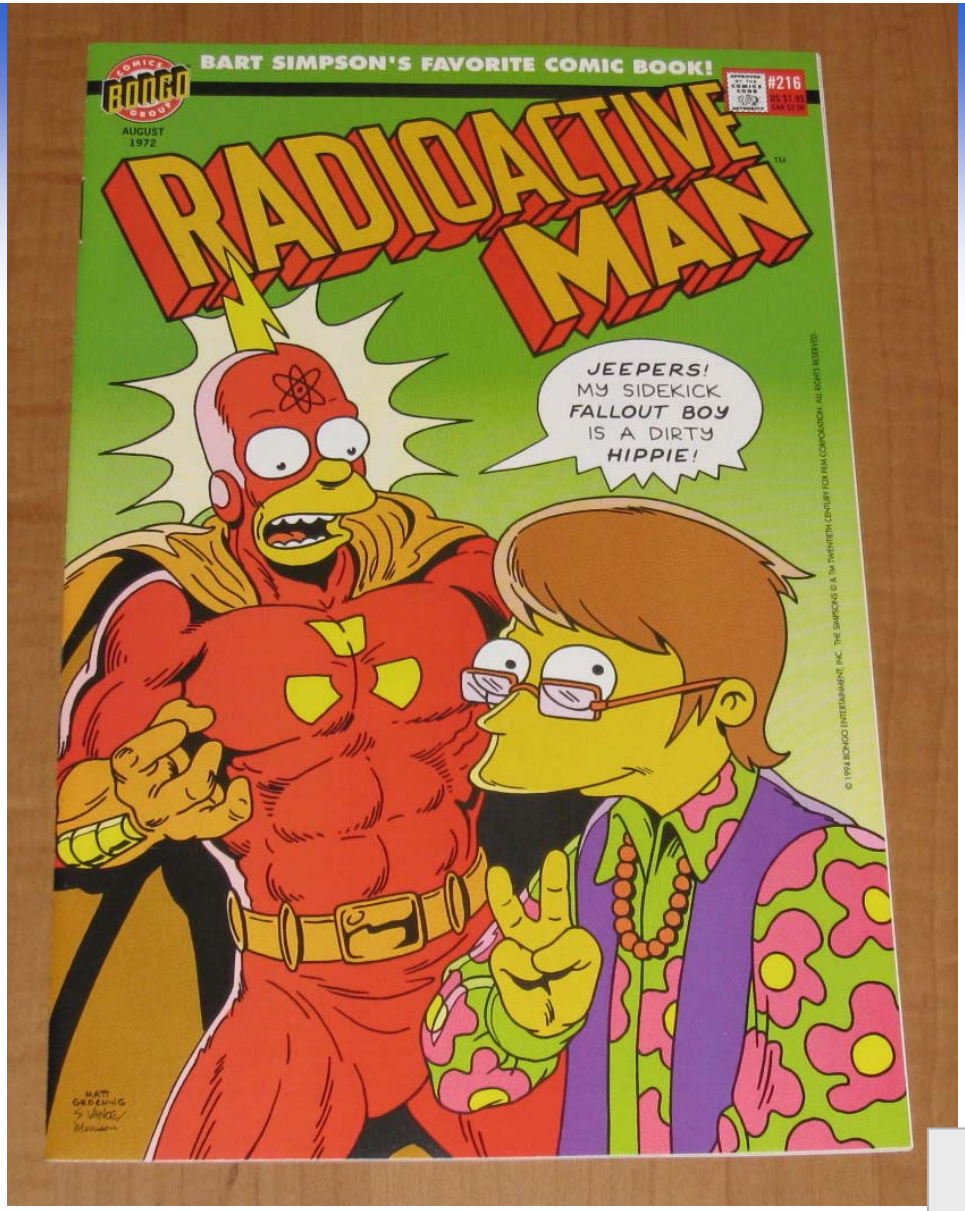


Kerne 1

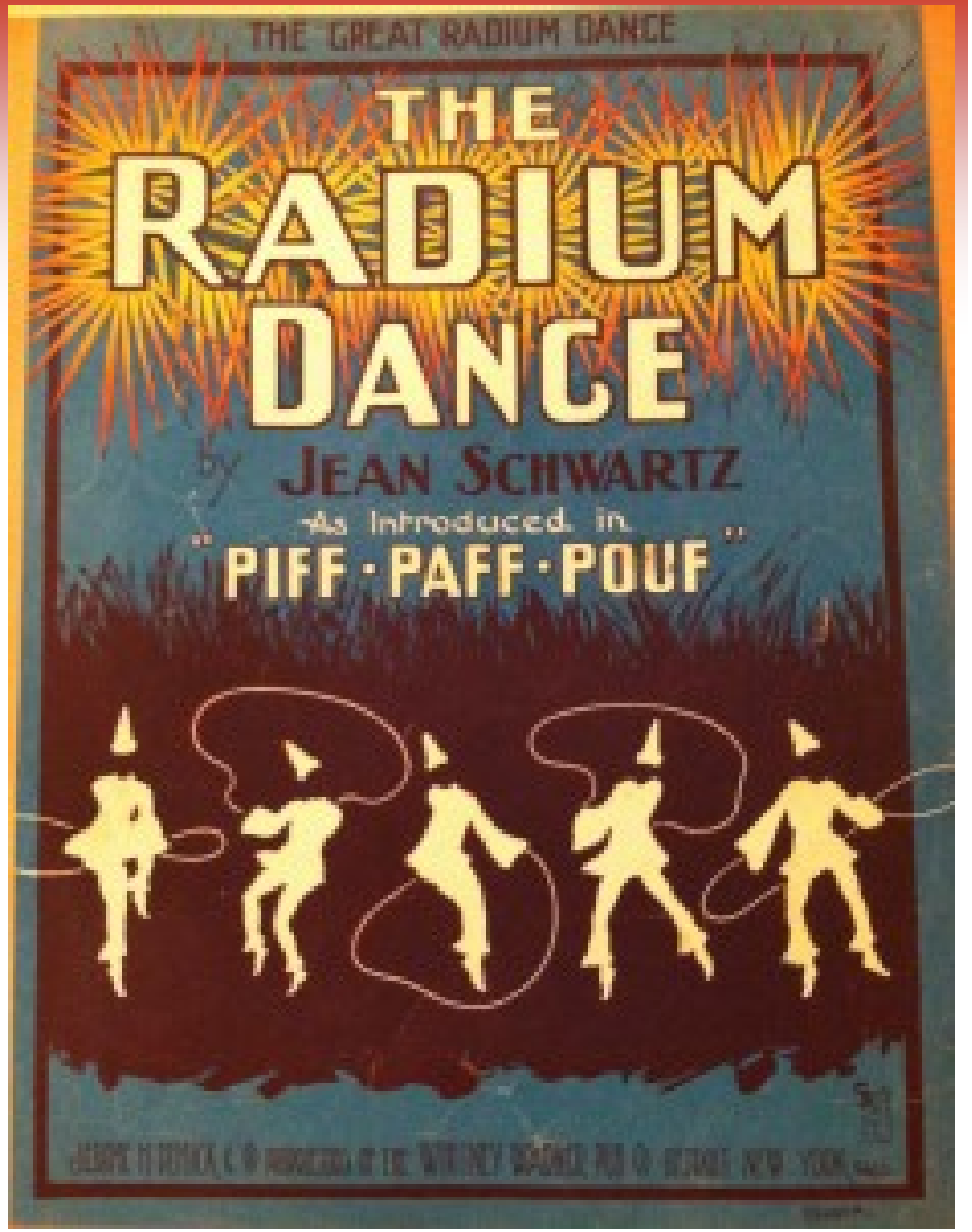
Nuklide
C-14 Methode
Starke Wechselwirkung
Massendefekt

Thema Kerne

Radium-Manie

1904

Radium-Manie



Extrablatt

Precious Radium *is Medicine's* Treacherous Helper

Rare metal is teamed with common lead to become an ally of science.

Weird masks impregnated with lead shield this doctor from the withering rays of radium held in the tiny vial. These same rays become healing agents when they are properly directed.

Lab—This solid lead container protects hospital attendants who transport radium. Above—Guarded by a lead shield containing thick lead glass, a nurse removes a vial of radium to its holder. Right—Lead vaults for radium. Box marked 100 contains one-tenth of a grain of radium. It is worth $7,500.

Lead is the only thing radium rays will not penetrate, and without a lead shield, this intense must work at a distance. Right—Radium is now valued at $1,000,000 an ounce. It looks like a white salt, and each grain must be well guarded.

Radium and Beauty

HERE are the first toilet preparations to embody Actual Radium, an astonishing new force for betterment, applied as an aid to Beauty. Learn how the amazing Energy of Radium has proved a boon to the human skin. Learn what Radium actually means to Beauty and how its power is employed in "Radior" Preparations. Study our $5,000 guarantee. Then turn to "Radior" Toilet Requisites. When you have used, enjoyed and tested them you will adopt them as *your own* first aid to Beauty.

PREHISTORIC woman first discovered her image in some quiet jungle pool. Ever since Beauty has engaged the world's attention.

Radium, though new to the world, is no less of absorbing interest. Its marvels have amazed and thrilled us all.

Who would have imagined that these two subjects would some day go hand in hand? Yet, in Radium, Science has discovered a revolutionary Beauty Secret.

Consult books on Radio-activity. Any number of them are in our public libraries. They will show you that Radium possesses an enormous power for human *betterment*.

The tiniest particle of Radium throws off a continuous stream of Energy Rays. An Energy never diminishing, never ceasing, day or night, year in, year out. A force a million times more powerful than any other known.

These Radium Rays are particularly valuable in effect upon the human skin. Dr. Louis Wickham and Dr. Degrais, specialists in the St. Lazare and the St. Louis Hospitals of Paris, have proved what Radium will do for even the most dreaded skin diseases.

Rays of Radium, in fact, energize and revivify any living matter with which they come in contact. They are "accepted by the human system as harmoniously as is sunlight by the plant."

This wonderful force for betterment has now been embodied in "Radior" Toilet Requisites, thus placing the power of Radium at the command of every woman who uses a face cream or powder, hair tonic or soap.

"Radior" Toilet Requisites are delightfully dainty and distinctive. They have an exquisite and exclusive fragrance all their own, a perfume not for sale in any market. They are the first and only preparations for the toilet to contain Actual Radium—Nature's greatest aid to Beauty.

Every "Radior" Preparation is *guaranteed*, under $5,000 penalty, to contain a definite amount of Actual Radium, and to retain its Radio-activity for at least twenty years. See Guarantee above.

In England, "Radior" Preparations are a success of several years' standing. They are used by noted women of title and fashion. They are the vogue in the leading shops.

We present them to the United States as the greatest boon ever offered—to those who value perfection of complexion; rounded, youthful facial contours; a healthy skin and beautiful hair.

Each and every "Radior" Beauty Aid is the formula of a famous Parisian specialist. Entirely aside from Radium, you would choose "Radior" Preparations for themselves alone—for the silky smoothness of the creams—the impalpable fineness of the powders and the tantalizing, haunting fragrance.

When to this perfection, as toilet preparations, is added the power of Actual Radium, the highest level of Beauty Culture is reached.

From velvety "Radior" Face Powder to healthful "Radior" Skin Soap—from delightful "Radior" Face Powder to wonderful "Radior" Hair Tonic, "Radior" Toilet Requisites all contain actual Radium for Beauty's sake.

Space does not permit us to go into further details, but there are further facts concerning Radium and Beauty which every woman should know. They are contained in our booklet sent free on request.

Write Today for This Vitally Interesting Booklet

This is probably the most revolutionary booklet on the subject of Beauty ever published. You who have imagined that all had been done for Beauty which could be done should lose no time in availing yourself of this "new knowledge." Investigate the subject of "Radium and Beauty."

The booklet is revised from the book "Radium—Its Discovery and Power," by C. Acey, one hundred and twenty thousand copies of which have been distributed in England. It is yours with our compliments. To secure your copy before our first edition is exhausted, mail the coupon NOW.

RADIOR CO., LTD., of LONDON.
235 Fifth Ave., New York.

Gentlemen: Please mail me a copy of your booklet, "Radium and Beauty." I understand that this request places me under no obligation to you.

Name .....

Address .....

.....

Radior
Toilet Requisites

"Radior" Toilet Requisites are necessarily higher in price. This must be expected in preparations containing the finest ingredients only, plus a definite quantity of Actual Radium. But the greater benefits obtained from "Radior" Preparations would justify an even higher price. The best is always the cheapest and goes further.

It is easy to prove the superiority of "Radior" Preparations. *Try them.* See how smoothly the Vanishing Cream rubs in.

Notice how your complexion improves with "Radior" Peau de Velour (night cream)

See how imperceptibly the face powder blends with the skin. How smoothly it adheres. Appreciate the soothing comfort of the Talc. Note the effects produced by the Hair Tonic.

Enjoy the strange, elusive fragrance.

Then remember that each preparation has the power to work for betterment—the power of Actual Radium. It is easy to apply these tests.

Purchase "Radior" Toilet Requisites at any of the leading department and drug stores. If you are not delighted with them, communicate with us and we will see that *your* money is refunded.

Radior Articles

1 Peau de Velours (Night Cream). Per jar	$2
2 Rouge (Compact). Per box	$1
3 Compact Powder. Per box	$1
4 Vanishing Cream. Per jar	$2
5 Talcum Powder. Per bottle	$1
6 Hair Tonic. Per bottle	$2
7 Skin Soap. Per Cake	$1
8 Under Chin Pad. Each	$10
9 Forehead Pad. Each	$5
10 Face Powder. Per box	$2

Six tints—Blanche, Sorelle, Rachel, Floré, Ochre and Brunette.

RADIOR TOILET REQUISITES
OBTAINABLE AT
Leading Department Stores of
New York, Brooklyn and Newark
and
Liggett's Drug Stores

Radior
Reg. Trade Mark
Toilet Requisites

Sole Manufacturers
Radior Co., Ltd., of London
235 Fifth Avenue, New York 167 Oxford St., London, W. 1.
If your Dealer cannot supply you communicate with us.

ALCO-GRAVURE INC. N.Y.

Extrablatt

Extrablatt


RADIUM-BRÄU
Das Qualitätsbier
SCHUTZ-MARKE
SCHLOSSBRAUEREI A. RENNER
RADIUMBAD BRAMBACH VOGTL.

Extrablatt


Quarks. Neutrinos. Mesons. All those damn particles you can't see. That's what drove me to drink. But now I can see them.

Thema Kerne

Nuklide

Extrablatt

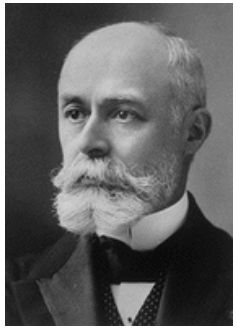

"--AND I WAS THE FIRST TO LOCATE THE ISOTOPE!"
HEY, MAN! IT'S--IT'S GLOWIN'!

Strahlung aus dem Kern

Natürliche Radioaktivität

Symptome

- spontane Aussendung von Strahlung durch beispielsweise Uranerz
- für Licht undurchsichtige Schichten werden durch neu entdeckte Strahlung durchdrungen
- chemische Reaktion löst Schwärzung photographischer Platten aus



Henri Antoine Becquerel
1852-1908

Zufallsentdeckung 1896

Bisher ist nicht zu erkennen, woher das Uran seine Energie nimmt, die es mit solcher Beharrlichkeit abstrahlt

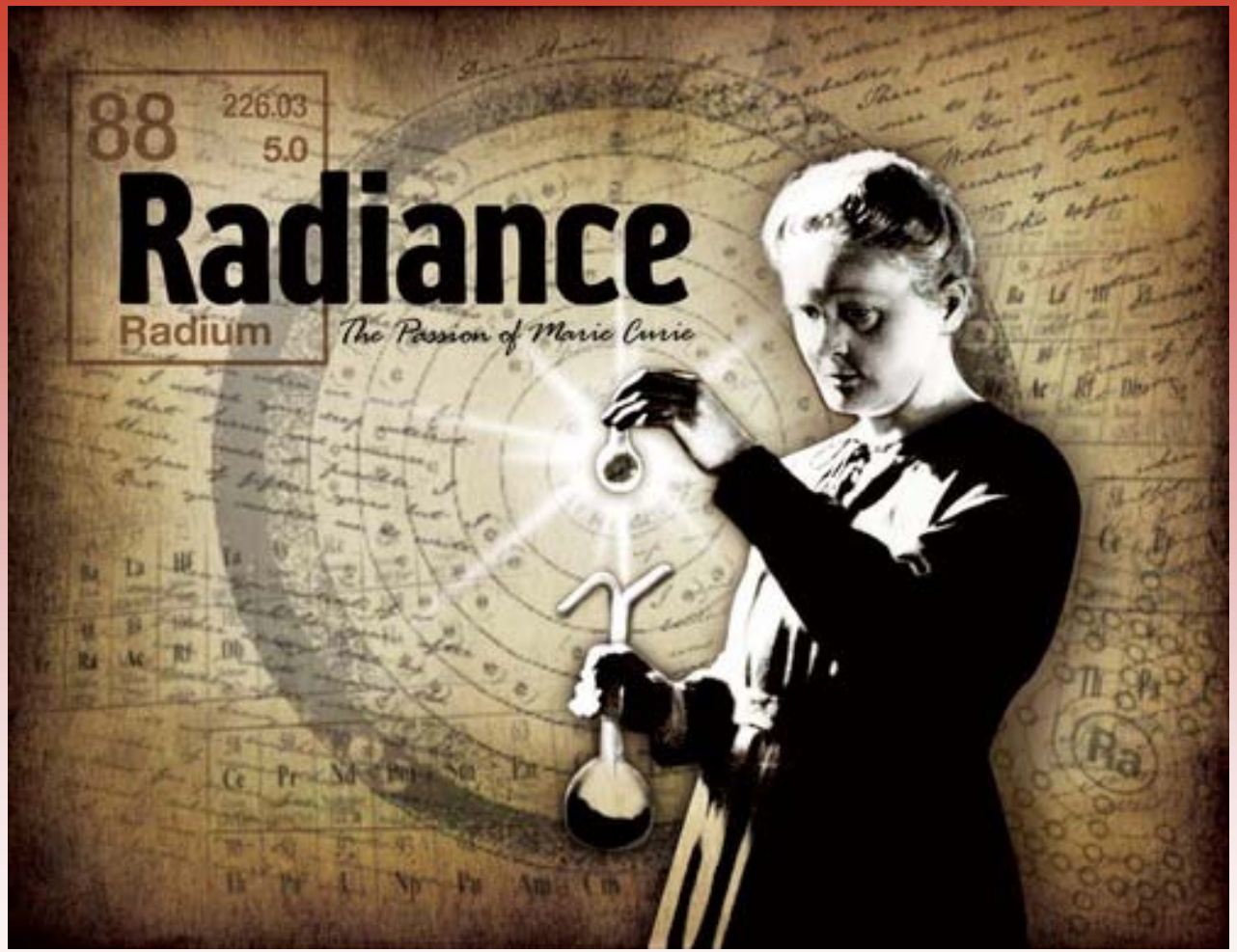
Diagnose

- emittierte Strahlung ist KEINE Fluoreszenz
externe Anregung und spätere Aussendung von Strahlung bei Rekombination in Grundzustand
- beobachtete Phänomene unterscheiden sich von Eigenschaften der Röntgenstrahlung

Extrablatt

The Nobel Prize in Physics 1903 was divided, one half awarded to Antoine Henri Becquerel "*in recognition of the extraordinary services he has rendered by his discovery of spontaneous radioactivity* **the other half jointly to Pierre Curie and Marie Curie, née Sklodowska *in recognition of the extraordinary services they have rendered by their joint researches on the radiation phenomena discovered by Professor Henri Becquerel***

Extrablatt



The Nobel Prize in Chemistry 1911 was awarded to Marie Curie
in recognition of her services to the advancement of chemistry by the discovery of the elements radium and polonium, by the isolation of radium and the study of the nature and compounds of this remarkable element

Extrablatt

Seizième année. — N° 779. Huit pages : CINQ centimes Dimanche 10 Janvier 1904.

Le Petit Parisien

SUPPLÉMENT LITTÉRAIRE ILLUSTRÉ

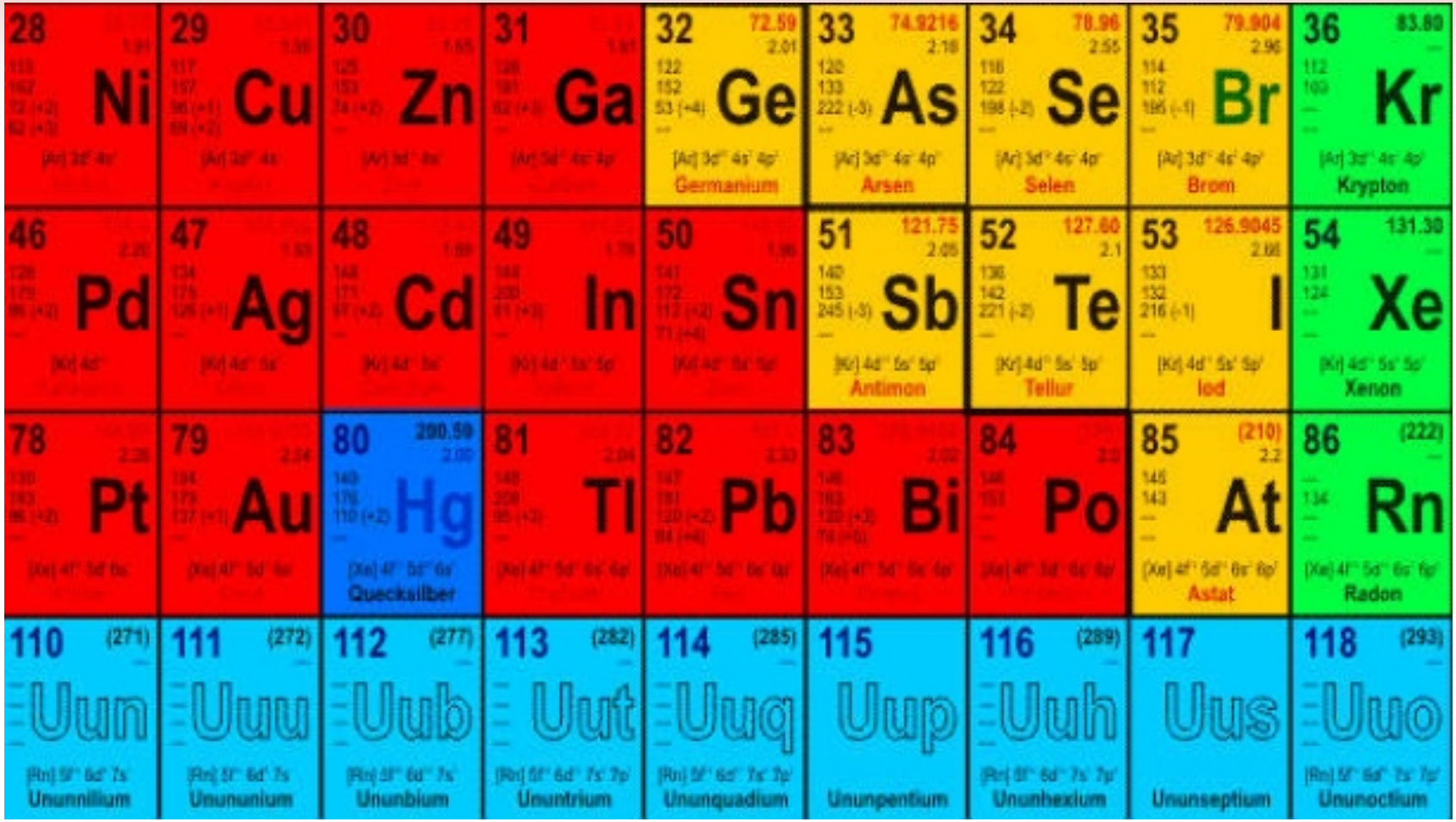
DIRECTION: 18, rue d'Enghien (10e). PARIS

UNE NOUVELLE DÉCOUVERTE. — LE RADIUM

M. ET Mme CURIE DANS LEUR LABORATOIRE

Extrablatt

Der Forschergeist der Curies



Diagnose

- Entdeckung neuer Elemente von Radium (Ra), Polonium (Po) und Thorium (Th)

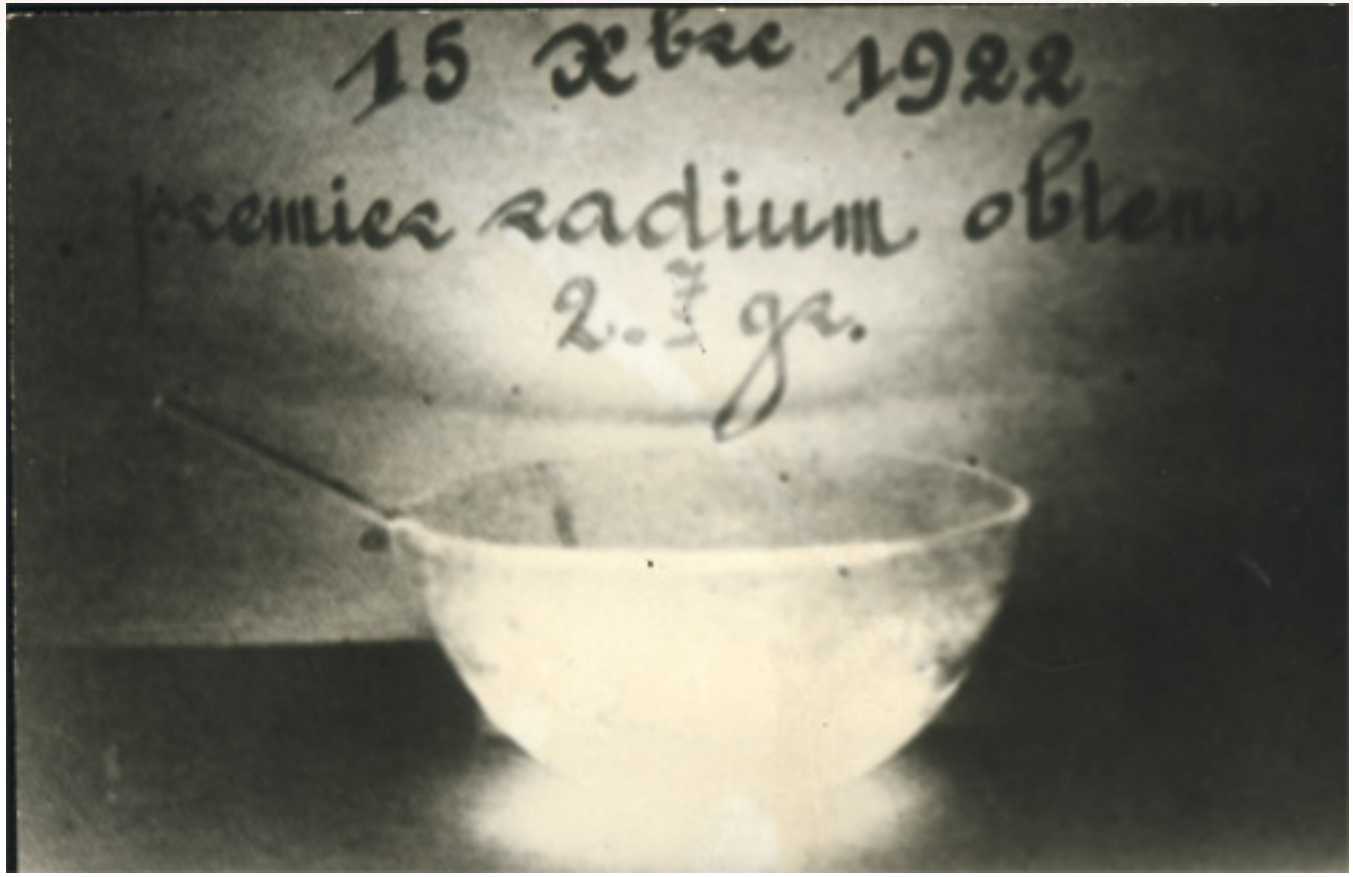
- systematische Untersuchungen der Mineraliensammlung des Musee d'Historie Naturelle

Extrablatt

Marie und Pierre Curie

Symptome

Luminesierender Becher gefüllt mit Radiumbromid (Photo von 1922)



Diagnose

- **Radium ist äußerst selten und selbst im Vergleich zu Uran stark radioaktiv**
- **erhitzt man das Salz emittiert es Licht von attraktive blauer Farbe**
- **Pierre and Marie Curie habe es sich gerne abends angeschaut**

Extrablatt

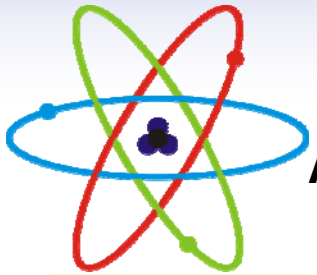
Rutherford 1910

Alpha-Zerfall

Strahlende Heliumschleudern

»Herr Rutherford hatte schon lange auf die große Wahrscheinlichkeit hingewiesen, daß die α-Teilchen doppelt geladene Heliumatome seien. 200 mg Radium wurden in einer evakuierten Glasröhre 83 Tage lang aufbewahrt. Nach Ablauf dieser Zeit wurden die vorhandenen Gase durch Tierkohle beseitigt. Die hat die Eigenschaft, alle Gase außer Helium zu absorbieren. Das schließlich restierende Gasquantum entsprach einer Heliumproduktion von 163 mm^3 pro Gramm Radium und Jahr. Damit ist eine neuerliche Stütze für das schon recht sicher fundierte Gebäude der Atomzerfallstheorie gewonnen.« *Naturwissenschaftliche Rundschau, 25. Jg., Nr. 16, 7. April 1910, S. 203*

Kernnotation



Allgemeine Schreibweise $^{238}_{92}U^{37+}_{2}$

Nukleonenzahl A
Ordnungszzahl Z
$\mathrm{Isotop}^{\text{q Ladung}}_{\text{n Anzahl der Atome im Molekül}}$

Anzahl Nukleonen = Anzahl Protonen + Anzahl Neutronen

relative Atomnummer

Schreibweise für den Kern $^{238}_{92}U$

Anzahl Protonen = Ordnungs-/ Kernladungszahl

für neutrales Atom gilt

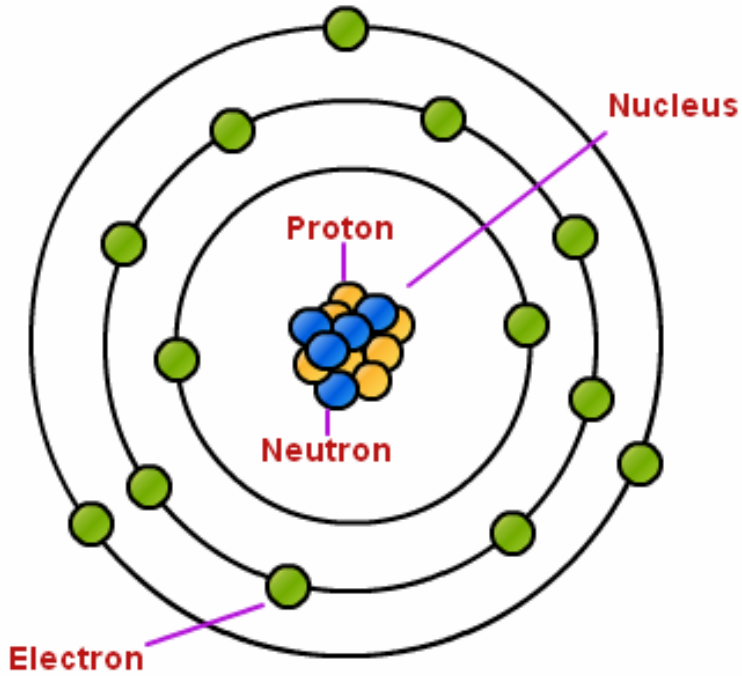
Anzahl Protonen = Anzahl Elektronen

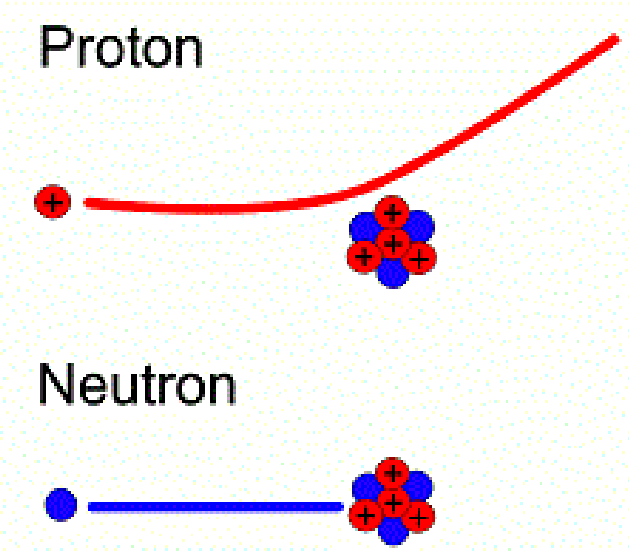
Who´s who in nuclear physics

Neutron

Symptome

- **Neutron ist elektrisch neutrales Teilchen**
- **Formelzeichen des Neutrons ist der Buchstabe (n)**
- **neben Proton (p) ist Neutron Bestandteil der Atomkerne**





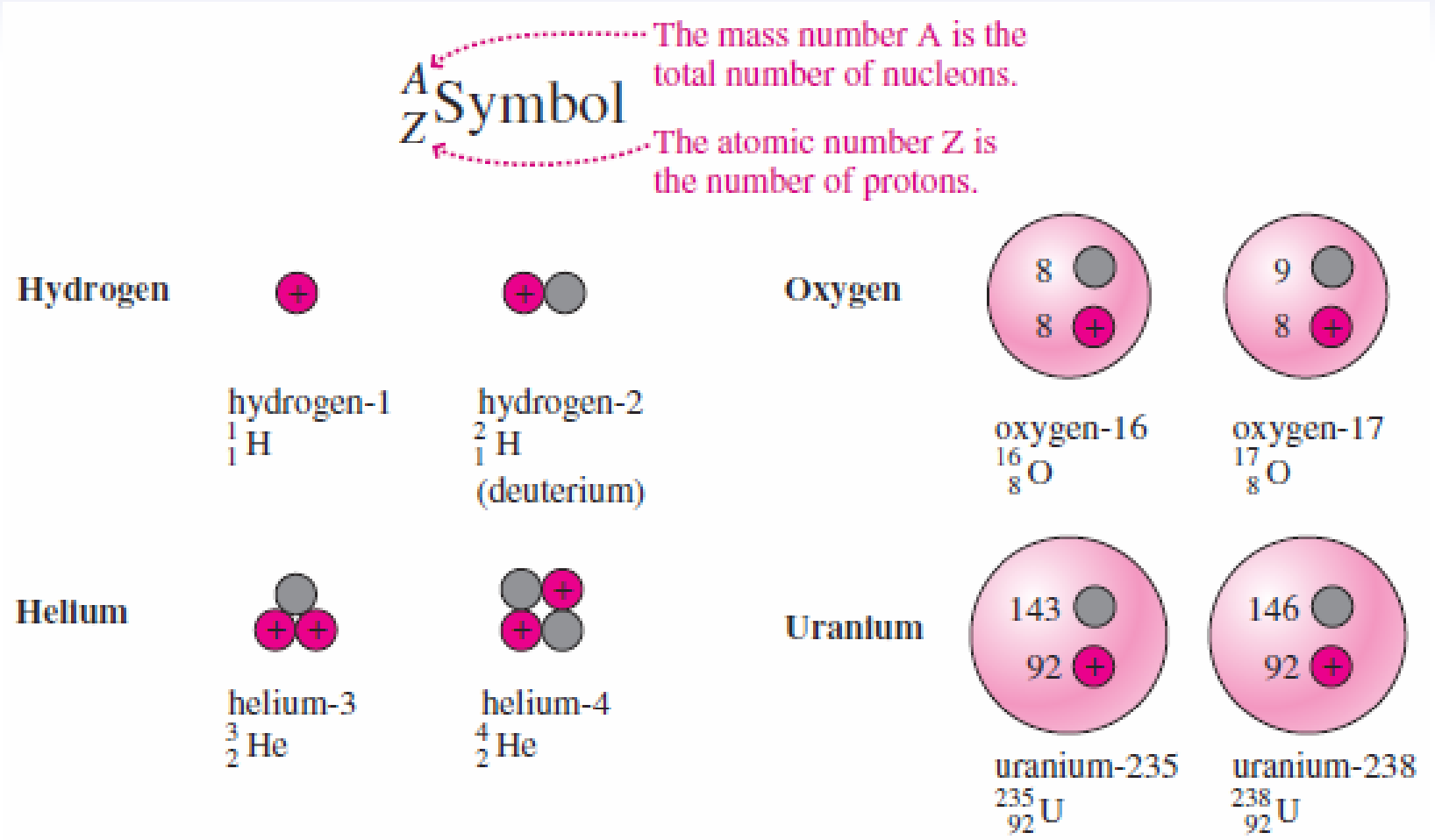
Fragen, die man sich stellen könnte:

Wie ist die Kernnotation des Neutrons?

$${}^{0}_{1}n \qquad {}^{1}_{0}n$$

Extrablatt

Isotope



Diagnose
Isotope eines Elements haben dieselbe Anzahl Protonen, aber unterschiedliche Neutronenzahl

Who´s who in nuclear physics

Wasserstoffnuklide

Atom

$^{1}_{1}H$

Anteil 99.98%

Proton

$^{1}_{1}H^{+}$

Isotop Deuterium
schwerer Wasserstoff

$^{2}_{1}H$

Anteil 0.0156%

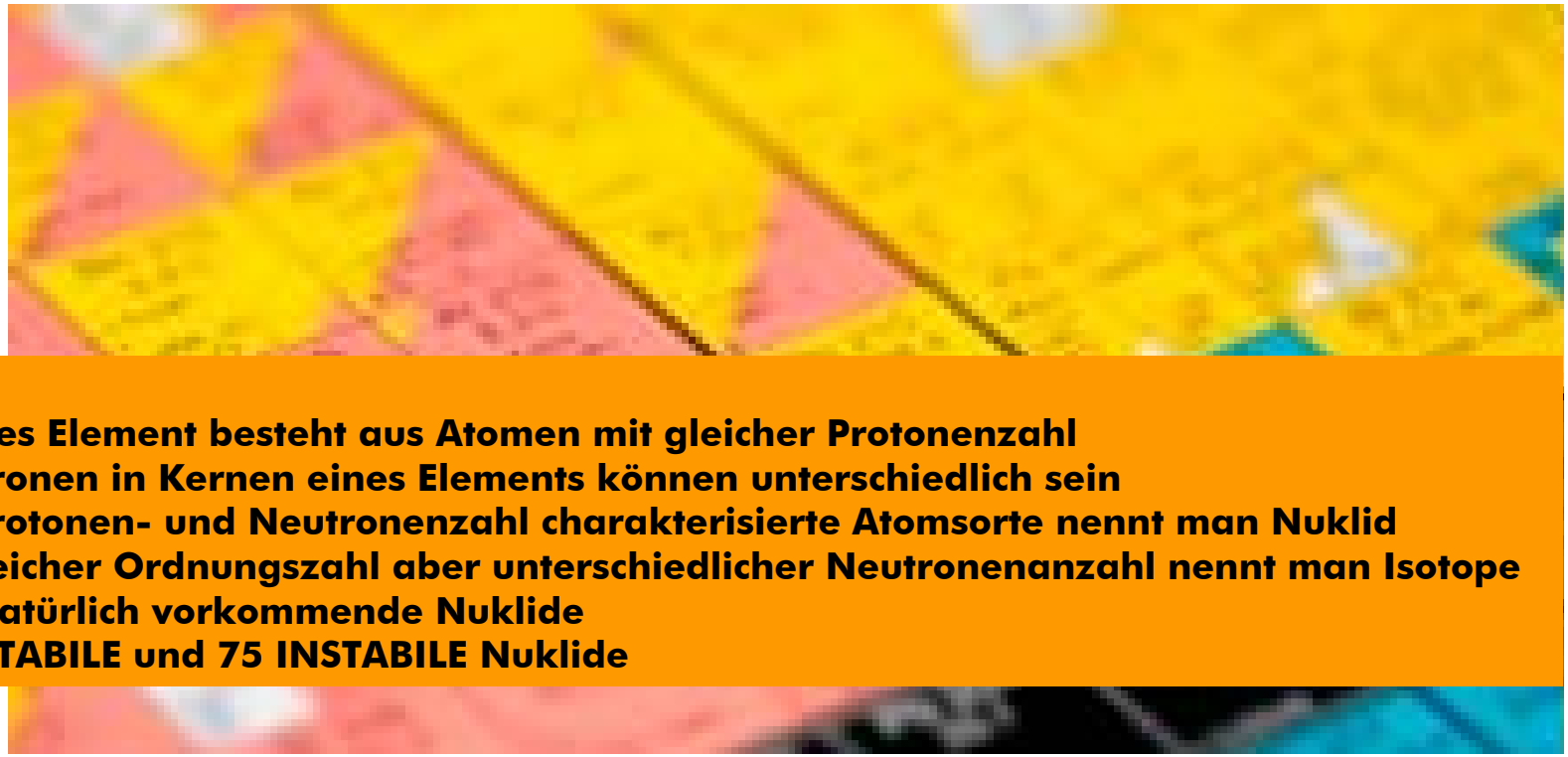
Tritium

$^{3}_{1}H$

instabiles Isotop

Molekül

$^{1}_{1}H^{+}_{2}$



Diagnose

- **ein chemisches Element besteht aus Atomen mit gleicher Protonenzahl**
- **Anzahl Neutronen in Kernen eines Elements können unterschiedlich sein**
- **eine durch Protonen- und Neutronenzahl charakterisierte Atomsorte nennt man Nuklid**
- **Kerne mit gleicher Ordnungszahl aber unterschiedlicher Neutronenanzahl nennt man Isotope**
- **es gibt 340 natürlich vorkommende Nuklide**
- **es gibt 265 STABILE und 75 INSTABILE Nuklide**

Who´s who in nuclear physics

Kohlenstoff

stabiles Isotop

$^{12}_{6}C$

Anteil 98.9%

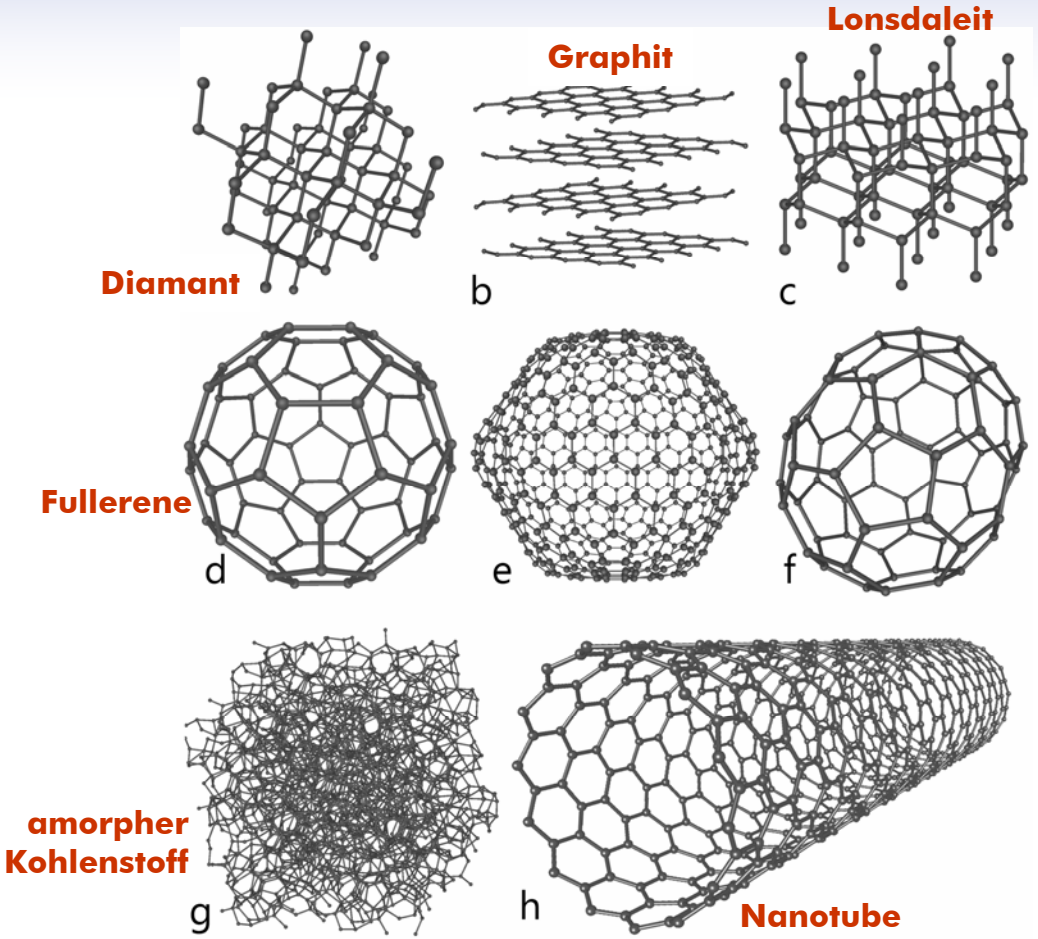
stabiles Isotop

$^{13}_{6}C$

Anteil 1.1%

instabiles Isotop

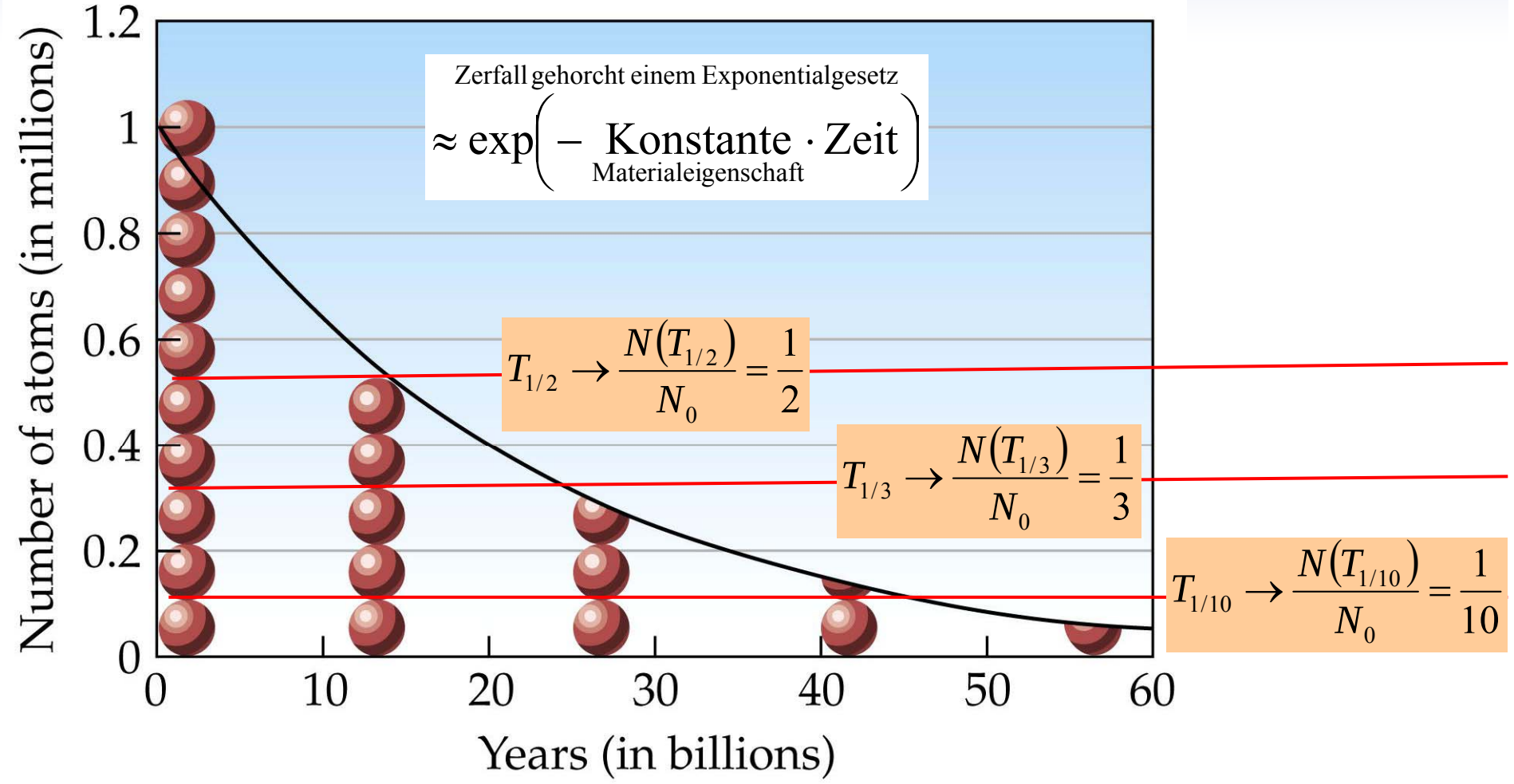
$^{14}_{6}C$



Diagnose

- **Kohlenstoff bildet aufgrund quantenchemischer Eigenschaften unterschiedlichste Strukturen**
- **Reichhaltigkeit in Struktur entscheidend für Leben auf der Erde**
- **C-14 Isotop spielt wichtige Rolle in Datierung beispielsweise archäologischer Artefake**

Radioaktiver Zerfall



Radioaktiver Zerfall
Aktivität

Herleitung

Zerfallsdynamik

$$\underbrace{dN(t)}_{\text{Anzahl Zerfallsprodukte}} = -\underbrace{\lambda_{decay}}_{\text{Zerfallskonstante}} \underbrace{N(t)}_{\substack{\text{Anzahl vorhandener} \\ \text{radioaktiver Kerne}}} dt$$

Aktivität einer Probe

$$\underbrace{A_{decay}}_{\text{Aktivität}} = \frac{dN(t)}{dt} = -\lambda_{decay} N(t)$$

Zerfallsgesetz für radioaktive Stoffe

$$N(t) = N_0 \exp(-\lambda_{decay} t)$$

Diagnose

- **Aktivität einer radioaktiven Stoffmenge ist Anzahl Kernzerfälle pro Zeiteinheit**
- **SI-Einheit der Aktivität ist das Becquerel (Bq)**
- **1.0 Bq entspricht einem Kernzerfall pro Sekunde**

Halbwertszeit

Symptome

Nach welcher Zeitspanne hat sich die Anzahl nicht zerfallener Atome halbiert?

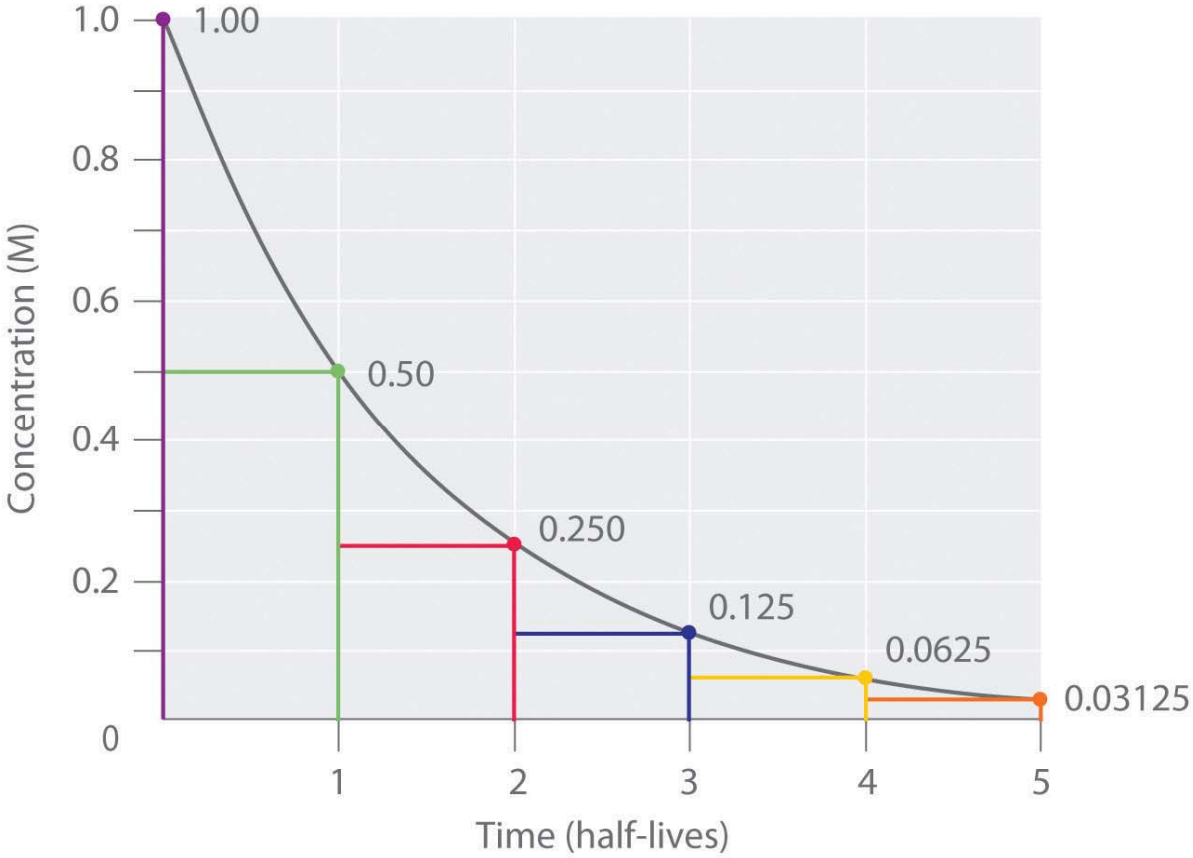
$$\frac{N(T_{1/2})}{N_0} = \frac{1}{2} = \exp(-\lambda_{decay} T_{1/2})$$

$$\overset{\frac{1}{x}}{\Leftrightarrow}$$

$$2 = \exp(\lambda_{decay} T_{1/2})$$

$$\Leftrightarrow$$

$$\ln 2 = \lambda_{decay} T_{1/2}$$



Dimensionskontrolle

$$[\lambda_{decay}] = \left[\frac{1}{\text{s}}\right]$$

Zerfallskonstante

$$\lambda_{decay} = \frac{\ln 2}{T_{1/2}} = \frac{0.693}{T_{1/2}}$$

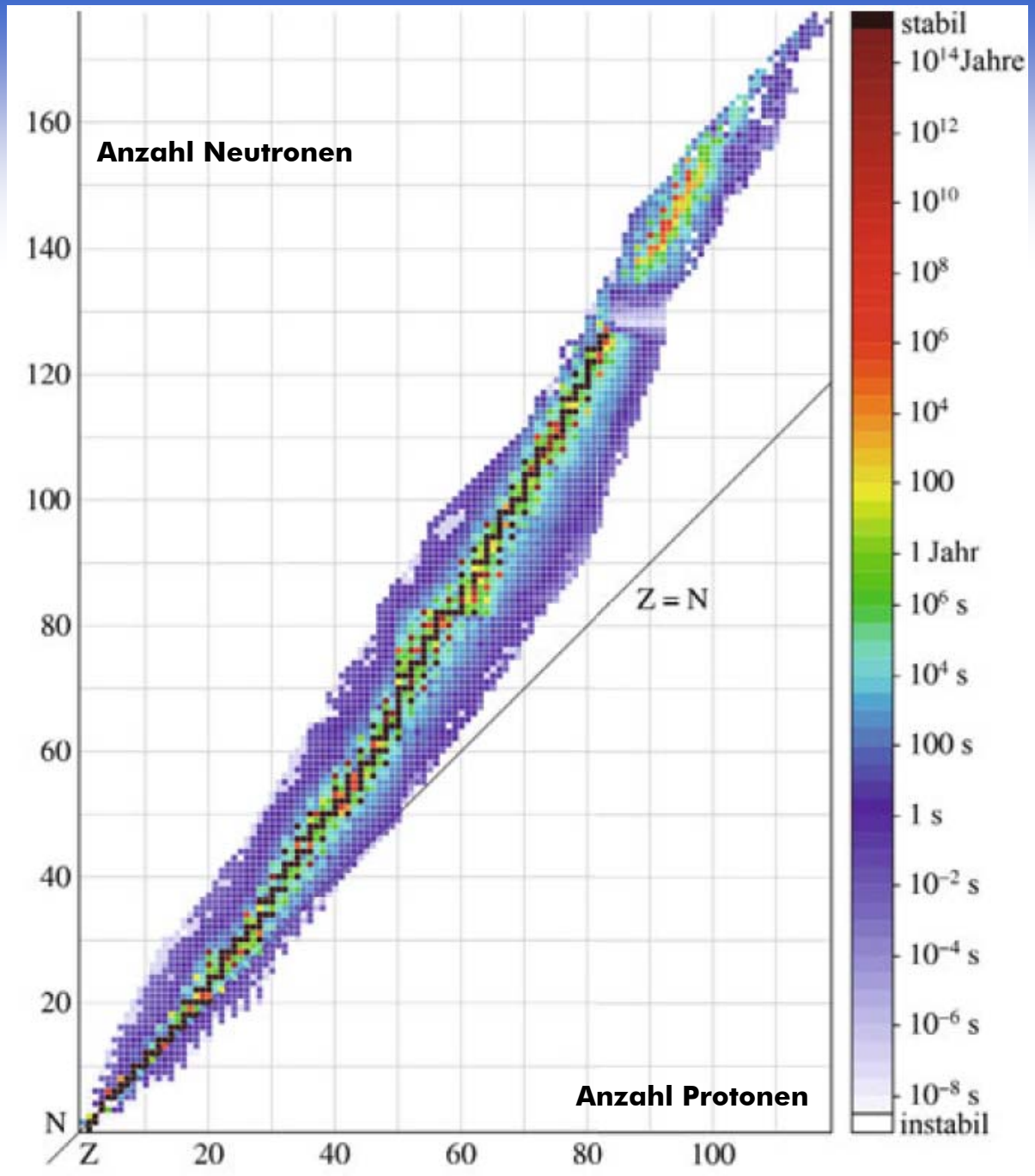
Halbwertszeit

Dimensionskontrolle

$$[T_{1/2}] = [\text{s}]$$

Lebensdauern

Halbwertszeit



Extrablatt

physikalisch relevant

Radioisotope

Isotope	Half-life	Decay Mode	Comments
Carbon-14 ($^{14}_{6}C$)	5730 years	β^-	Used in radiocarbon dating
Iodine-131 ($^{131}_{53}I$)	8.04 days	β^-	Fission product abundant in fallout from nuclear weapons and reactor accidents; damages thyroid gland
Oxygen-15 ($^{15}_{8}O$)	2.03 minutes	β^+	Short-lived oxygen isotope produced with cyclotrons and used for medical diagnosis in PET
Potassium-40 ($^{40}_{19}K$)	1.25×10^9 years	β^-	Comprises 0.012% of natural potassium; dominant radiation source within the normal human body; used in radioisotope dating
Plutonium-239 ($^{239}_{94}Pu$)	24,110 years	α	Fissile isotope used in nuclear weapons; produced by neutron capture in $^{238}_{92}U$
Radium-226 ($^{226}_{88}Ra$)	1600 years	α	Highly radioactive isotope discovered by Marie and Pierre Curie; results from decay of $^{238}_{92}U$
Radon-222 ($^{222}_{86}Rn$)	3.82 days	α	Radioactive gas formed naturally in decay of $^{226}_{88}Ra$; seeps into buildings, where it may cause serious radiation exposure
Strontium-90 ($^{90}_{38}Sr$)	29 years	β^-	Fission product that behaves chemically like calcium; readily absorbed into bones
Tritium ($^{3}_{1}H$)	12.3 years	β^-	Hydrogen isotope used in biological studies and to enhance yields of nuclear weapons
Uranium-235 ($^{235}_{92}U$)	7.04×10^8 years	α	Fissile isotope comprising 0.72% of natural uranium; used as reactor fuel and in simple nuclear weapons
Uranium-238 ($^{238}_{92}U$)	4.46×10^9 years	α	Predominant uranium isotope; cannot sustain a chain reaction

Zerfallszeiten

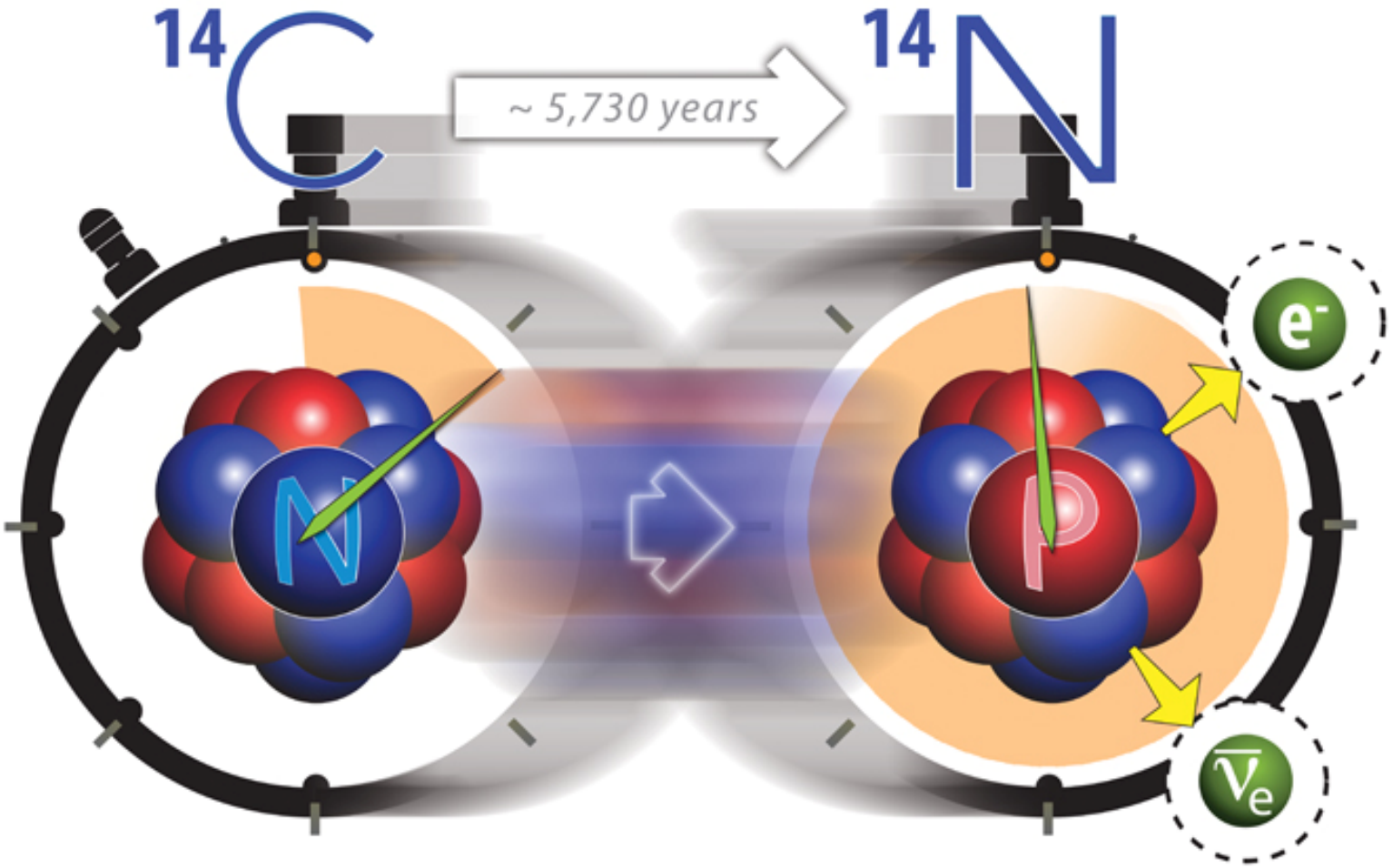
Extrablatt

Bismuth breaks half-life record for α–decay

Physicists in France have measured the longest ever radioactive half-life - over twenty billion billion years - in a naturally occurring element that decays by emitting alpha-particles. Noel Coron and colleagues at the Institut d'Astrophysique Spatiale in Orsay used a *scintillating bolometer* at very low temperatures to detect the emission of alpha particles – charged particles that consist of two protons and two neutrons – as bismuth-209 decays into thallium-205

Experimental detection of α-particles from the radioactive decay of natural bismuth
P. de Marcillac *et al.* Nature 422 876 (2003)

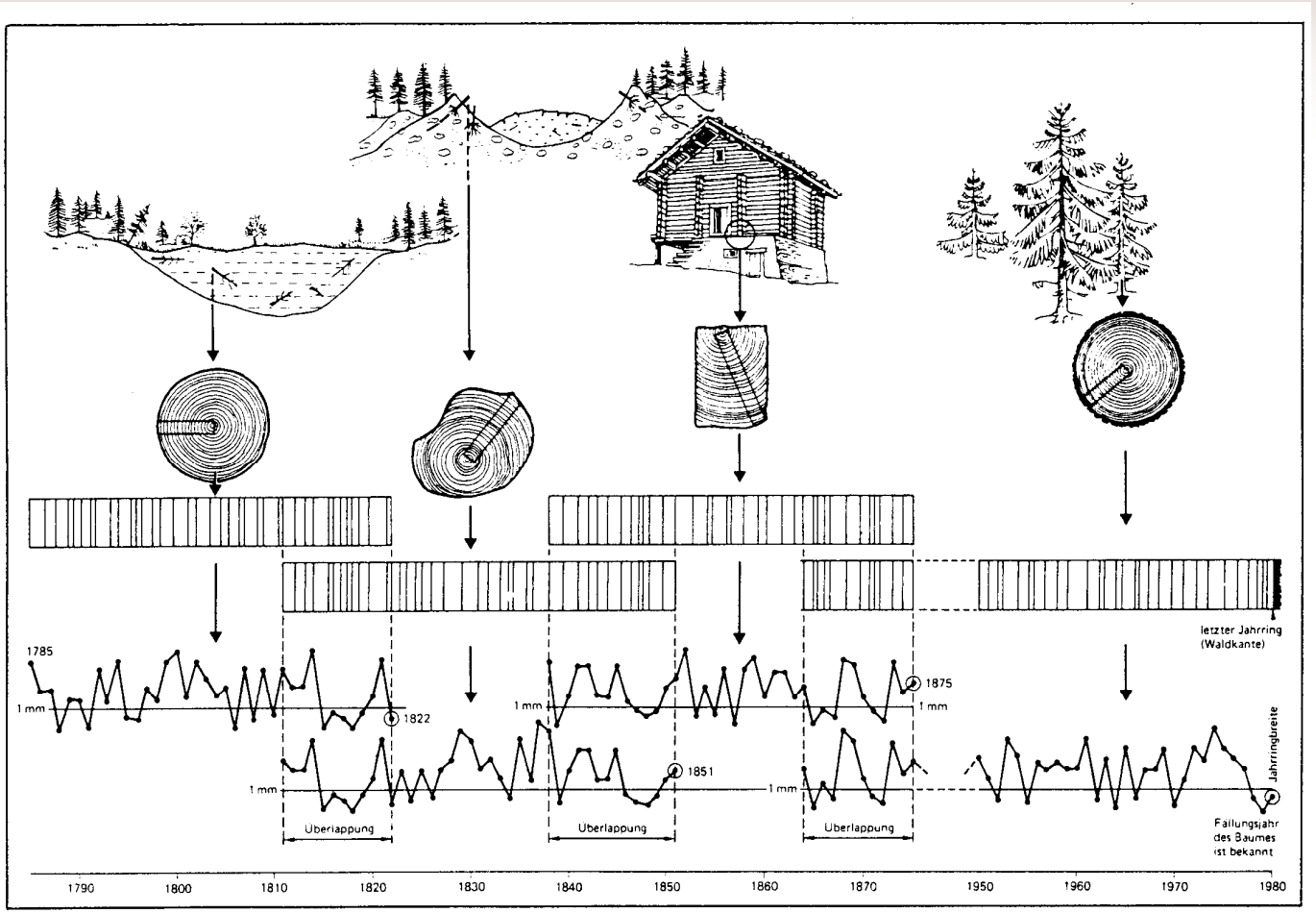
C14-Methode



Dendrochronologie

Analyse der Jahresringen von Bäumen

Archäologie
Hausbaugeschichte
Siedlungsgeschichte
Kunstgeschichte
Paläoklimatologie
Klimatologie
Gletscherwachstum
Waldbrandhistorie
Überflutungsgeschichte
Vulkanismus
Insektenschäden
Immissionsschäden
Kriminalistik
Kunstfälschungen



Diagnose
Durch Analyse Jahresringe Bäume erfasst man Zeitraum Jahrhunderte

Extrablatt

Dendrochronologie

Analyse der Jahresringen von Bäumen

C^{14}-Methode

Kreislauf der Natur

Symptome

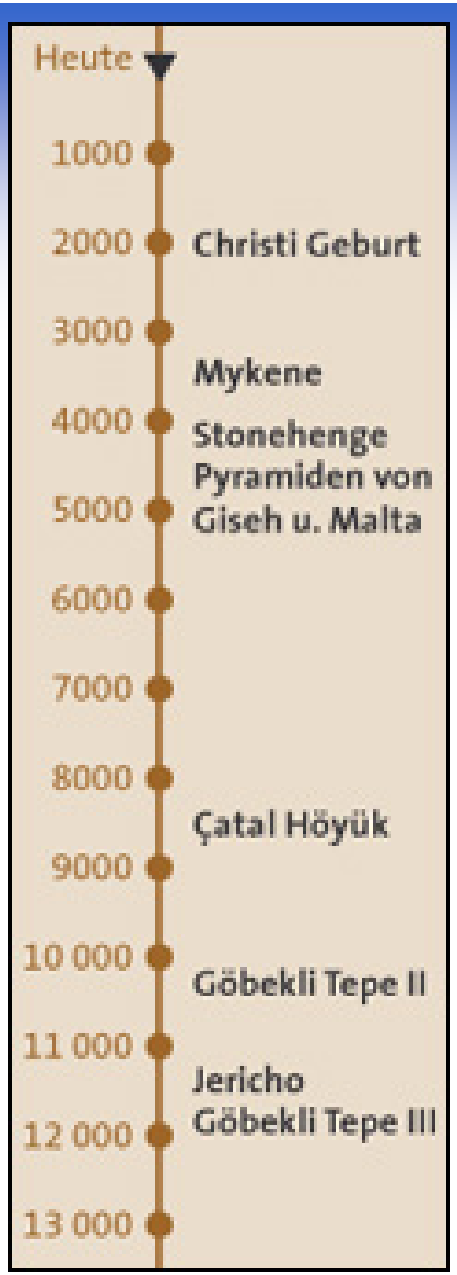
Bestimmung der Zeitspanne, die seid signifikantem physikalischen Ereignis vergangen ist

Diagnose

- lebende Organismen nehmen ständig Kohlenstoffatome über die Nahrung auf

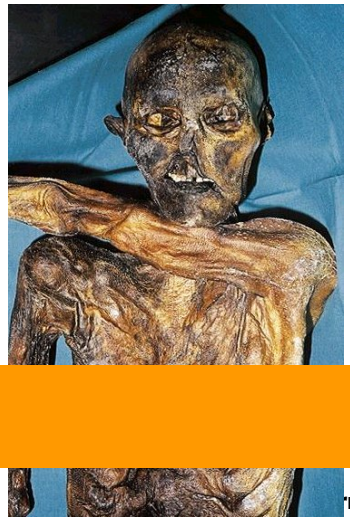
- Kohlenstoff wieder vom Körper wieder abgegeben, wie zum Beispiel über die Atmung

Kohlenstoff-Isotope



Isotop	Häufigkeit	Halbwertszeit
$^{9}_{6}C$	*instabil*	0.13 Sekunden
$^{10}_{6}C$	*instabil*	10 Sekunden
$^{11}_{6}C$	*instabil*	20.6 Minuten
$^{12}_{6}C$	99 %	∞
$^{13}_{6}C$	1 %	∞
$^{14}_{6}C$	*instabil*	5730 Jahre
$^{15}_{6}C$	*instabil*	2.25 Sekunden
$^{16}_{6}C$	*instabil*	0.74 Sekunden

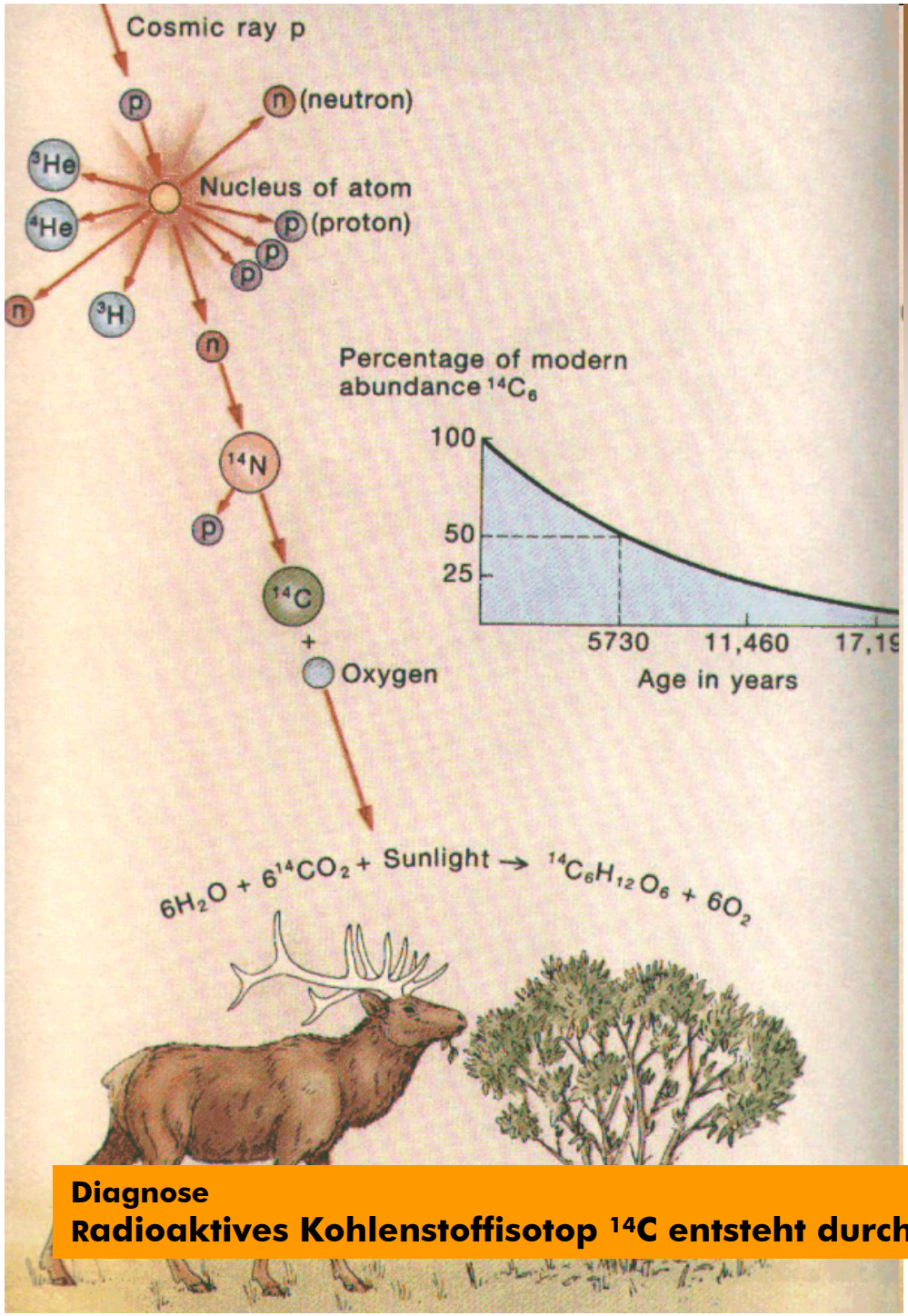
C14-Methode



Diagnose
C-14 hat Halbwertszeit in der Größenordnung der Menschheitsgeschichte

Kreislauf der Natur

C^{14}-Methode

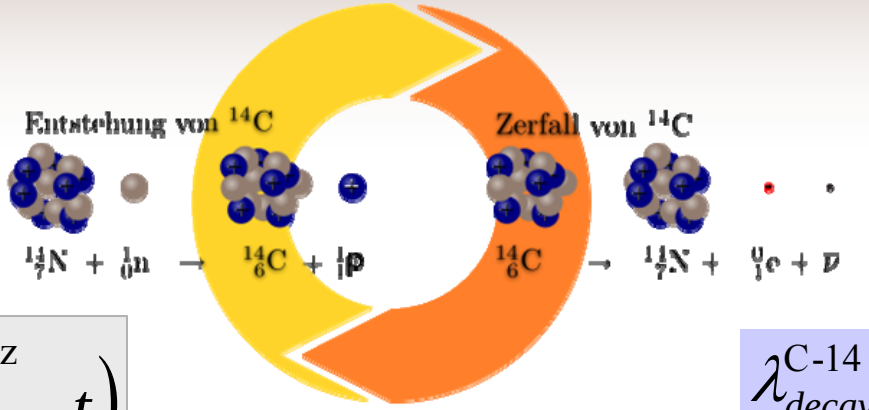


Diagnose

Radioaktives Kohlenstoffisotop ^{14}C entsteht durch kosmische Strahlung in oberer Atmosphäre

β^-– Zerfall

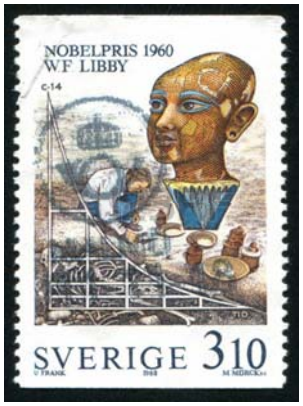
C-14 Methode

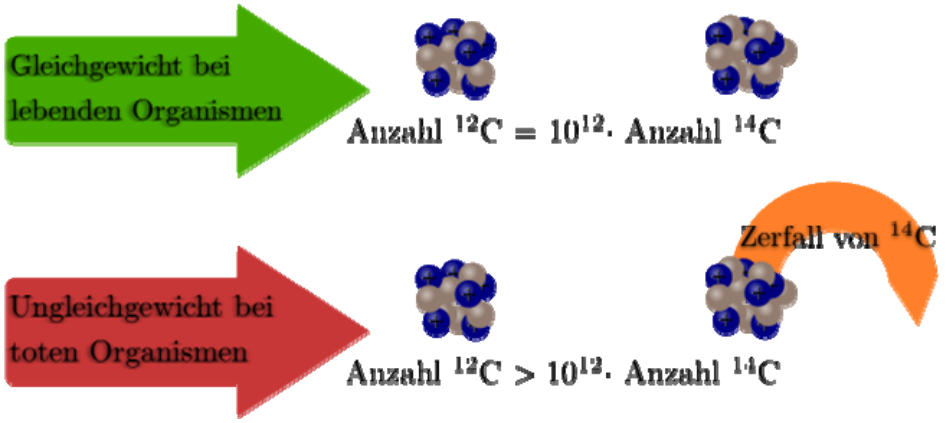


radioaktives Zerfallsgesetz

$$N(t) = N_0 \exp(-\lambda_{decay} t)$$

$$\lambda_{decay}^{\text{C-14}} = 5730\ \text{a}$$

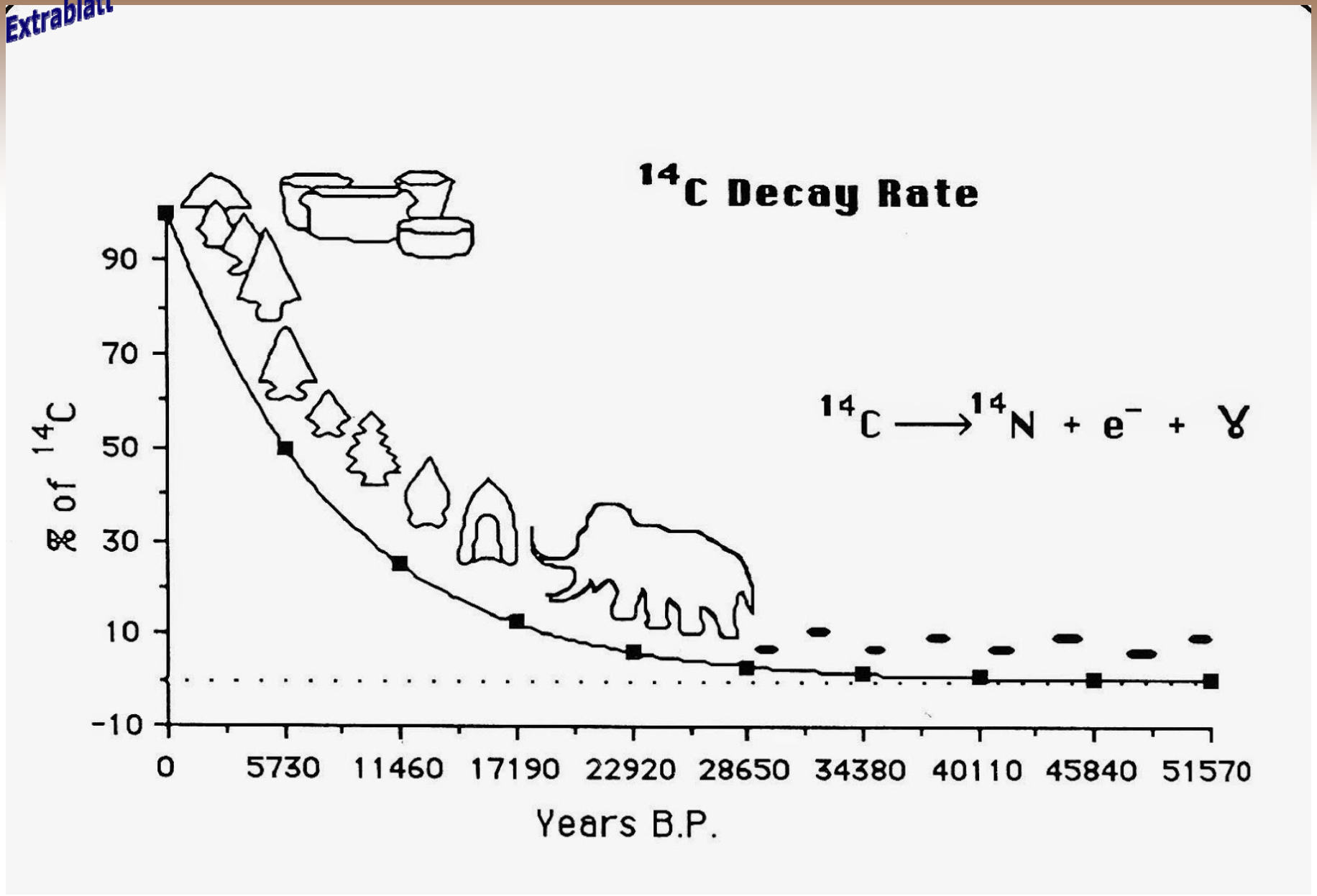




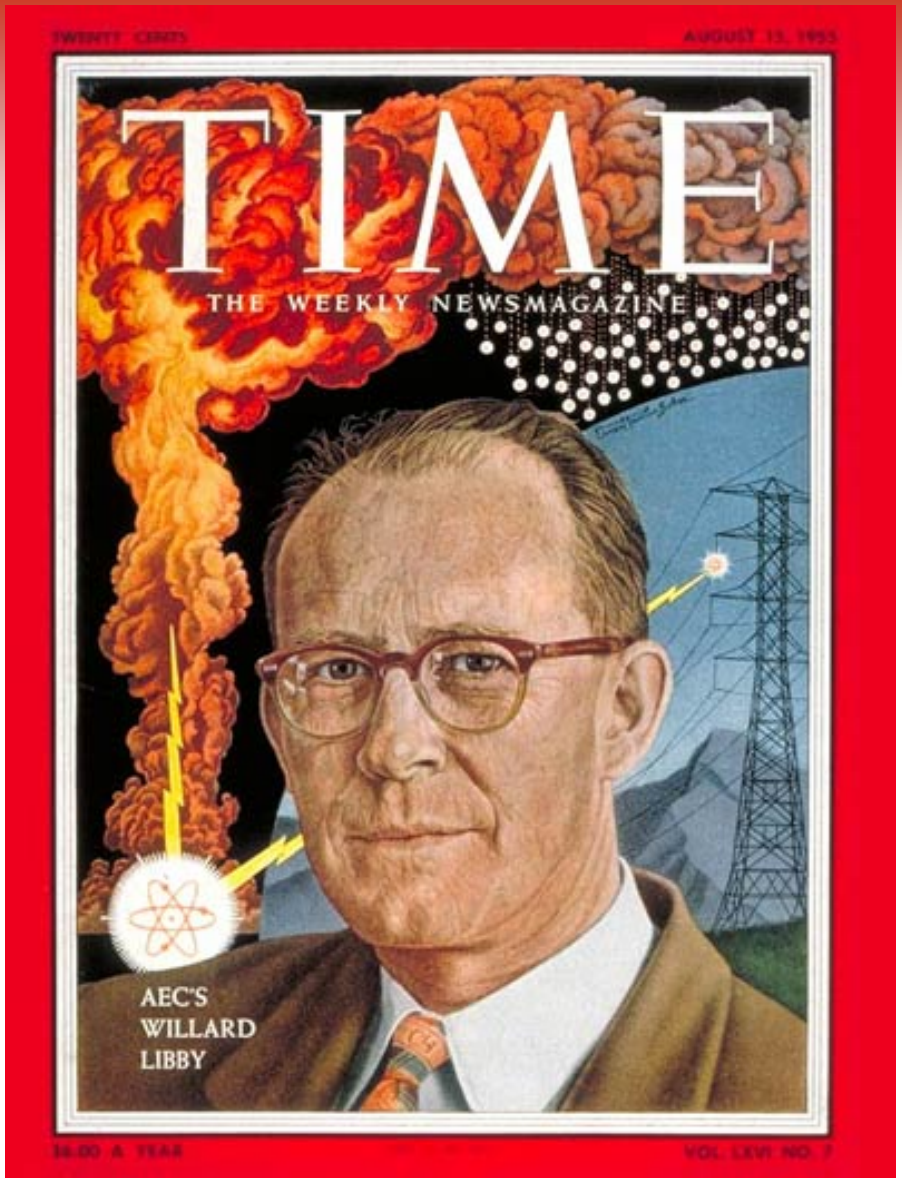
Diagnose

- **über die Nahrungskette ist Kohlenstoff und speziell ^{14}C in jedem Organismus vorhanden**
- **Anteil im Körper entspricht dem Anteil von C-14 in der Umgebung (Gleichgewicht)**
- **Situation ändert sich, wenn Organismus stirbt**
- **Radioaktiver Zerfall wird analysiert und Zeitspanne extrahiert**

Extrablatt


^{14}C Decay Rate
$^{14}C \longrightarrow {}^{14}N + e^- + \bar{\nu}$
% of ^{14}C
90
70
50
30
10
-10
0
5730
11460
17190
22920
28650
34380
40110
45840
51570
Years B.P.

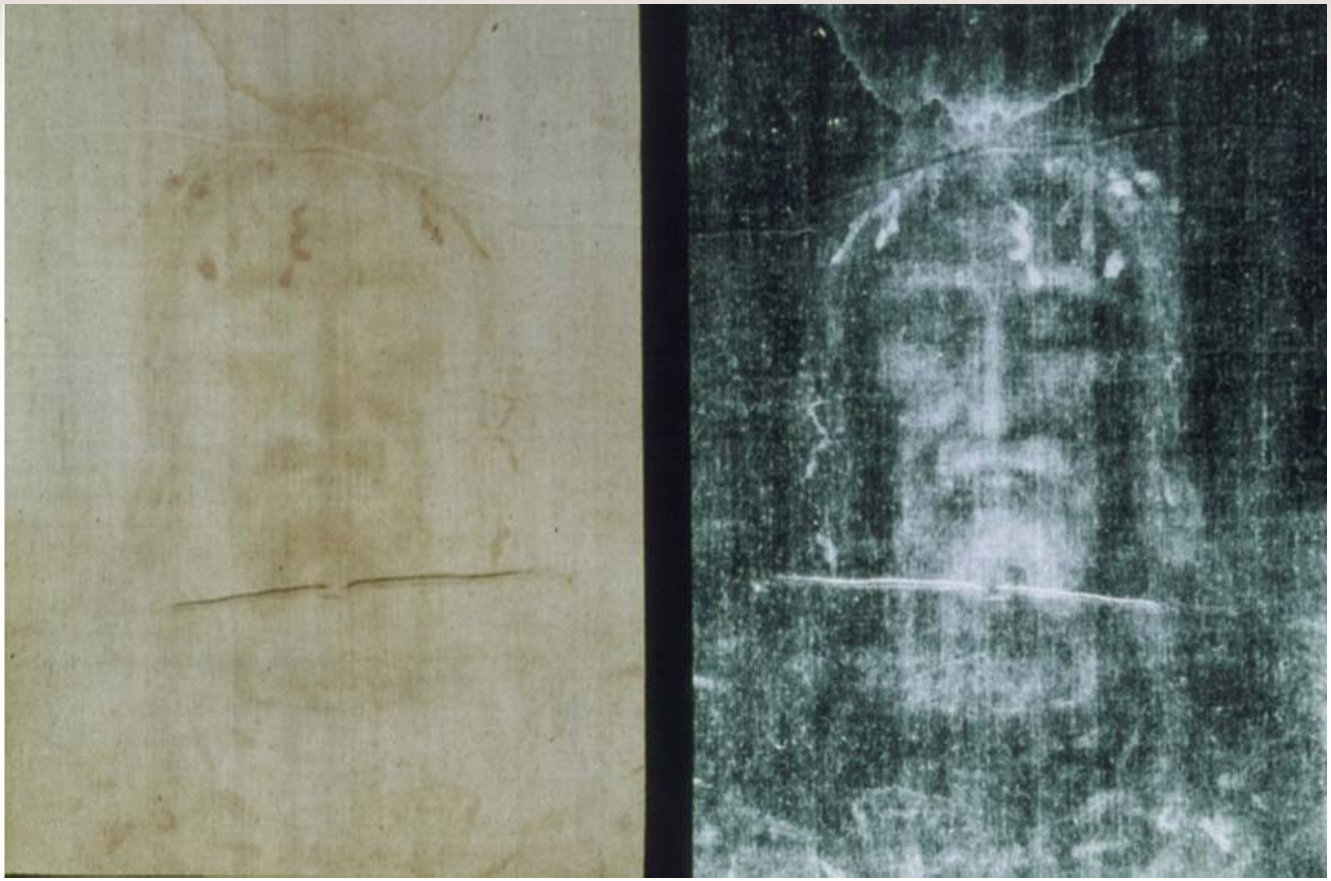
Extrablatt



The Nobel Prize in Chemistry 1960 was awarded to Willard F. Libby for his method to use carbon-14 for age determination in archaeology, geology, geophysics, and other branches of science

C-14 Methode

Turiner Grabtuch



Diagnose

- **C-14 Datierung 1988 zur Ermittlung des Alters**
- **Probe auf Zeit zwischen 1260 und 1390 nChr datiert**
- **Mittelwert der Untersuchungen 1325 n. Chr. als wahrscheinlichster Wert**
- **in das Jahr 1357 fällt älteste gesicherte Erwähnung des Grabtuches**

Kalibration der C^{14} Zeitskala

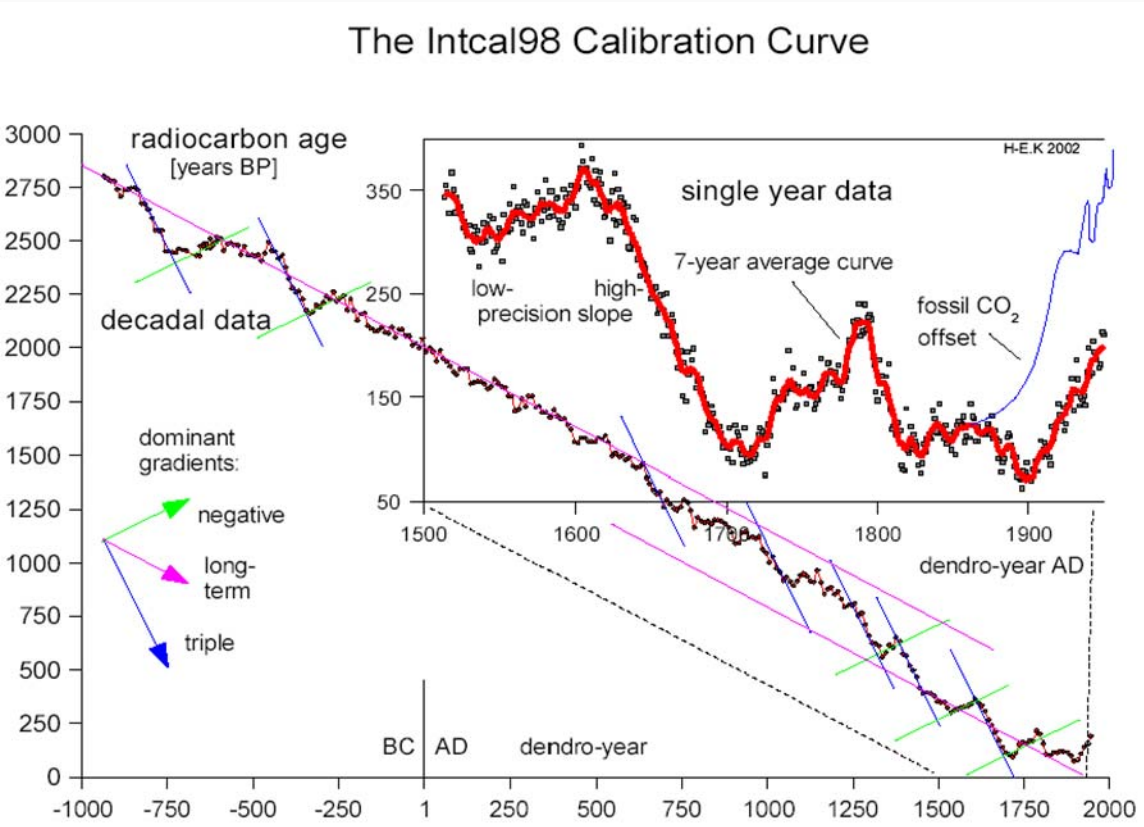
Industrielle Revolution

Symptome

- massive Verbrennung von fossilem Kohlenstoff (Kohle, Erdöl) nach 1850 verfälscht Daten

- der aus der Verbrennung stammende Kohlenstoff enthält kaum ^{14}C Anteile

Hans E. Suess
1909–1993



Diagnose

- Anteil von ^{14}C in der Atmosphäre verringert sich

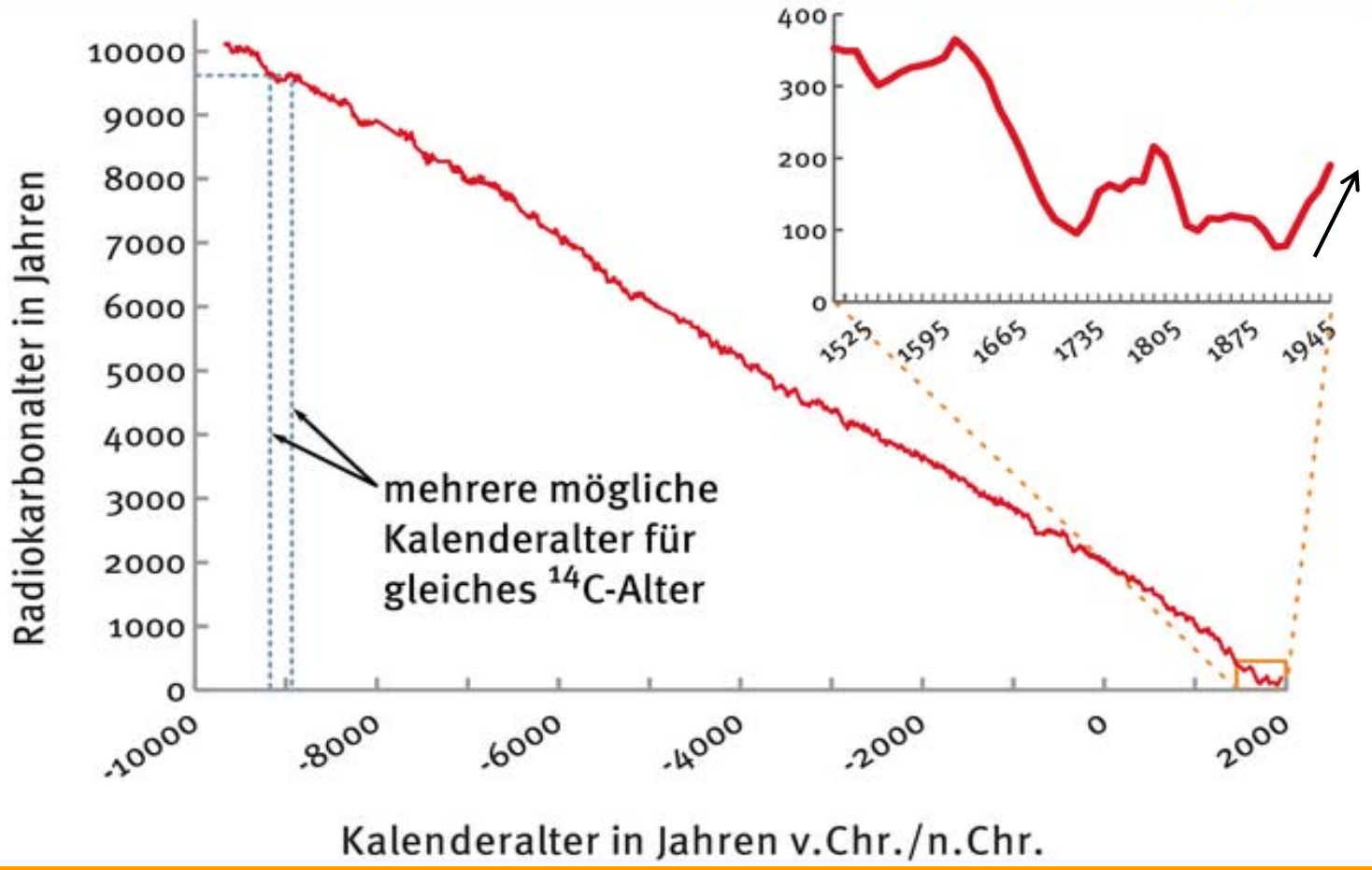
- Steigung der Kalibrierungsgeraden ändert sich im 19. Jahrhundert

- Anteil von ^{14}C in der Atmosphäre wird unterschätzt

H. E. Suess *Radiocarbon concentration in modern wood* Science122, 415 (1955)

Kalibration der C^{14} Zeitskala

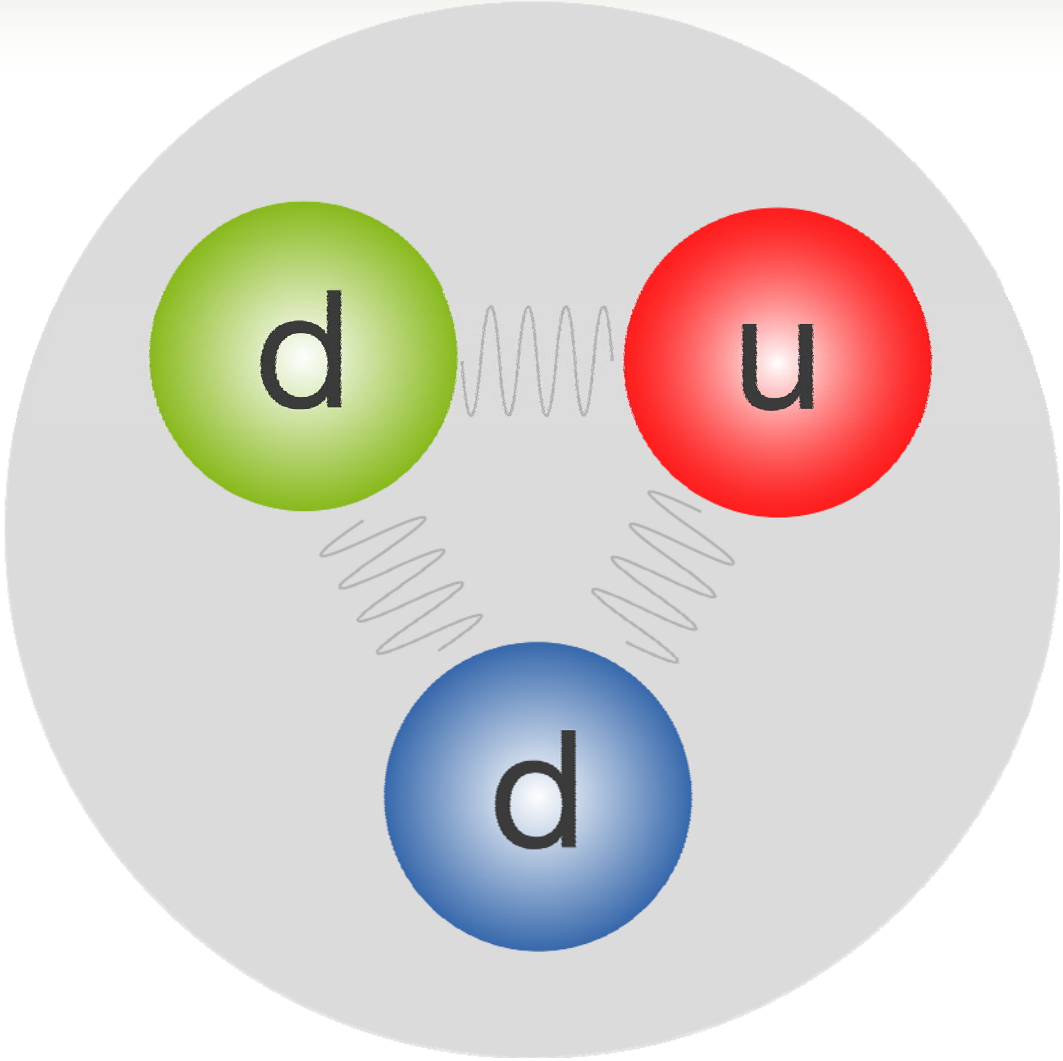
Atombomben



Diagnose

Oberirdische Atombombentest in den 50 Jahren haben ^{14}C Gehalt kurzzeitig verdoppelt

Starke Wechselwirkung

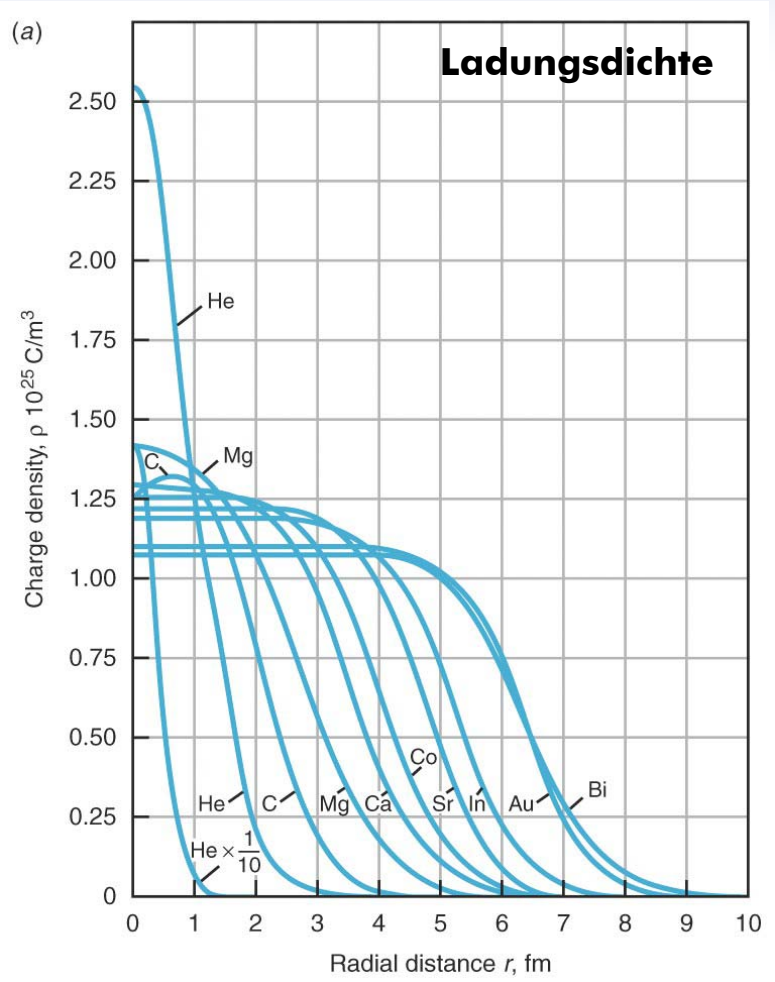


Konzentration von Masse und Ladung

Kerndichte

Dichteverhältnisse in Neutronenstern

$$\rho_{NS} = 10^{17} \text{ bis } 2.5 \cdot 10^{18} \text{ kg/m}^3$$



Massendichte

$$\rho_{Kern} = \frac{m_{Kern}}{V_{Kern}} = \frac{m_p}{\frac{3}{4}\pi\, r_{Kern}^3} = \frac{1.67 \cdot 10^{-27}\,\text{kg}}{\frac{3}{4}\pi\left(1.2 \cdot 10^{-15}\,\text{m}\right)^3}$$

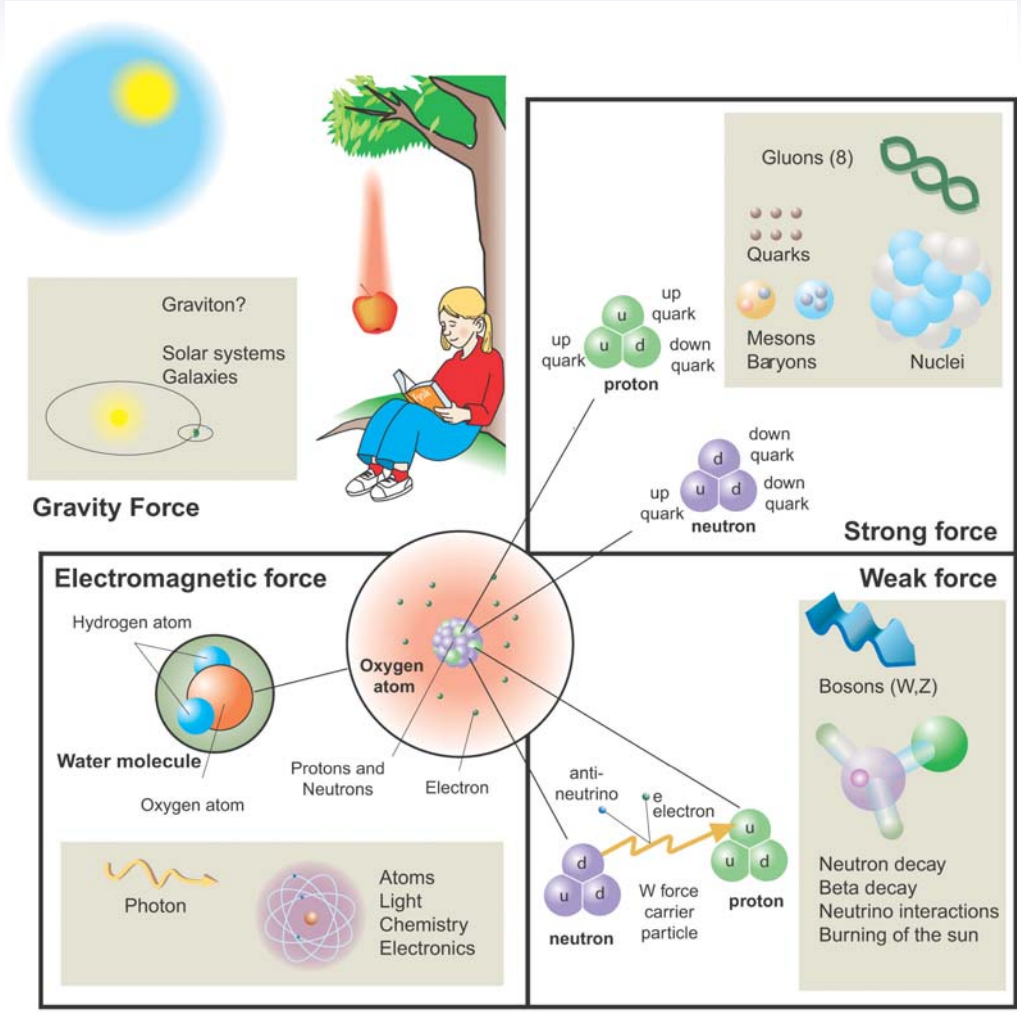
$$\rho_{Kern} = 1.67 \cdot 10^{17}\,\frac{\text{kg}}{\text{m}^3}$$

Diagnose

- Konzentration von Protonen auf enges Raumgebiet erzeugt enorm hohe Ladungsdichte

- Dichte der Kernmaterie ist vergleichbar zu Materie in Neutronensternen

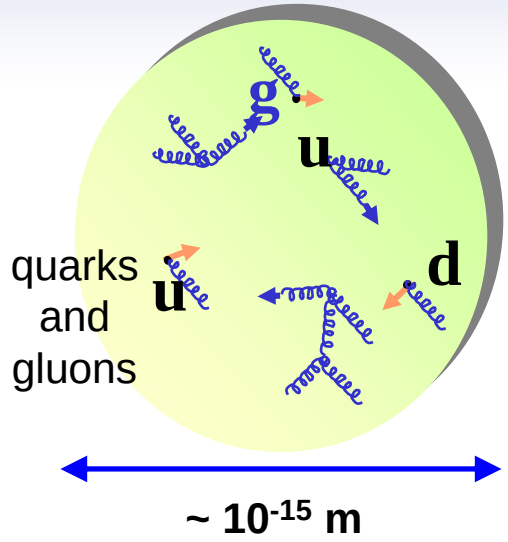
Fundamentale Kräfte

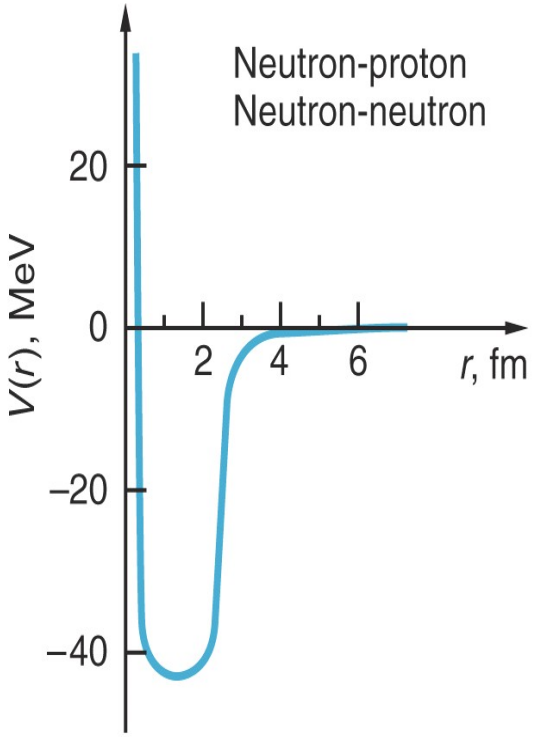


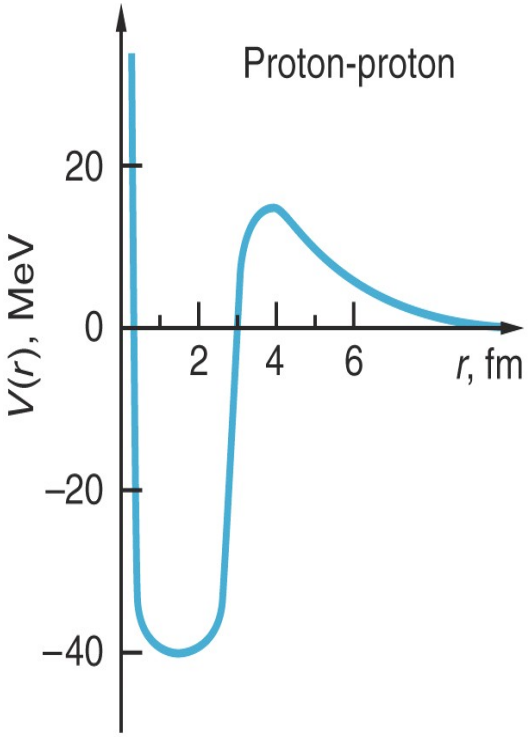
Diagnose

Gravitation und Coulomb-Wechselwirkung sind NICHT für Stabilität Atomkern verantwortlich

Starke Wechselwirkung



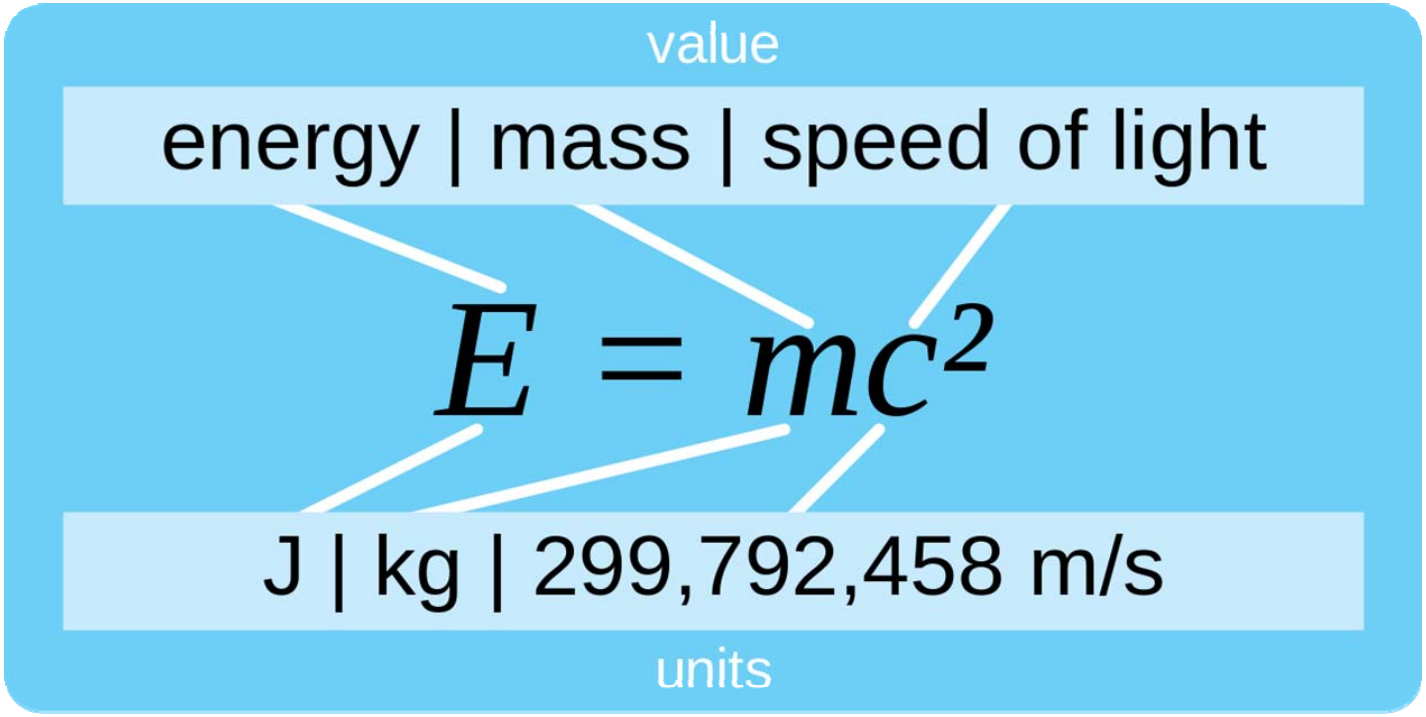




Diagnose

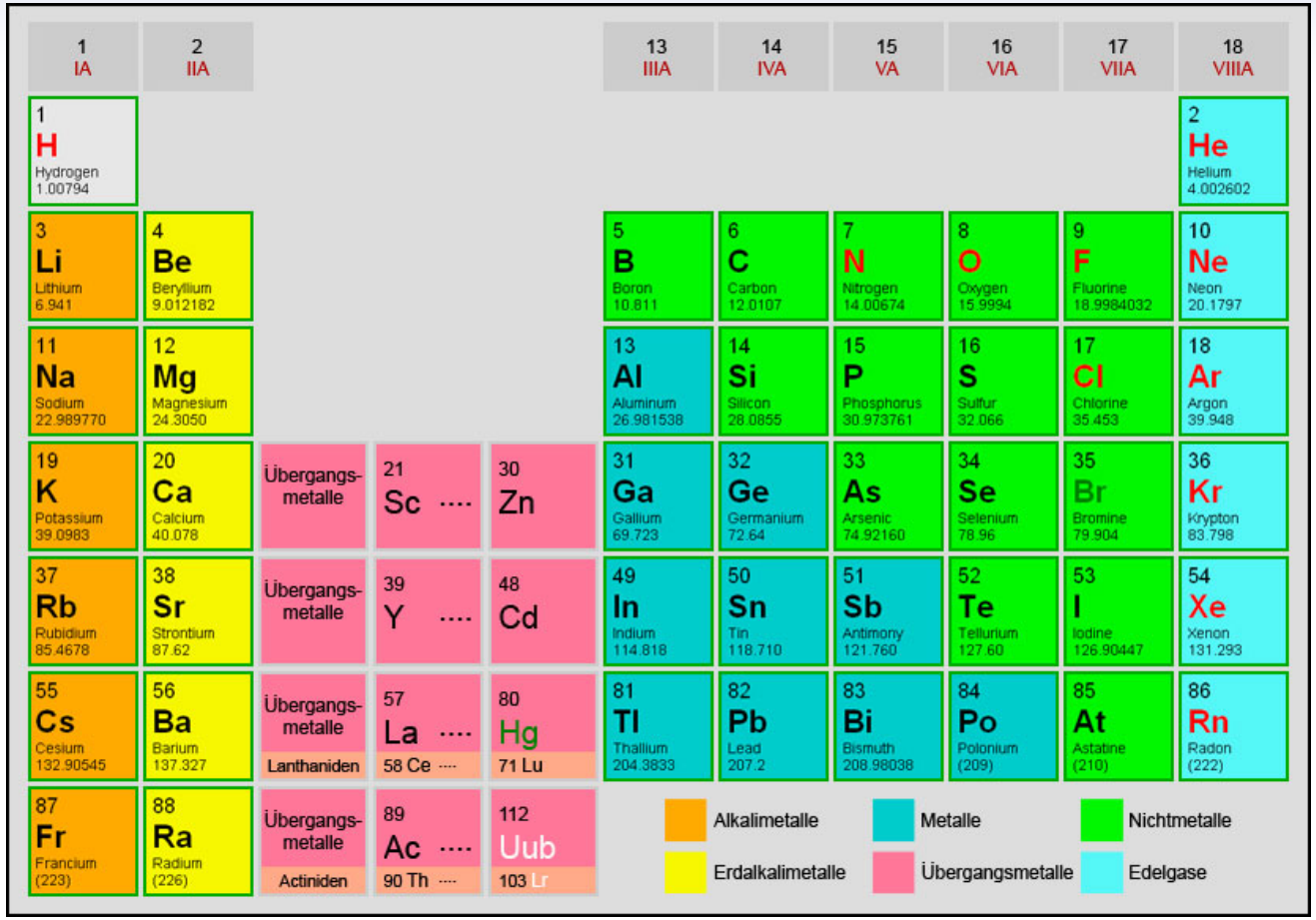
- **starke Wechselwirkung bestimmt Bindung zwischen Protonen und Neutronen (pp, pn, nn)**
- **keine Wechselwirkung mit anderen Teilchen, wie zum Beispiel Elektronen**
- **Reichweite der Wechselwirkung mit 2×10^{-15}m äußerst gering**

Massendefekt



$c^2 = 89{,}875{,}517{,}873{,}681{,}800\ m^2/s^2$

Ein Blick ins
Periodensystem



Diagnose

- Masse der Atomkerne ist NICHT ein Vielfaches der Masse des Protons

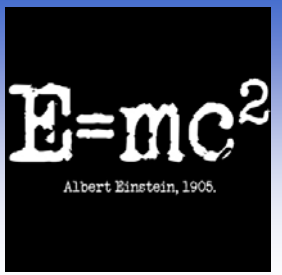
- Massenunterschied kann nicht auf Isotope zurückgeführt werden

Aluminium zum Beispiel hat nur ein einziges Isotop (Z=13, N=14) und hat Masse 26,9815385 amu

- Aluminiumatom ist leichter als Summe der Kernbestandteile

Zusammen wird wir leichter

Masse des Kerns



Symptome

- bei der Bildung des Atoms wird Masse in Form von Energie frei

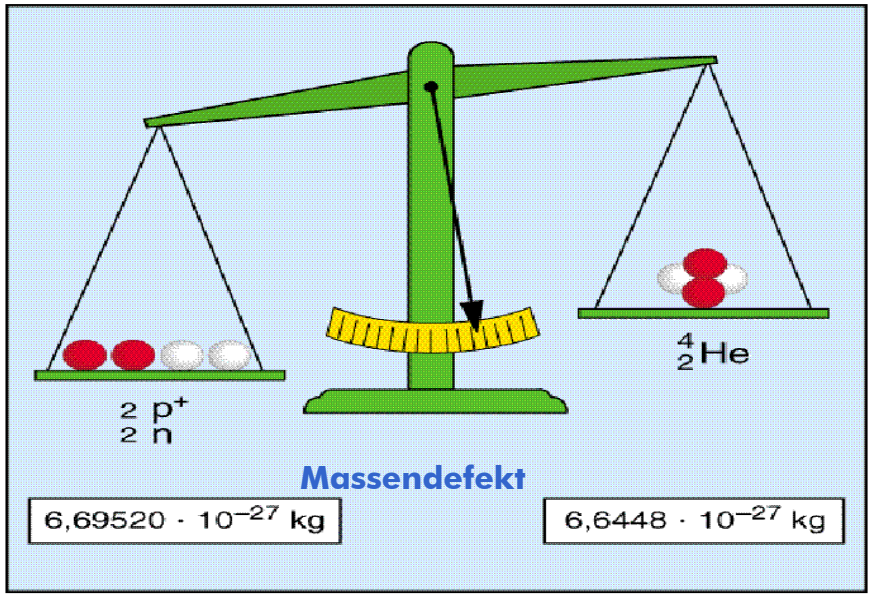
- chemische Bindung und Kernbindung liefern Beitrag zur Masse des Atoms

Wie ergibt sich die Masse eines Atoms

$$m_{atom} = z_p m_p + n_n m_n + z_e m_e - \frac{E^{binding}_{nucleus}}{c^2} - \frac{E^{binding}_{Coulomb}}{c^2}$$

$$m_p c^2 >> E^{binding}_{nucleus} >> E^{binding}_{Coulomb}$$

vernachlässigbar klein im Vergleich zu den beiden anderen Beiträgen



Massendefekt ist konzentriert im Kern

$$\frac{\Delta E^{binding}_{nucleus}}{c^2} = z_p m_p + n_n m_n - m_{nucleus}(z_p, n_n)$$

Diagnose

- Masse eines Atomkerns geringer als Summe der Massen der Kernbausteine

- Differenz in Energien entspricht der Bindungsenergie und nennt sich Massendefekt

- Energie ist erforderlich, um Kern in Bestandteile zu zerlegen

E=mc² vs Chemie

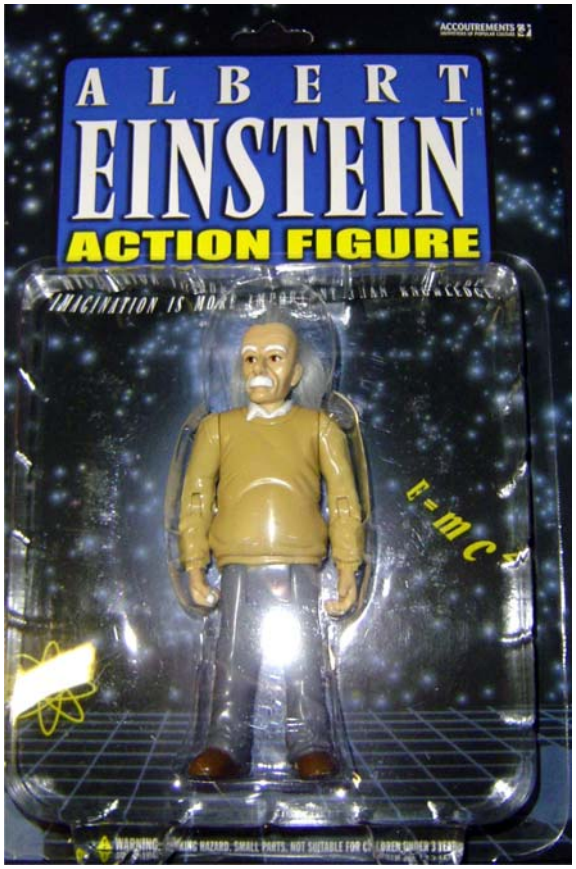
Kernbindungsenergie

Symptome

Masse Heliumkern geringer als Masse der vier Nukleonen

Atomare Masseneinheit

$$[m_p] = [1.0\ \text{amu}] = [1.67 \cdot 10^{-27}\ \text{kg}]$$



Massendefekt für Heliumkern

$$\Delta m_{He} = 4.029\ \text{amu} - 4.0015\ \text{amu} = 0.0276\ \text{amu}$$

$$\Delta m_{He} = 4.58 \cdot 10^{-29}\ \text{kg}$$

Massendifferenz

Energie aus Massendefekt für Heliumkern

$$\Delta E_{He} = m_{He} c^2 = 4.12 \cdot 10^{-12}\ \text{J}$$

Energiemenge pro Kern

Chemie

Energieeinheit der Chemie kJ pro mol

$$\frac{1.0\ \text{J}}{1000 \cdot n_{Avo}} = \frac{1.0\ \text{J} \cdot 6.022 \cdot 10^{23}\ /\ \text{mol}}{1000} = 6.022 \cdot 10^{-20}\ \frac{\text{kJ}}{\text{mol}}$$

Bei chemischen Reaktionen werden Energien in Höhe von typisch 100 kJ/ mol freigesetzt

Energiefreisetzung pro Mol

$$n_{Avo} \Delta E_{He} = \frac{6.022 \cdot 10^{23}}{\text{mol}} \cdot 4.12 \cdot 10^{-12}\ \text{J} = 2.5 \cdot 10^{12}\ \frac{\text{J}}{\text{mol}}$$

Diagnose

- typische chemische Reaktionen liefern Energie in Höhe von nur 100 bis 200 kJ/mol

- Bindungsenergie im Kern sind mit 1000 GJ/ mol um viele Größenordnungen höher