Nuclear Physics II
Nuclear Structure & Reactions

Prof. Dr. Peter Reiter
preiter@ikp.uni-koeln.de
phone –49 221 4703624
IKP, room 306

location: Seminarraum Institut für Kernphysik

time: Wednesday 16:00 – 16:45
Thursday 12:00 – 13:30

https://www.ikp.uni-koeln.de/groups/reiter/vorlesungen/

Nuclear Physics II
Nuclear Structure & Reactions

Subjects of the lecture:

- Conservation laws and symmetries
- Nuclear reactions $\longrightarrow$ fusion & fission
- Astrophysical reactions
- Weak interaction $\longrightarrow$ neutrinos
- Shell model and exotic nuclei

What you should know after nuclear and particle physics I

www.ikp.uni-koeln.de/groups/reiter/lehre

Prerequisites nuclear and particle physics:

- Nuclear binding energy, masses
- Radioactivity α-, β-, γ-decay
- Rutherford scattering, cross section
- Fermis Golden Rule
- Basics of scattering theory
- Electron scattering
- Form factor, charge distribution
- EM-moments

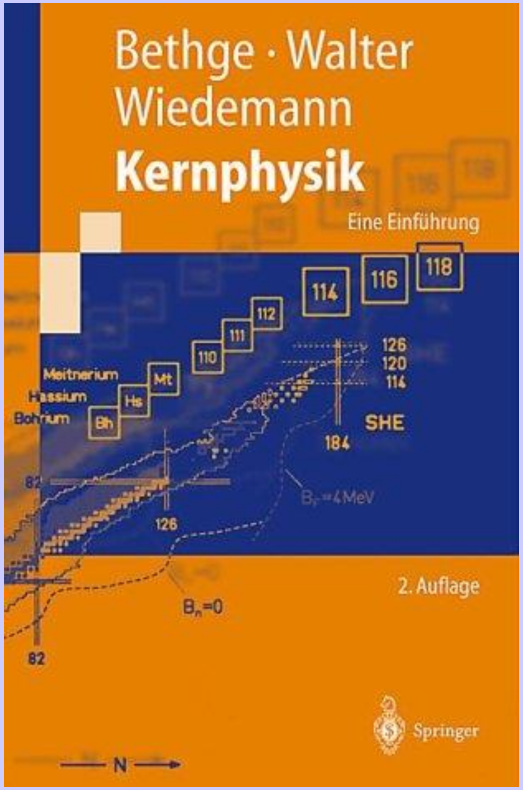
prerequisites

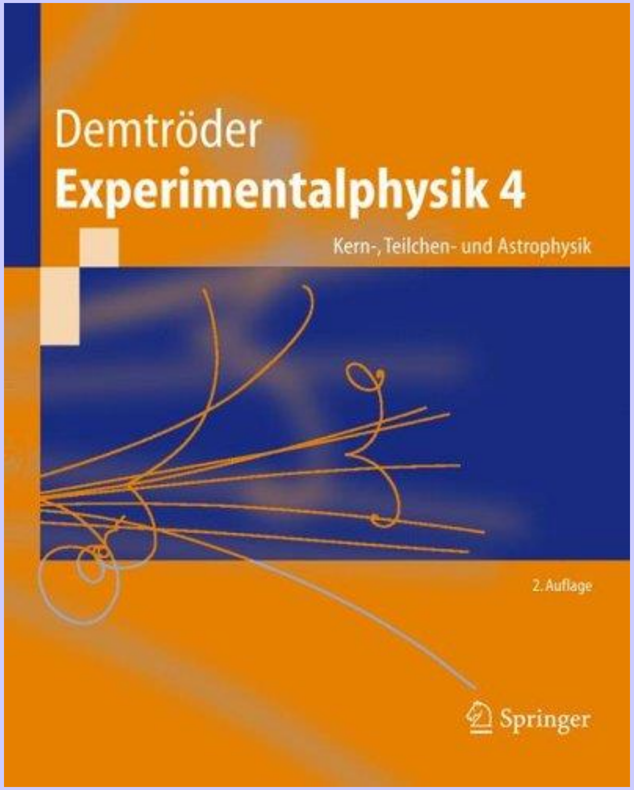
www.ikp.uni-koeln.de/groups/reiter/lehre

- Basics of accelerator physics
- Basics of detector physics
- Properties of nuclear forces
- Isospin
- Deuteron
- nucleon-nucleon-interaction
- Shell model
- Excited states in atomic nuclei

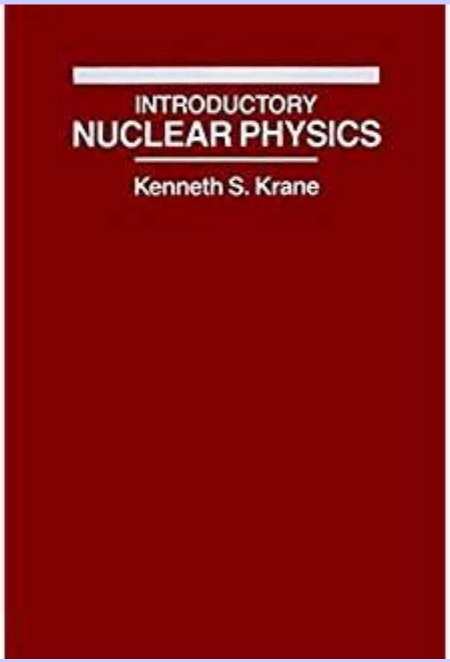
Nuclear physics II

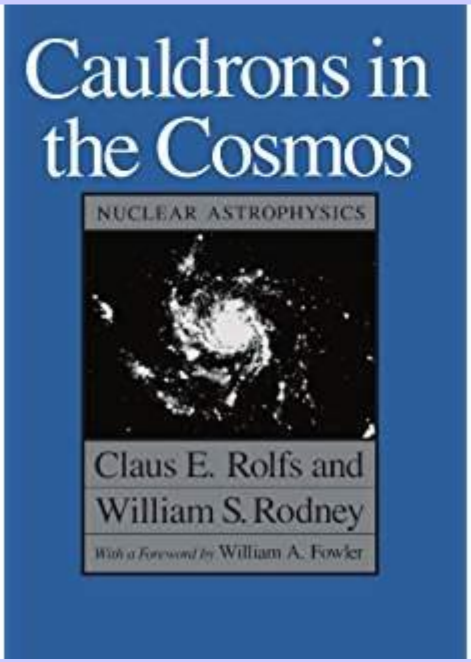
text books for beginners, introduction (Physik VI)

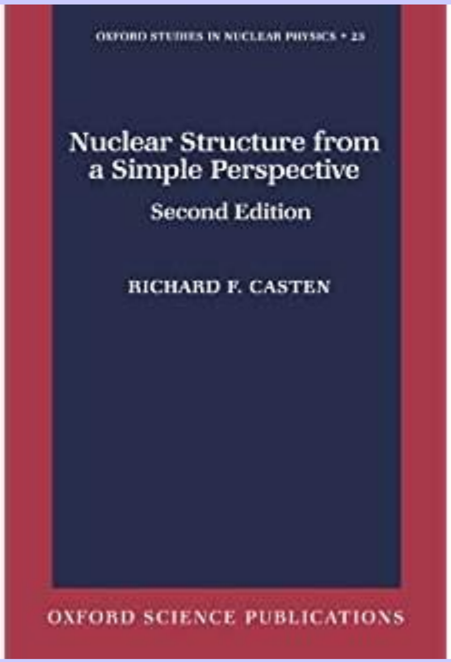




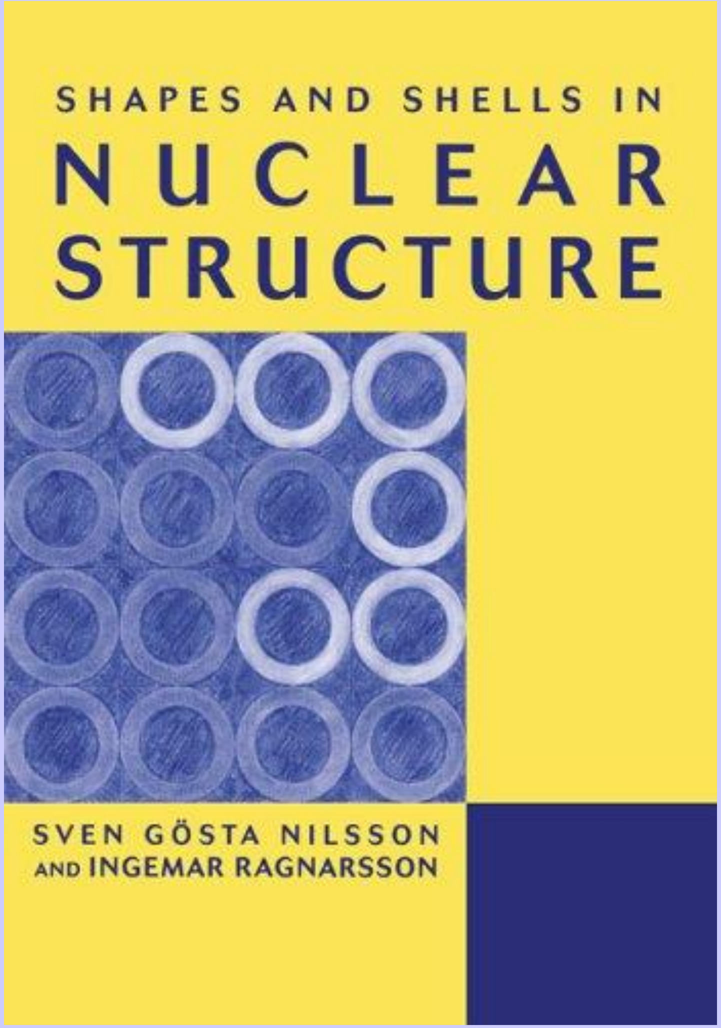
Nuclear physics II
advanced text books nuclear physics

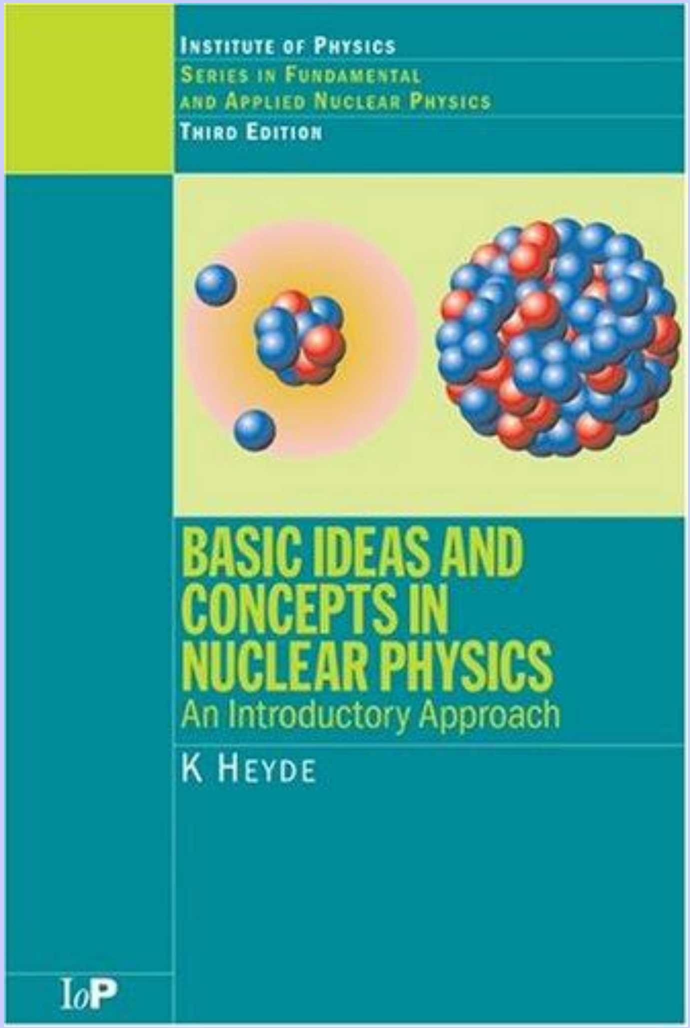






Nuclear physics II
text books related to theoretical concepts





Nuclear physics II
advanced text books nuclear physics

Introductory Nuclear Physics
von Kenneth S. Krane
John Wiley and Sons (WIE) (März 2002)

Cauldrons in the Cosmos Nuclear Astrophysics
von Claus E. Rolfs, William S. Rodney
University of Chicago Press (August 2005)

Nuclear Structure from a Simple Perspective
von Richard F. Casten
Oxford University Press (Juni 2001)

Why more nuclear physics?

Simple and basic question:

Why is the sun shining?

Where is most of the energy on earth coming from?

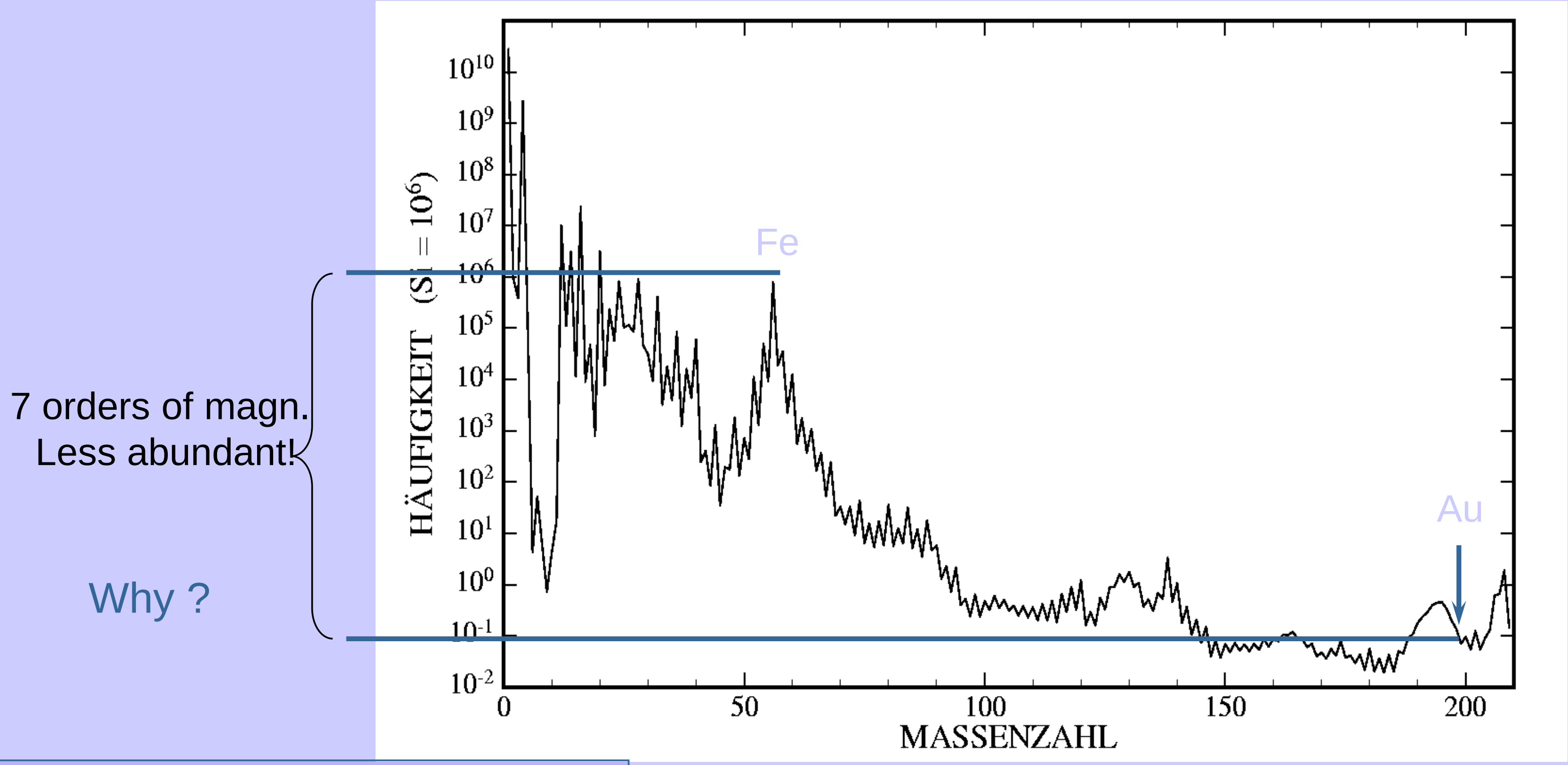
What happens in a nuclear power plant and what remains left?

How and where are carbon and oxygen produced?

What about the other elements?

Abundance of chemical elements

Mass distribution – chemical composition of solar system



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How were the elements from iron to uranium made?

"The 11 Greatest Unanswered Questions of Physics"
National Academy of Science Report

[Committee for the Physics of the Universe (CPU)]

units in nuclear- and particle physics

- length

  nuclei have radii of several femto meter *fm*

  (1*fm* = 10^{-15} *m*), 1*fm* (is also named Fermi)

- energy

  energies are given in electron volt *eV*

  energy of a particle with elemental charge 1*e* (= 1,602 $\cdot 10^{-19}$ *C*) after it has gained the potential energy of 1*V*

  1 *eV* = 1,602 $\cdot$ 10^{-19} *J*.

  typical values: atomic physics: *eV*

  nuclear physics: *keV, MeV*

  high energy physics: *GeV, TeV* (LHC runs at 13 TeV CM energy)

- masses

  atomic mass unit amu (1*u* = 1/12m[^{12}C] = 1, 66 $\cdot$ 10^{-27} *kg*)

  or considering the mass energy equivalence $E = mc^2$ in MeV/c^2

  one atomic mass unit: 1 *u* = 931,5 MeV/c^2

glossary

- A nuclide is an atomic nucleus with *Z* protons and *N* neutrons.
- Mass number *A is* sum of proton number and neutron number sum of all nucleons in an atomic nucleus: $A = N + Z$
- Atomic number *Z* is specific for the chemical element.
  Sometimes also *q* the ion charge is given for atomic processes.
- Nuclide with equal *Z*, *N* or *A* have the following names:

  Isotope: equal *Z*

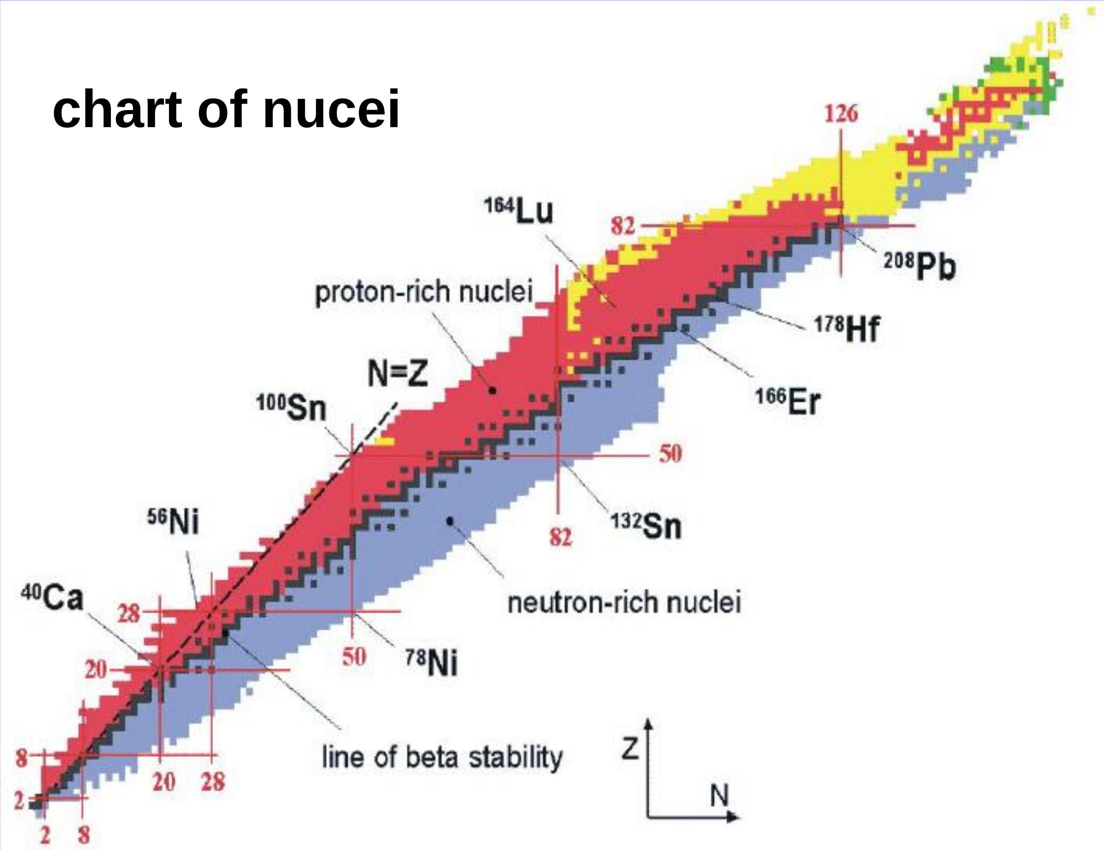
  Isotone: equal *N*

  Isobare: equal *A*
- Complete notation:

$$ {}^{A}_{Z}X^{q}_{N} $$

- Some redundancy

  Z~X, A=N+Z



Units and constants

Quantum mechanical systems:

Heisenberg‘s uncertainty relationship interrelates length and energy scales, Planck constant (quantum of action):

$$\hbar = 6,582 \cdot 10^{-22} MeV s = 197 MeV fm/c$$

speed of light:

$$c = 2,998 \cdot 10^{8} m/s.$$

Fine structure constant

$$\alpha = \frac{e^2}{\hbar c} = \frac{1}{137}$$

- Simple expression for electric charge
- Measure of strength of electro-magnetic interaction

Natural units

System of units (meter m, kilo gramm Kg, second s) is transfered into equivalent set of units given by (ħ, *c, MeV*) or (ħ, *c, fm*)

[Energie]	$=$	MeV	oder	$\hbar c/fm$	$(1MeV = \hbar c/197fm)$
[Masse]	$=$	MeV/c^2	oder	$\hbar/fmc$	$(1MeV/c^2 = \hbar/197fmc)$
[Impuls]	$=$	MeV/c	oder	$\hbar/fm$	$(1MeV/c = \hbar/197fm)$
[Länge]	$=$	fm	oder	$\hbar c/MeV$	$(1fm = \hbar c/197MeV)$
[Zeit]	$=$	fm/c	oder	$\hbar/MeV$	$(1fm/c \approx 3 \cdot 10^{-24}s)$
	oder	$(\hbar/mc)1/c$	oder	λ_c/c	(λ_c: Compton Wellenlänge)
[Ladung]	$=$	e	oder	$\sqrt{\alpha\hbar c}$	$(= 1,2\sqrt{MeV\,fm})$

Relationship between both systems is given by:

$$\hbar c = 197MeV\,fm$$

$$\alpha = \frac{e^2}{\hbar c} = \frac{1}{137}$$