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Title:	Basics of Neutrons for First Responders
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Basics of Neutrons

For First Responders

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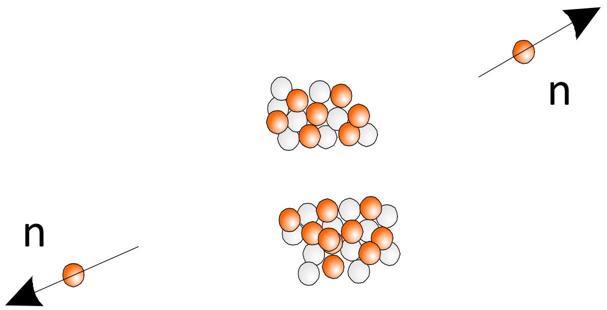
Basic stuff

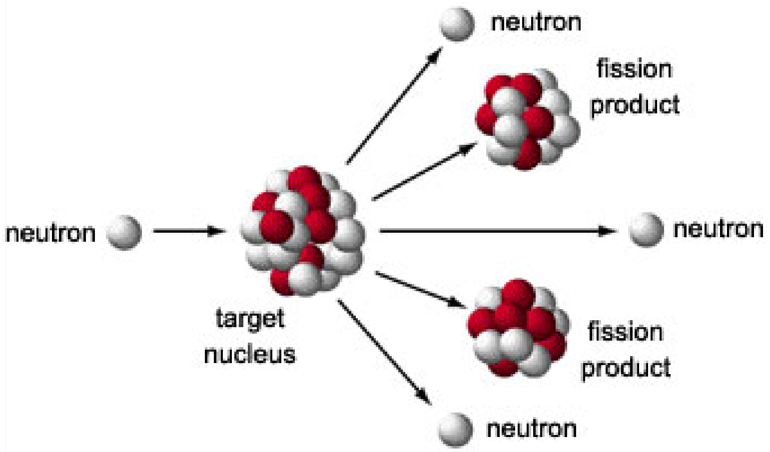
- Neutron mass 1.008664 amu
- Proton mass 1.007276 amu
- Electron 0.00054858 amu
- Half life 10.25 minutes

Common Origins of Terrestrial Neutron Radiation

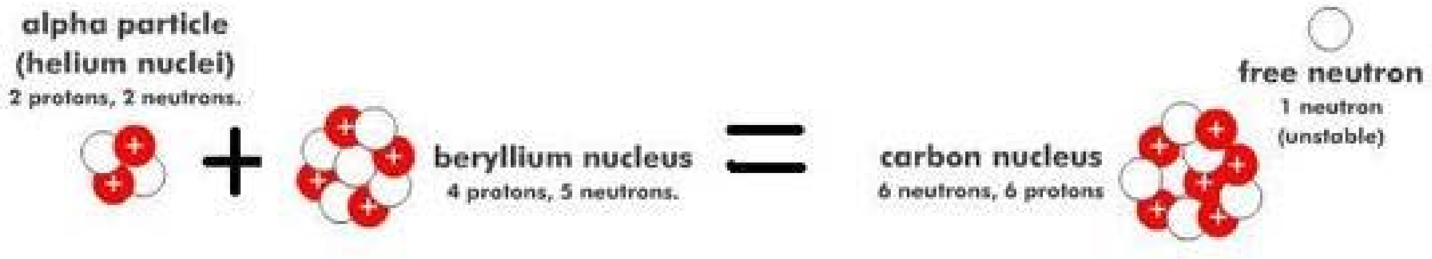
Spontaneous Fission



Induced Fission



(α,n) Reactions



Neutron Sources

- Reactors and fuel
- Particle Accelerators
- (α,n) sources: used in research and industry
- Transuranics: spontaneous fission (Pu, Cf-252)
- Natural Neutron Background:
  - Generally from ‘cosmic ray’ spallation
  - Very weak signal compared with natural gamma-ray background

Almost all neutron sources are man-made!

Neutron energy

- Thermal neutrons ~2200 m/sec (0.025 eV) 17° C (62° F)
- Epithermal Faster than thermal
- Cadmium cutoff ~0.5 eV
- Slow neutrons
- Fast neutrons Fission mean energy ~ 2 MeV - 20,000 km/sec
  - D-T fusion 14.1 MeV – 52,000 km/sec
- Ultra fast >~20 MeV

Interactions

- Collide with protons
  - About the same mass
  - May displace the proton
    - Attracts an electron
    - Ionizes material
- Absorbed by another nucleus
  - Atom is stable
  - Atom is unstable
  - Energy may be released during or soon after reaction

Detecting Neutrons

- Absorption and nuclear reactions
  - He3
    - $_{2}He^{3} + _{0}n^{1} \longrightarrow _{1}H^{3} + _{1}p^{1}$
  - BF3
    - $_{5}B^{10} + _{0}n^{1} \longrightarrow _{3}Li^{7} + _{2}\alpha^{4}$
  - Fission chambers
  - Other detectors
    - Li^{6}
- Moderation is key to most systems
- Liquid scintilators

Gammas from Neutron Interactions

Neutron-Capture Gammas

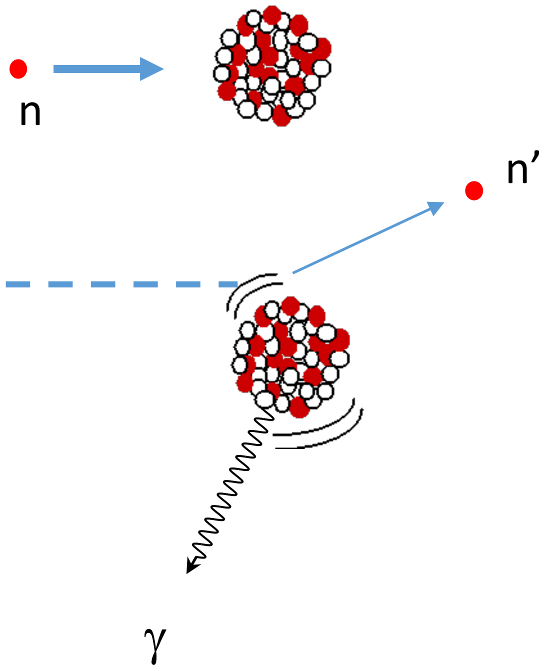
Thermal neutron is absorbed by target nucleus.

Resulting nucleus emits a gamma ray.

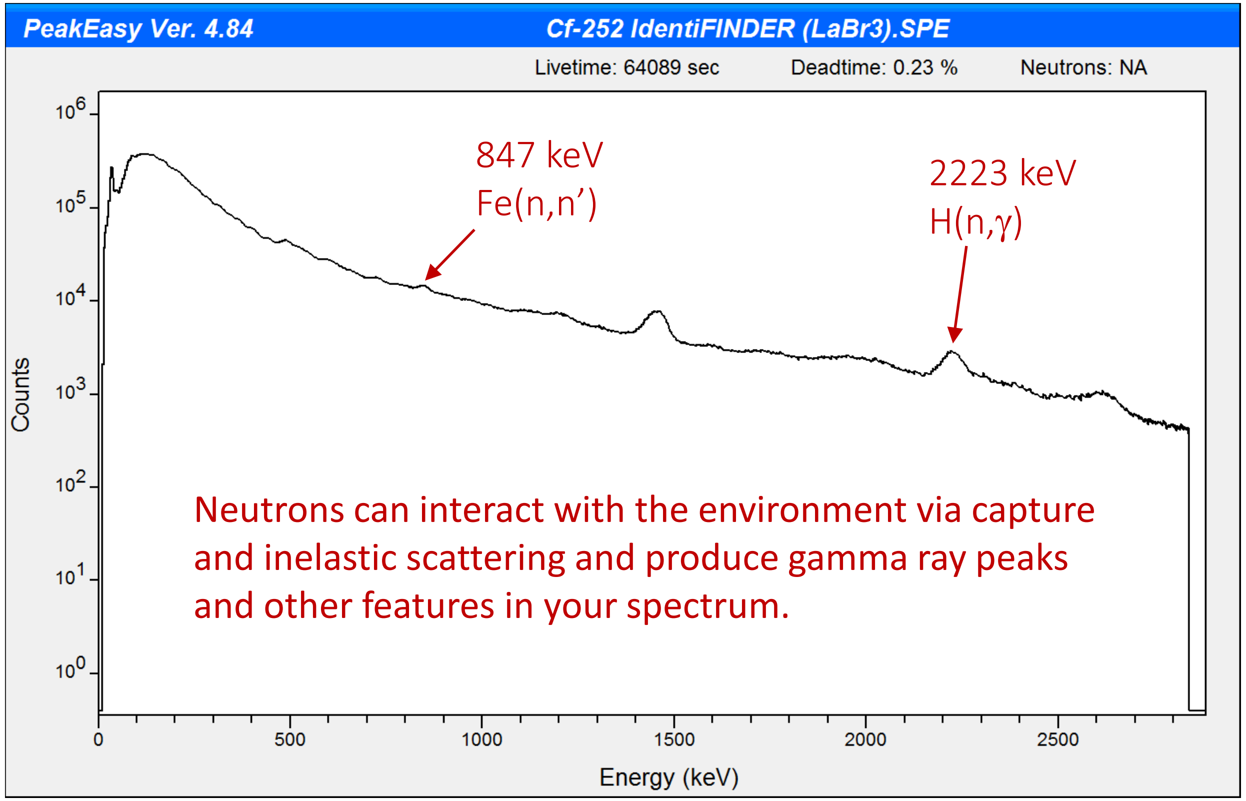
Neutron-Scatter Gammas

Fast neutron scatters from target nucleus.

Resulting nucleus emits a gamma ray.

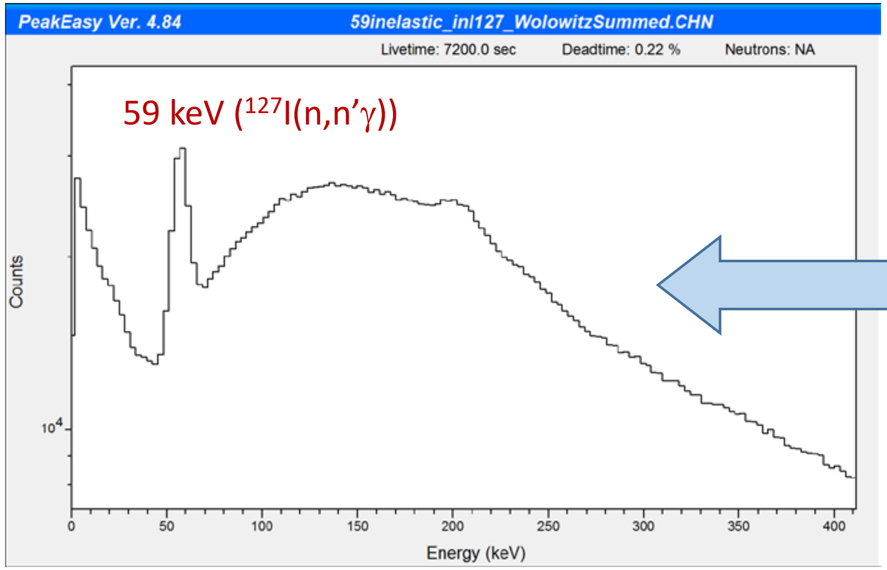


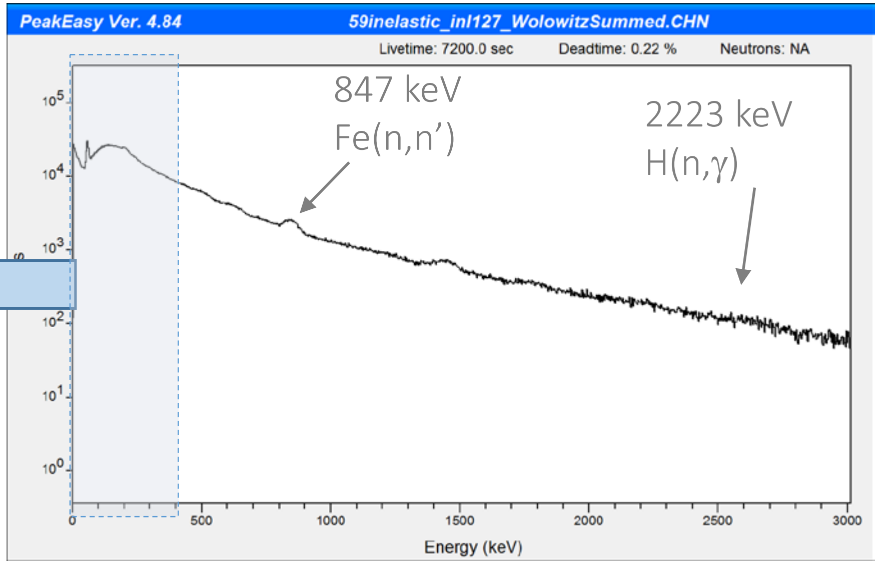
Neutron Signatures in Gamma-Ray Spectra



Neutrons & NaI

Fast neutrons on NaI can inelastically scatter off of ^{127}I and produce a gamma ray at ~59 keV.





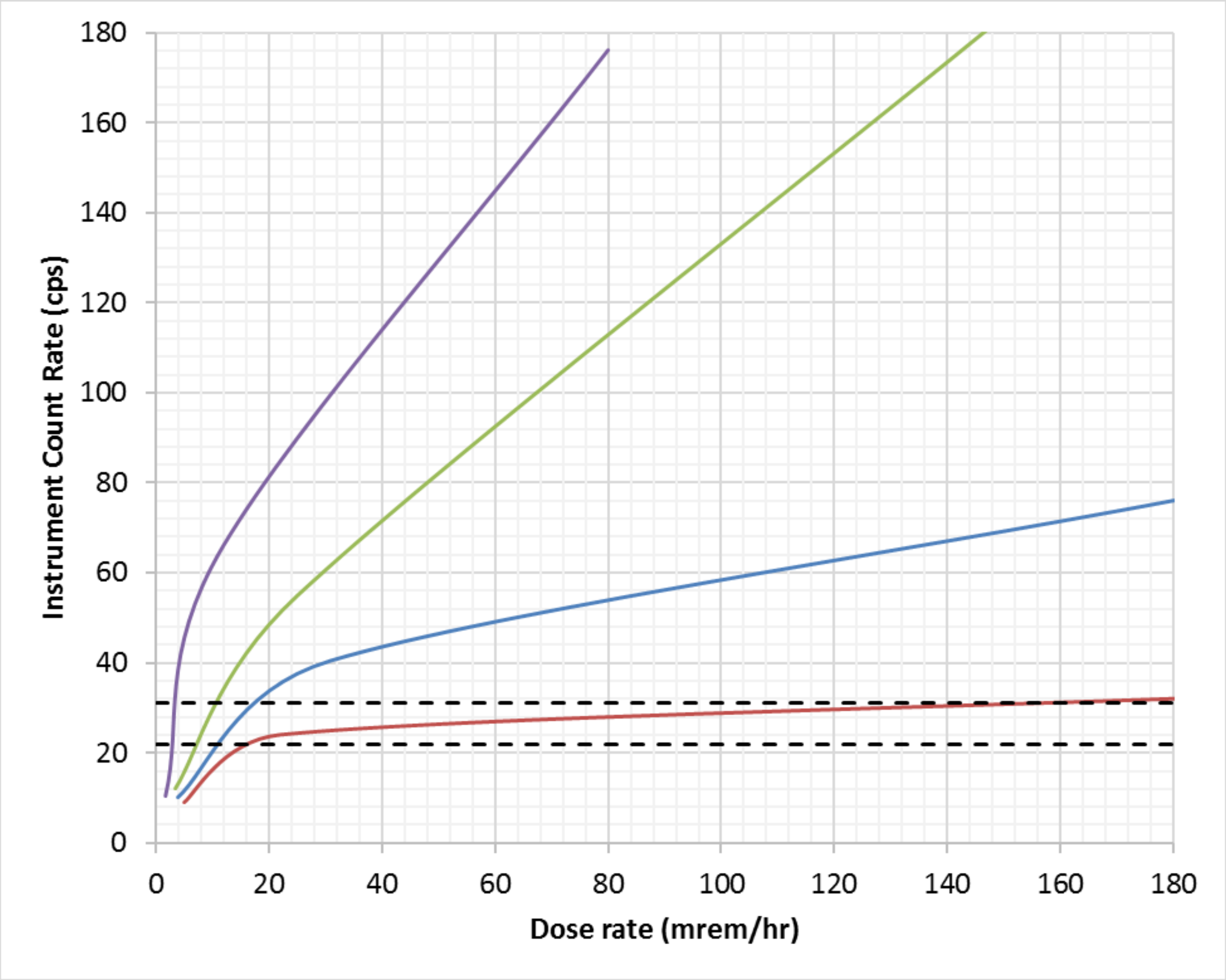
Neuton Fluence to dose (mSv)

Neutron energy (MeV)	Quality factor[a] (Q)	Fluence per unit dose equivalent[b] (neutrons cm^{-2} mSv^{-1})
2.5×10^{-8} (thermal)	2	980×10^{5}
1×10^{-7}	2	980×10^{5}
1×10^{-6}	2	810×10^{5}
1×10^{-5}	2	810×10^{5}
1×10^{-4}	2	840×10^{5}
1×10^{-3}	2	980×10^{5}
1×10^{-2}	2.5	1010×10^{5}
1×10^{-1}	7.5	170×10^{5}
5×10^{-1}	11	39×10^{5}
1	11	27×10^{5}
2.5	9	29×10^{5}
5	8	23×10^{5}
7	7	24×10^{5}
10	6.5	24×10^{5}
14	7.5	17×10^{5}
20	8	16×10^{5}

[a] Value of quality factor (Q) at the point where the dose equivalent is maximum in a 30-cm diameter cylinder tissue-equivalent phantom.

[b] Monoenergetic neutrons incident normally on a 30-cm diameter cylinder tissue-equivalent phantom.

Instruments' response to neutrons



- Common field RIID
- Dose rate taken with a REM ball (tissue equivalent)
- Different amounts of neutron shielding
  - You don't know what you have
- Rare to find > 1 mSv neutron sources
- 32 CPS = 30µSv – 1.6 mSv