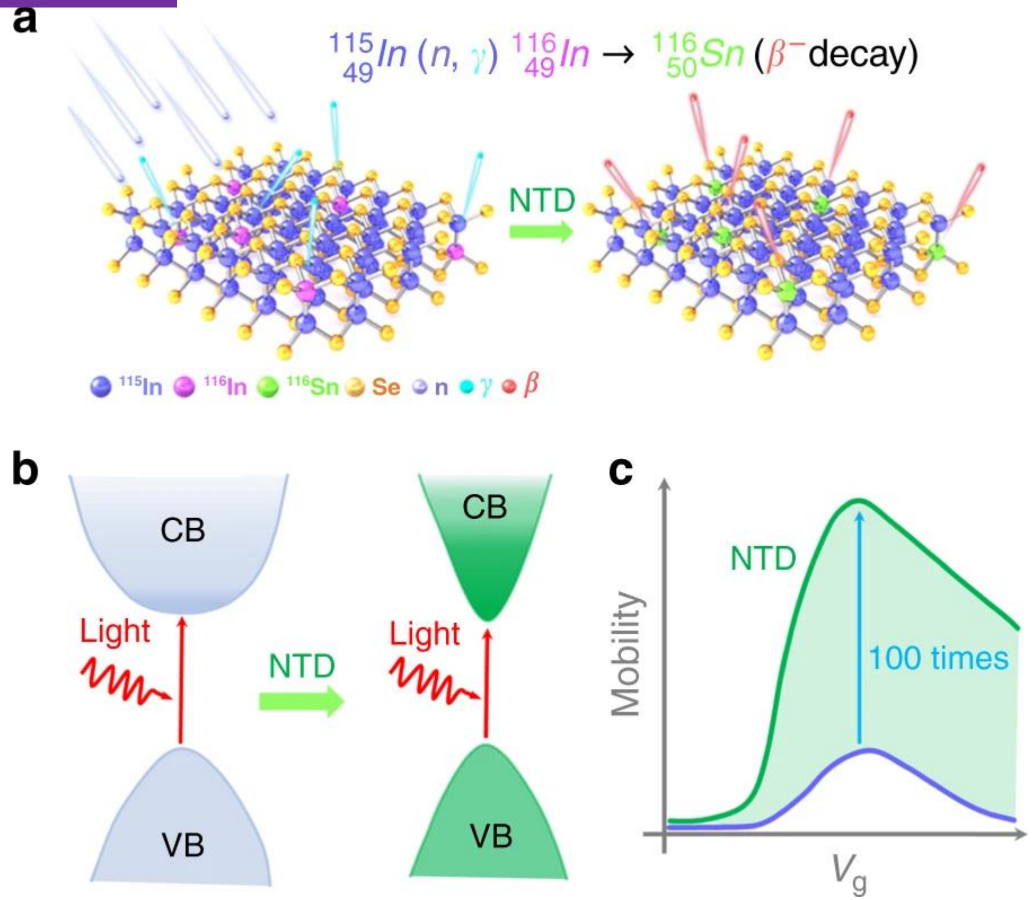
Sn

Indium

Modifying electrical and optical properties



http://dx.doi.org/10.1016/j.ceramint.2024.11.252



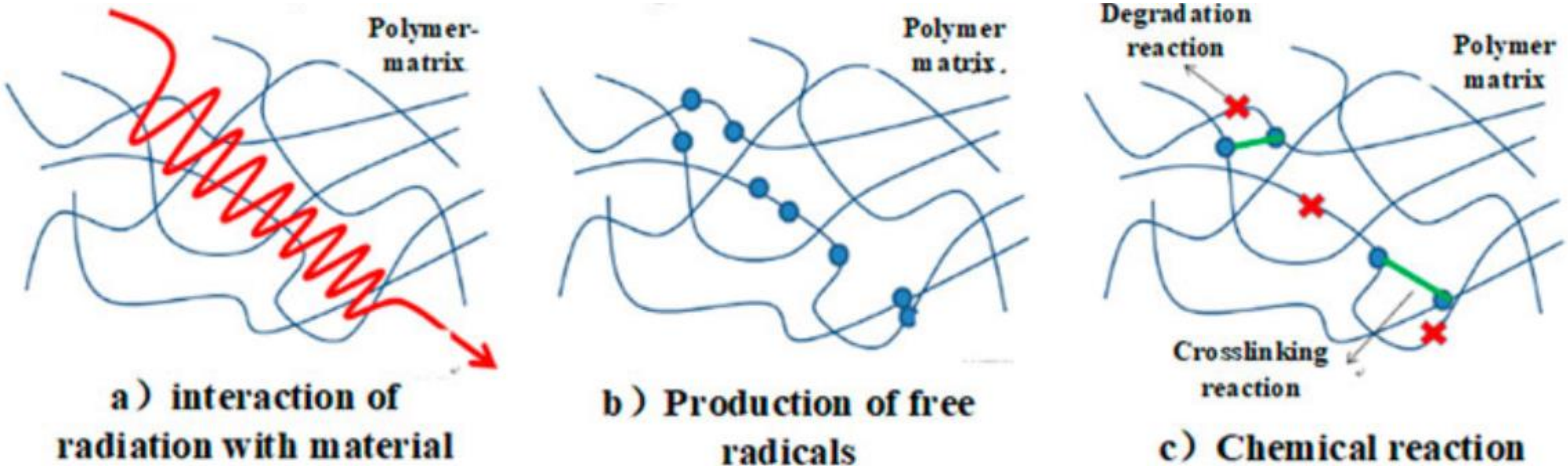
a Transmutation neutron doping (NTD) scheme for 2D layered InSe, including the capture of thermal neutrons and decay of γ and β- particles. b, c Energy band structures and mobility in 2D layered InSe before and after transmutation neutron doping. CB and VB represent the conduction band and valence band, respectively

Article: “Clean” doping to advance 2D material phototransistors

https://www.nature.com/articles/s41377-022-00842-4

Neutron induced molecular changes

Neutron irradiation can break chemical bonds and create free radicals. This affects properties of polymers.



Radiation Physics and Chemistry
Volume 218, May 2024, 111590

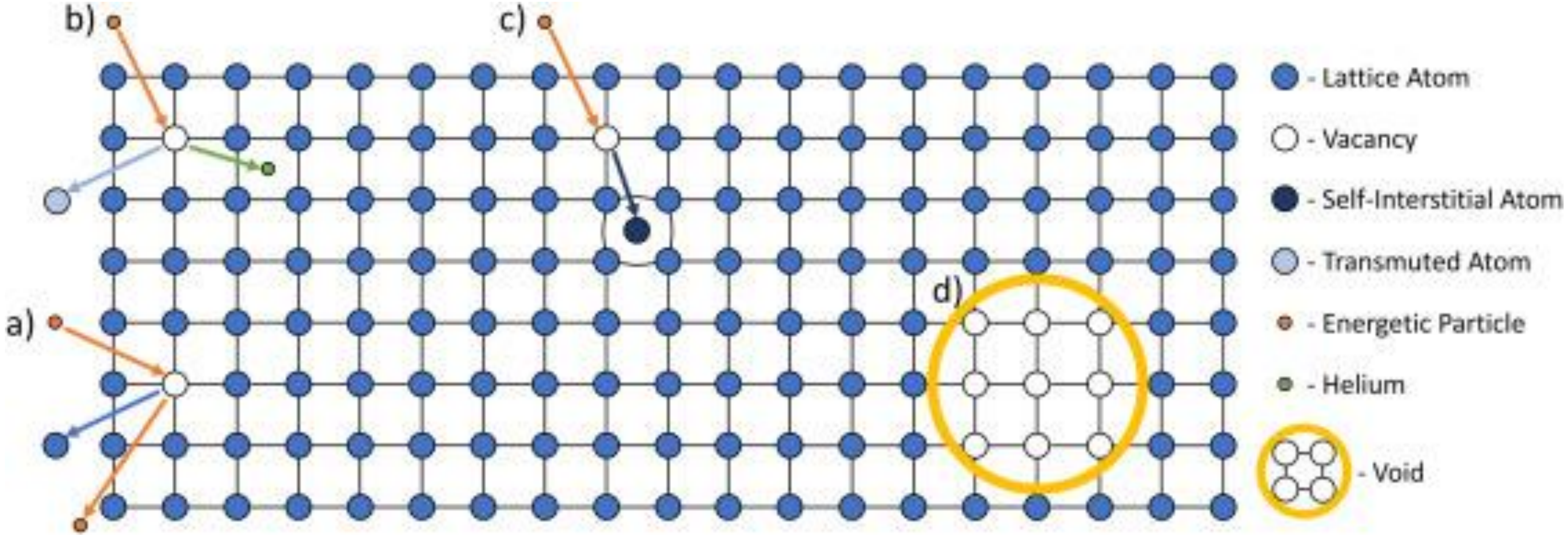
A novel approach to enhance the ionic conductivity of silver nanoparticles incorporated PVA:NaBr polymer electrolyte films via fast neutron irradiation

M.P. Shilpa [a], Vipin Cyriac [b], S.C. Gurumurthy [a], Ismayil [b], Sachin Shet [c], K.V. Subbaiah [c], M.S. Murari [d]

https://doi.org/10.1016/j.radphyschem.2024.111590

Lattice Defects & Displacement Damage

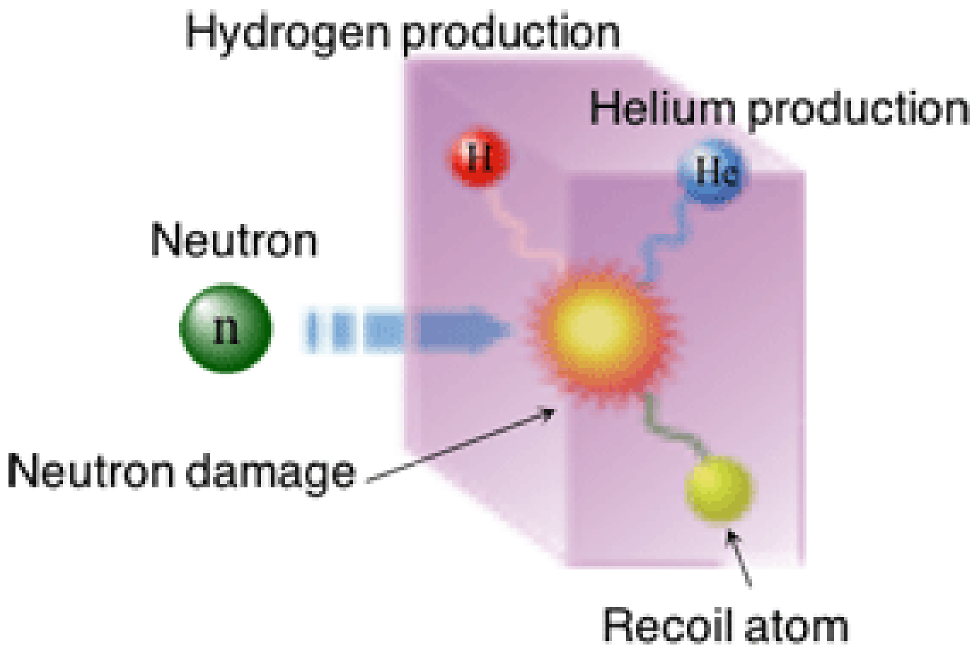
Neutrons displace atoms, creating defects in crystal structures, which
Alters electrical, mechanical, and optical properties of materials.



A schematic showing some of the defects caused by irradiation: a) an energetic particle (such as a neutron) collides with a lattice atom resulting in its ejection, b) an energetic particle collides with a lattice atom in a transmutation reaction resulting in a transmuted atom, a vacancy, and helium, c) an energetic particle collides with a lattice atom resulting in its displacement forming a vacancy and a self-interstitial, and d) a cluster of vacancies forming a void.

https://doi.org/10.1016/B978-0-12-822944-6.00044-X

Gas production inside materials by neutrons



Nuclear Environments
Defence and Security
Space Exploration

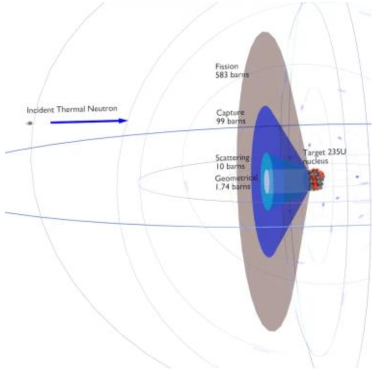
Stainless Steel (e.g., 316 SS): Nickel and iron undergo (n, p) and (n, α), producing H and He.

Zirconium Alloys (e.g., Zircaloy): Used in fuel cladding; less prone but still generates gas from trace impurities.

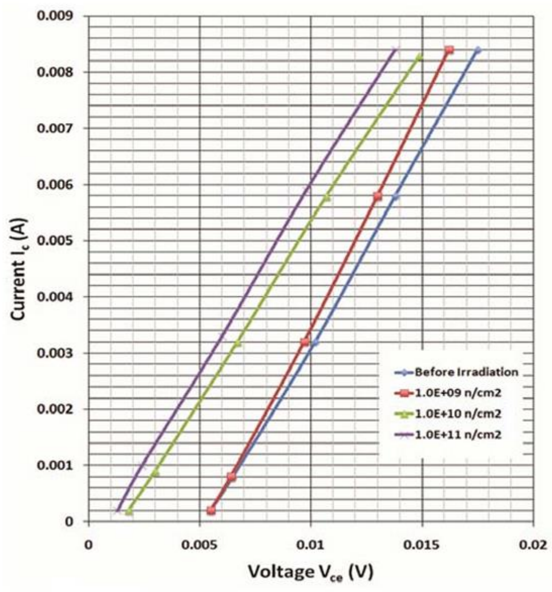
(n, α) Reactions A neutron is absorbed, and an alpha particle (helium nucleus) is emitted.
Common in: Boron (e.g., in control rods or impurities), nitrogen, or oxygen.

(n, p) Reactions A neutron hits a nucleus, ejecting a proton and leaving a new isotope.
Common in: Nickel, iron, or other metals in alloys.

Research applications



Neutron cross section measurement



I-V characteristics of transistor BC547

Neutron irradiation of IC

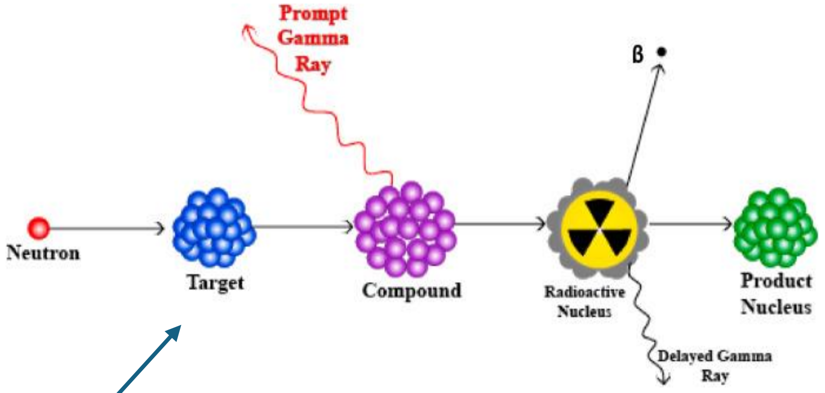
Optical fiber

Solar cell

Ref: (PDF) Experimental study of neutron irradiation effect on elementary semiconductor devices using Am-Be neutron source

NAA

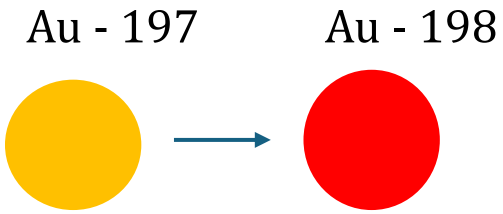
Neutron Capture Which produces radioisotope in the sample, this can be used as a tool to investigate elemental composition

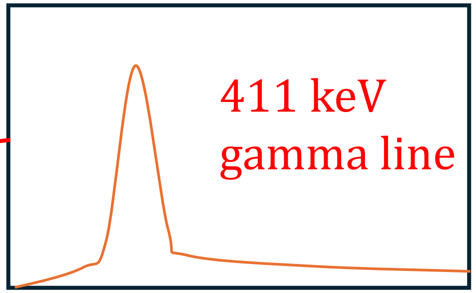


$$A = N \sigma \varphi (1 - e^{-\lambda t_i})$$

$$C = \Delta N \gamma \varepsilon = \Phi_{th} \sigma_{eff} \frac{N_{Av} \theta m_x}{M_a} (1 - e^{-\lambda t_i}) e^{-\lambda t_d} \frac{(1 - e^{-\lambda t_m})}{\lambda} \Gamma \varepsilon$$

Φ = Neutron flux
λ = decay constant of produced isotope
$t_{i=}$= Irradiation time





https://doi.org/10.1016/j.sab.2010.12.011

Applications

Non-destructive material analysis: Determining the elemental composition of materials without damaging them

Quality control: Ensuring the purity

Archaeology & Cultural Heritage:

Elemental analysis of biological samples

Neutron cross section measurement

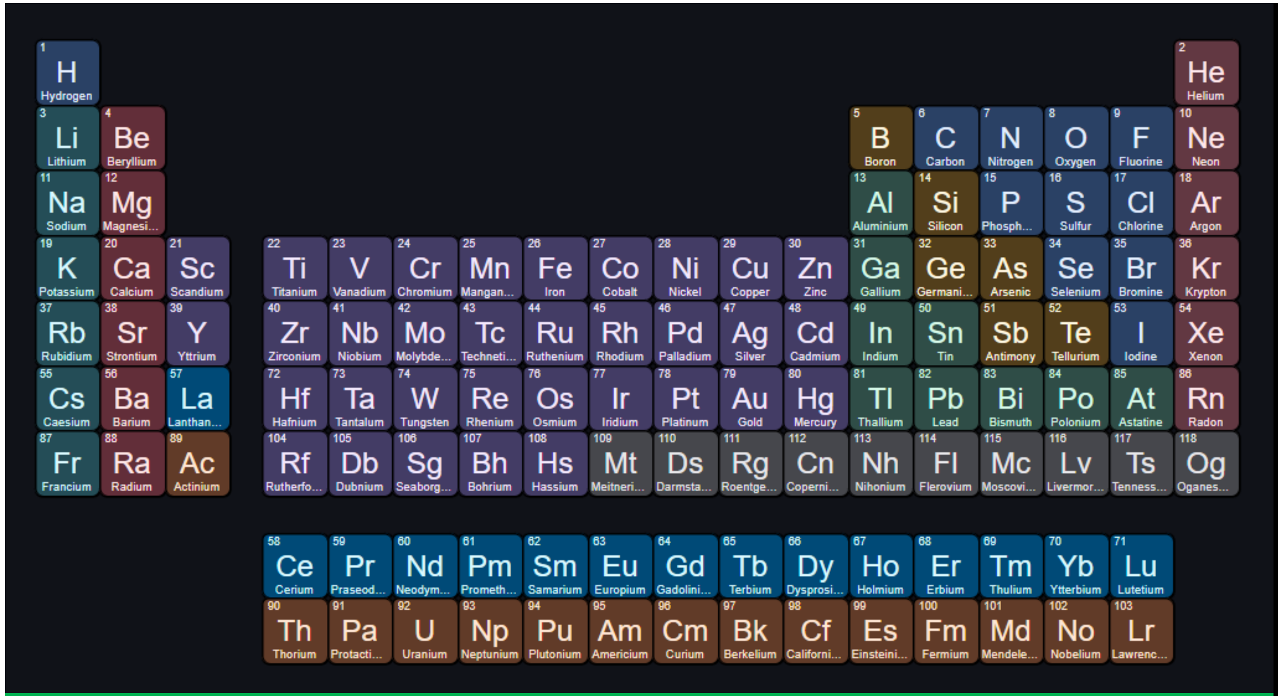
Art Authentication - analyzing pigment or material composition

What can be done with neutron..?

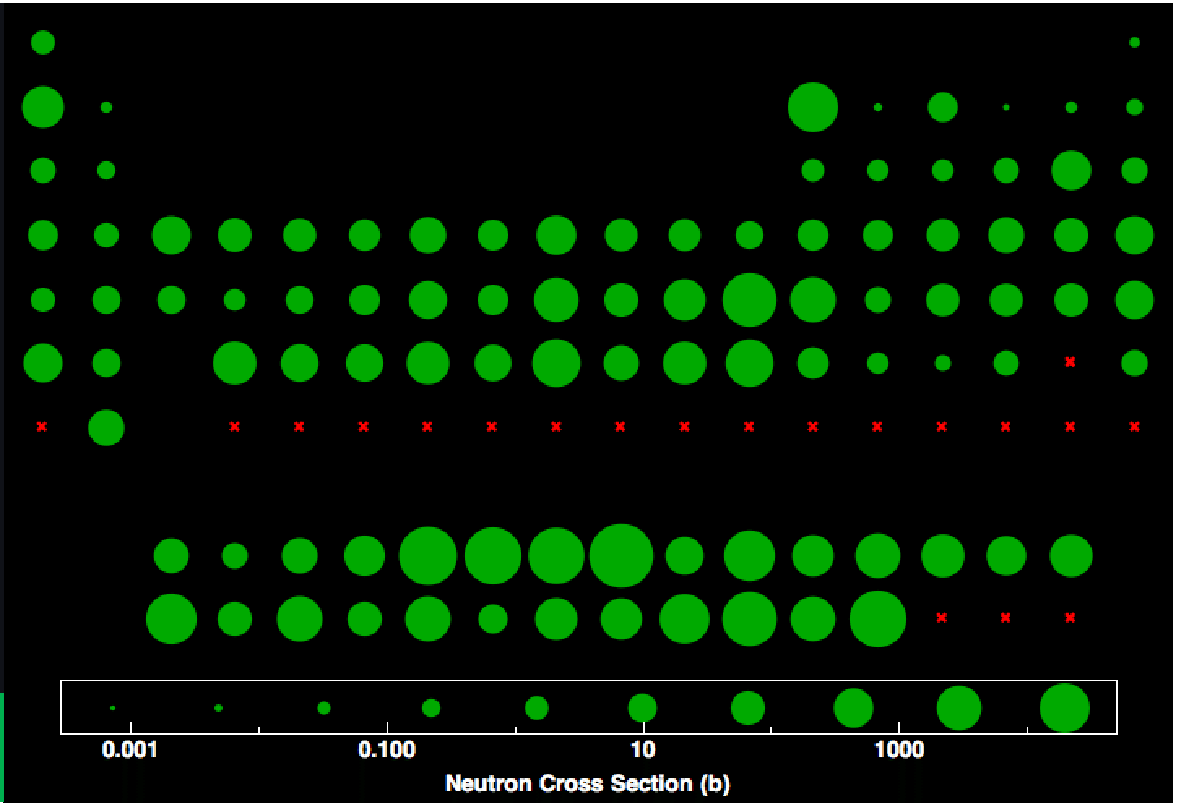
- Neutron irradiation to enhance material properties
- Neutron irradiation check material behavior in radiation fields
- Sample's elemental analysis with Neutron activation
- Radiation hardness
- Biological sample – mutation, cell damage and repair
- Neutron shielding

MANY MORE……

Neutron Irradiation on + "Research Domain" **Search**



Neutron Cross Section



Thank You...,

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