Real Academia de Ciencias

Madame Curie: Scientific Contributions and Impact

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Maria Sklodowska-Curie

A model for modern women

Biographical notes 1

Née Maria Sklodowska, 1867, Warsaw. 1883 gold medal at Sch. Governess at relatives homes since she was 18 till 23. 1890 works at a chemistry lab in Warsaw, directed by her cousin and former Mendeleev's student, Jozef Boguski.

1891 to 1894 studies at La Sorbonne and obtains her 'Licence ès Sciences' and her 'Licence ès Mathématiques'.

1894 Marie meets Pierre Curie and they marry in 1895. *She is allowed to work in Pierres's Physics Lab.*

1895 Pierre defends his PhD Thesis on magnetic properties of materials (Curie's Law). He and his brother Jacques had discovered piezoelectricity in the 1880's.

Biographical notes 2

1896 Marie commences her research on the newly discovered uranium radiations. Soon Pierre gets also involved.

1897 her first daughter Irène is born.

1903 Marie defends her PhD Thesis on the Radioactivity of Polonium and Radium.
Nobel Prize in Physics to the Curies & to Becquerel.

1904 her second daughter Ève is born.

1906 Pierre dies at 46 and Marie accepts to take his former position at La Sorbonne aiming to create a world-class laboratory as a tribute to Pierre.

1911 Nobel Prize in Chemistry to Marie.

Biographical notes 3

1914 the Radium Institute is built in Paris which, once the war was finished, produced four more Nobel Prize winners (the Joliot-Curie couple, in particular)

1914 to 1918 directs the Red Cross Radiology Service during World War I.

1919 to 1922 recognitions and honors in USA and many other countries, including Poland and Spain.

1922 appointed to the French Academy of Medicine and to the newly created International Commission for Intelectual Cooperation of the League of Nations.

1925 the Radium Institute in Warsaw is created.

Solvay Conference 1911

What did she discover?

How did she make her discoveries?

What did she do next?

What did she discover?

Two new elements: Polonium and **Radium** (also Thorium radiations).

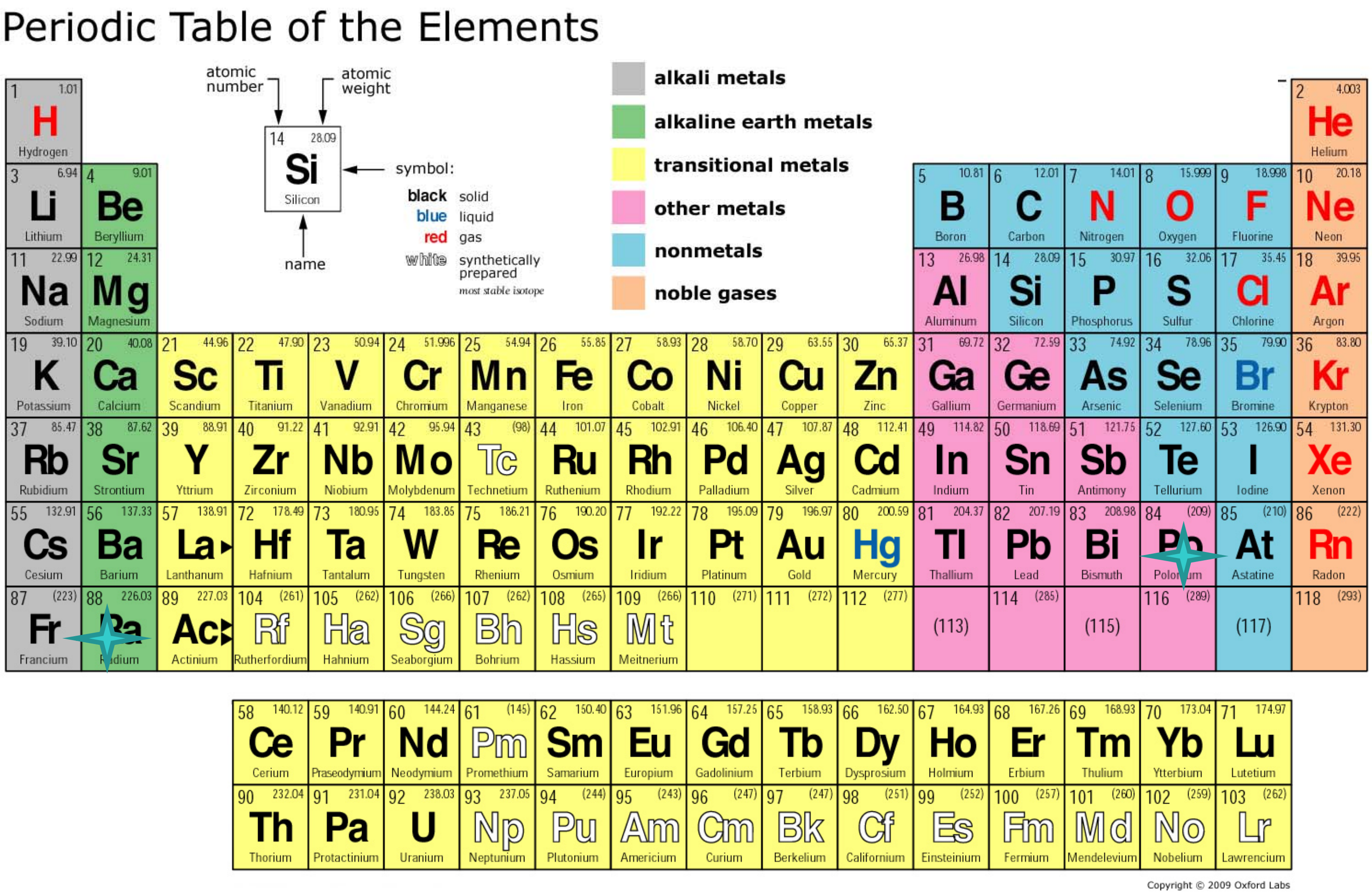
She coined the terms *Radioactive* and *Radioactivity* (*Radioactif* and *Radioactivité*) to describe the new substances and processes.

She correctly assumed that radiations were **coming off the "atom"** (radioactivity is an 'atomic' property of matter), a hypothesis that was proved to be crucial: to dissentangle the **nature** of the new radiations, to discover **new radioactive elements,** and to come up with the **transmutation** concept. More than 30 elements were discovered in 10 ys..

Together with Pierre they developed completely **new techniques** to isolate Radium from pitchblende, which **they never wanted to patent**. The Radium Industry was soon a big business.

She established a **standard measure** of radioactivity allowing for the comparison of results from different laboratories in the world.

She found **medical applications** of Radium and devoted herself to health **treatments** and **diagnoses** during World War I and afterwards.



Periodic Table of the Elements

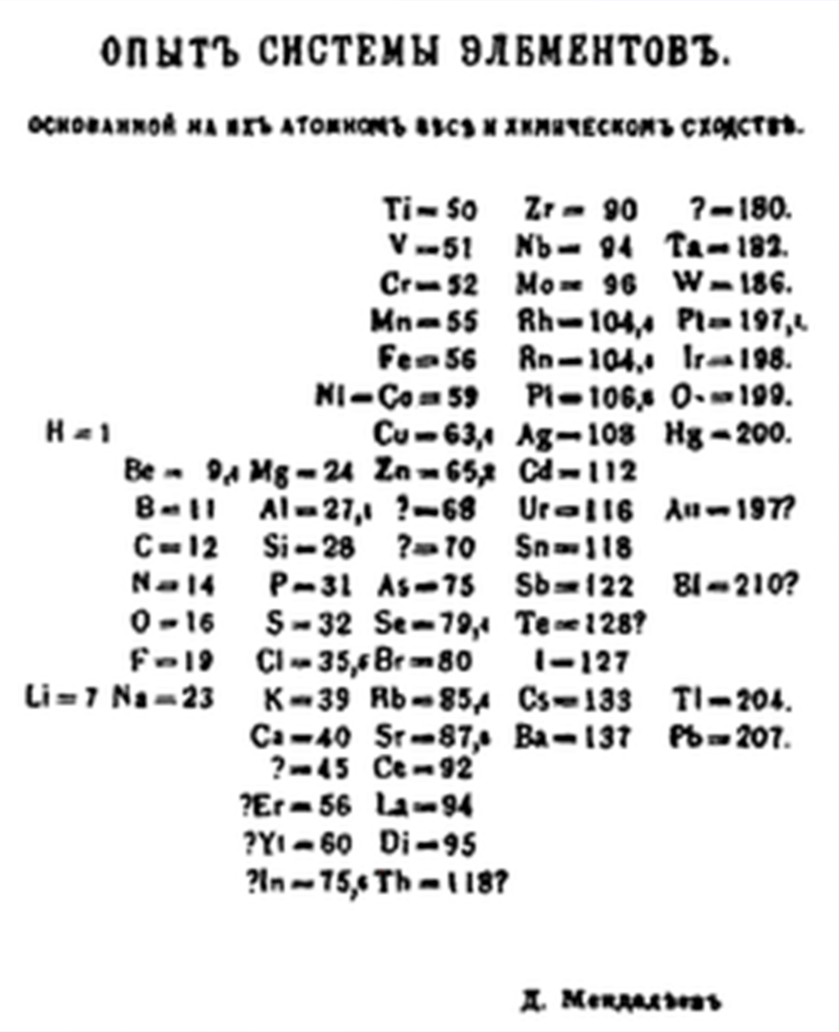
atomic number → 14, atomic weight → 28.09, symbol: Si, name: Silicon

symbol:
- black solid
- blue liquid
- red gas
- white synthetically prepared
- *most stable isotope*

- ⬜ alkali metals
- 🟩 alkaline earth metals
- 🟨 transitional metals
- 🟪 other metals
- 🟦 nonmetals
- 🟧 noble gases

1 1.01 H Hydrogen																	2 4.003 He Helium
3 6.94 Li Lithium	4 9.01 Be Beryllium											5 10.81 B Boron	6 12.01 C Carbon	7 14.01 N Nitrogen	8 15.999 O Oxygen	9 18.998 F Fluorine	10 20.18 Ne Neon
11 22.99 Na Sodium	12 24.31 Mg Magnesium											13 26.98 Al Aluminum	14 28.09 Si Silicon	15 30.97 P Phosphorus	16 32.06 S Sulfur	17 35.45 Cl Chlorine	18 39.95 Ar Argon
19 39.10 K Potassium	20 40.08 Ca Calcium	21 44.96 Sc Scandium	22 47.90 Ti Titanium	23 50.94 V Vanadium	24 51.996 Cr Chromium	25 54.94 Mn Manganese	26 55.85 Fe Iron	27 58.93 Co Cobalt	28 58.70 Ni Nickel	29 63.55 Cu Copper	30 65.37 Zn Zinc	31 69.72 Ga Gallium	32 72.59 Ge Germanium	33 74.92 As Arsenic	34 78.96 Se Selenium	35 79.90 Br Bromine	36 83.80 Kr Krypton
37 85.47 Rb Rubidium	38 87.62 Sr Strontium	39 88.91 Y Yttrium	40 91.22 Zr Zirconium	41 92.91 Nb Niobium	42 95.94 Mo Molybdenum	43 (98) Tc Technetium	44 101.07 Ru Ruthenium	45 102.91 Rh Rhodium	46 106.40 Pd Palladium	47 107.87 Ag Silver	48 112.41 Cd Cadmium	49 114.82 In Indium	50 118.69 Sn Tin	51 121.75 Sb Antimony	52 127.60 Te Tellurium	53 126.90 I Iodine	54 131.30 Xe Xenon
55 132.91 Cs Cesium	56 137.33 Ba Barium	57 138.91 La ▸ Lanthanum	72 178.49 Hf Hafnium	73 180.95 Ta Tantalum	74 183.85 W Tungsten	75 186.21 Re Rhenium	76 190.20 Os Osmium	77 192.22 Ir Iridium	78 195.09 Pt Platinum	79 196.97 Au Gold	80 200.59 Hg Mercury	81 204.37 Tl Thallium	82 207.19 Pb Lead	83 208.98 Bi Bismuth	84 (209) Po Polonium	85 (210) At Astatine	86 (222) Rn Radon
87 (223) Fr Francium	88 226.03 Ra Radium	89 227.03 Ac ▸ Actinium	104 (261) Rf Rutherfordium	105 (262) Ha Hahnium	106 (266) Sg Seaborgium	107 (262) Bh Bohrium	108 (265) Hs Hassium	109 (266) Mt Meitnerium	110 (271)	111 (272)	112 (277)	(113)	114 (285)	(115)	116 (289)	(117)	118 (293)
			58 140.12 Ce Cerium	59 140.91 Pr Praseodymium	60 144.24 Nd Neodymium	61 (145) Pm Promethium	62 150.40 Sm Samarium	63 151.96 Eu Europium	64 157.25 Gd Gadolinium	65 158.93 Tb Terbium	66 162.50 Dy Dysprosium	67 164.93 Ho Holmium	68 167.26 Er Erbium	69 168.93 Tm Thulium	70 173.04 Yb Ytterbium	71 174.97 Lu Lutetium	
			90 232.04 Th Thorium	91 231.04 Pa Protactinium	92 238.03 U Uranium	93 237.05 Np Neptunium	94 (244) Pu Plutonium	95 (243) Am Americium	96 (247) Cm Curium	97 (247) Bk Berkelium	98 (251) Cf Californium	99 (252) Es Einsteinium	100 (257) Fm Fermium	101 (260) Md Mendelevium	102 (259) No Nobelium	103 (262) Lr Lawrencium	

Original Mendeleev's Table



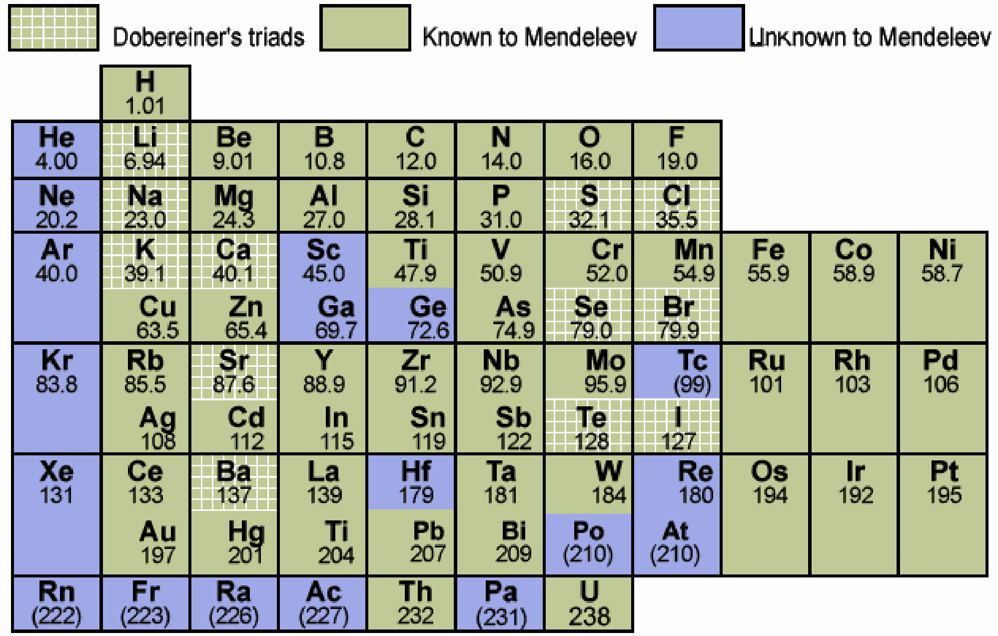
ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

			Ti=50	Zr=90	?=180.
			V=51	Nb=94	Ta=182.
			Cr=52	Mo=96	W=186.
			Mn=55	Rh=104,4	Pt=197,4
			Fe=56	Ru=104,4	Ir=198.
			Ni=Co=59	Pl=106,6	Os=199.
H=1			Cu=63,4	Ag=108	Hg=200.
	Be=9,4	Mg=24	Zn=65,2	Cd=112	
	B=11	Al=27,4	?=68	Ur=116	Au=197?
	C=12	Si=28	?=70	Sn=118	
	N=14	P=31	As=75	Sb=122	Bi=210?
	O=16	S=32	Se=79,4	Te=128?	
	F=19	Cl=35,5	Br=80	I=127	
Li=7	Na=23	K=39	Rb=85,4	Cs=133	Tl=204.
		Ca=40	Sr=87,6	Ba=137	Pb=207.
		?=45	Ce=92		
		?Er=56	La=94		
		?Yt=60	Di=95		
		?In=75,6	Th=118?		

Д. Менделѣевъ

User's friendly view of Mendeleev's Table



▨ Dobereiner's triads 🟩 Known to Mendeleev 🟦 Unknown to Mendeleev

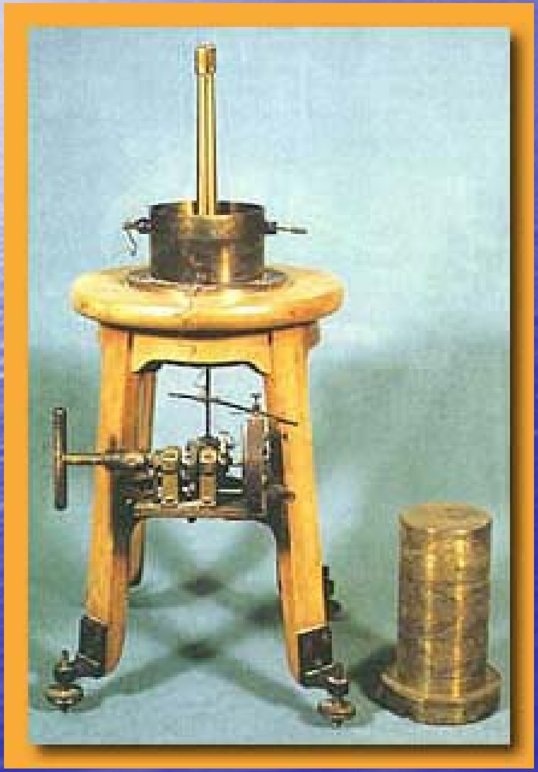
	🟩 **H** 1.01									
🟦 **He** 4.00	▨ **Li** 6.94	🟩 **Be** 9.01	🟩 **B** 10.8	🟩 **C** 12.0	🟩 **N** 14.0	🟩 **O** 16.0	🟩 **F** 19.0			
🟦 **Ne** 20.2	▨ **Na** 23.0	🟩 **Mg** 24.3	🟩 **Al** 27.0	🟩 **Si** 28.1	🟩 **P** 31.0	▨ **S** 32.1	▨ **Cl** 35.5			
🟦 **Ar** 40.0	▨ **K** 39.1 🟩 **Cu** 63.5	▨ **Ca** 40.1 🟩 **Zn** 65.4	🟦 **Sc** 45.0 🟦 **Ga** 69.7	🟩 **Ti** 47.9 🟦 **Ge** 72.6	🟩 **V** 50.9 🟩 **As** 74.9	🟩 **Cr** 52.0 ▨ **Se** 79.0	🟩 **Mn** 54.9 ▨ **Br** 79.9	🟩 **Fe** 55.9	🟩 **Co** 58.9	🟩 **Ni** 58.7
🟦 **Kr** 83.8	🟩 **Rb** 85.5 🟩 **Ag** 108	▨ **Sr** 87.6 🟩 **Cd** 112	🟩 **Y** 88.9 🟩 **In** 115	🟩 **Zr** 91.2 🟩 **Sn** 119	🟩 **Nb** 92.9 🟩 **Sb** 122	🟩 **Mo** 95.9 ▨ **Te** 128	🟦 **Tc** (99) ▨ **I** 127	🟩 **Ru** 101	🟩 **Rh** 103	🟩 **Pd** 106
🟦 **Xe** 131	🟩 **Ce** 133 🟩 **Au** 197	▨ **Ba** 137 🟩 **Hg** 201	🟩 **La** 139 🟩 **Ti** 204	🟦 **Hf** 179 🟩 **Pb** 207	🟩 **Ta** 181 🟩 **Bi** 209	🟩 **W** 184 🟦 **Po** (210)	🟦 **Re** 180 🟦 **At** (210)	🟩 **Os** 194	🟩 **Ir** 192	🟩 **Pt** 195
🟦 **Rn** (222)	🟦 **Fr** (223)	🟦 **Ra** (226)	🟦 **Ac** (227)	🟩 **Th** 232	🟦 **Pa** (231)	🟩 **U** 238				

How did she do it?
Marie & Pierre’s methods

Right after Becquerel (1896) noticed and reported spontaneous emission of rays from Uranium salts

Marie undertook the task of the precise measurements of their intensity

How the radiation was measured?



…We learned from Becquerel that one of the most important properties of the radioactive elements is that of ionizing the air in their vicinity. When a compound containing radioactive elements is placed on a metal plate A situated opposite another plate B and a difference in potential is maintained between the plates A and B, an electric current is set up between these plates; this current can be measured with accuracy and serves as a measure of the activity of the substance. The conductivity imparted to the air can be ascribed to ionization produced by the rays emitted by the radioactive elements.

She soon found that there was also Th emitting radiation and that for some minerals with U-salts the activity was even larger than that of U.

From which she concluded on the existence of another two elements in the ores (Po & Ra).

...Actually, we gradually learned from experience that the radium is contained in the raw material in the proportion of a few decigrams per ton. The activity of these sulphates is even then 30 to 60 times greater than that of uranium. These sulphates are purified and converted to chlorides. In the mixture of barium and radium chlorides the radium is present only in the proportion of about 3 parts per 100,000. To separate the radium from the barium I have used a method of fractional crystallization of the chloride (the bromide can also be used). The radium salt, less soluble than the barium salt, becomes concentrated in the crystals. Fractionation is a lengthy, methodical operation which gradually eliminates the barium. To obtain a very pure salt I have had to perform several thousands of crystallizations. The progress of the fractionation is monitored by activity measurements.

Piezoelectric quartz electrometer (invented in the 1880's by the Curie's brothers After their discovery of piezoelectric effect)

Radioactive analysis by electrometric methods allows us to calculate to within 1% a thousandth of a milligram of radium, and to detect the presence of 10^{-10} grams of radium diluted in a few grams of material. We are also accustomed to deal currently in the laboratory with substances the presence of which is only shown to us by their radioactive properties but which nevertheless we can determine, dissolve, reprecipitate from their solutions and deposit electrolytically. This means that we have here an entirely separate kind of chemistry for which the current tool we use is the electrometer, not the balance, and which we might well call the chemistry of the imponderable.

Pierre Curie Nobel Lecture (1903_ 1905)

..The Becquerel's rays leave an impression on photographic plates. They pass through black paper and metals; they make air electrically conductive. The radiation does not vary with time, and the cause of its production is unknown.

Marie showed in 1898 that from all the substances prepared in the lab only those containing U and Th were capable of emitting such rays and called these substances radioactive.

..In making the measurements Mme. Curie found that certain of these minerals were more active than they should be according to the U and Th concentration. Mme.Curie then made the assumption that these substances contained radioactive chemical elements which were as yet unknown. We, mme. Curie and me, have sought to find these new hypothetical substances in a uranium ore, pitchblende. […] effects of the radiations from radium are intense and varied. They pass through matter and produce: Discharge of electroscope, sparks, phosphorescence, coloration of glass, thermoluminescence, radiographs…

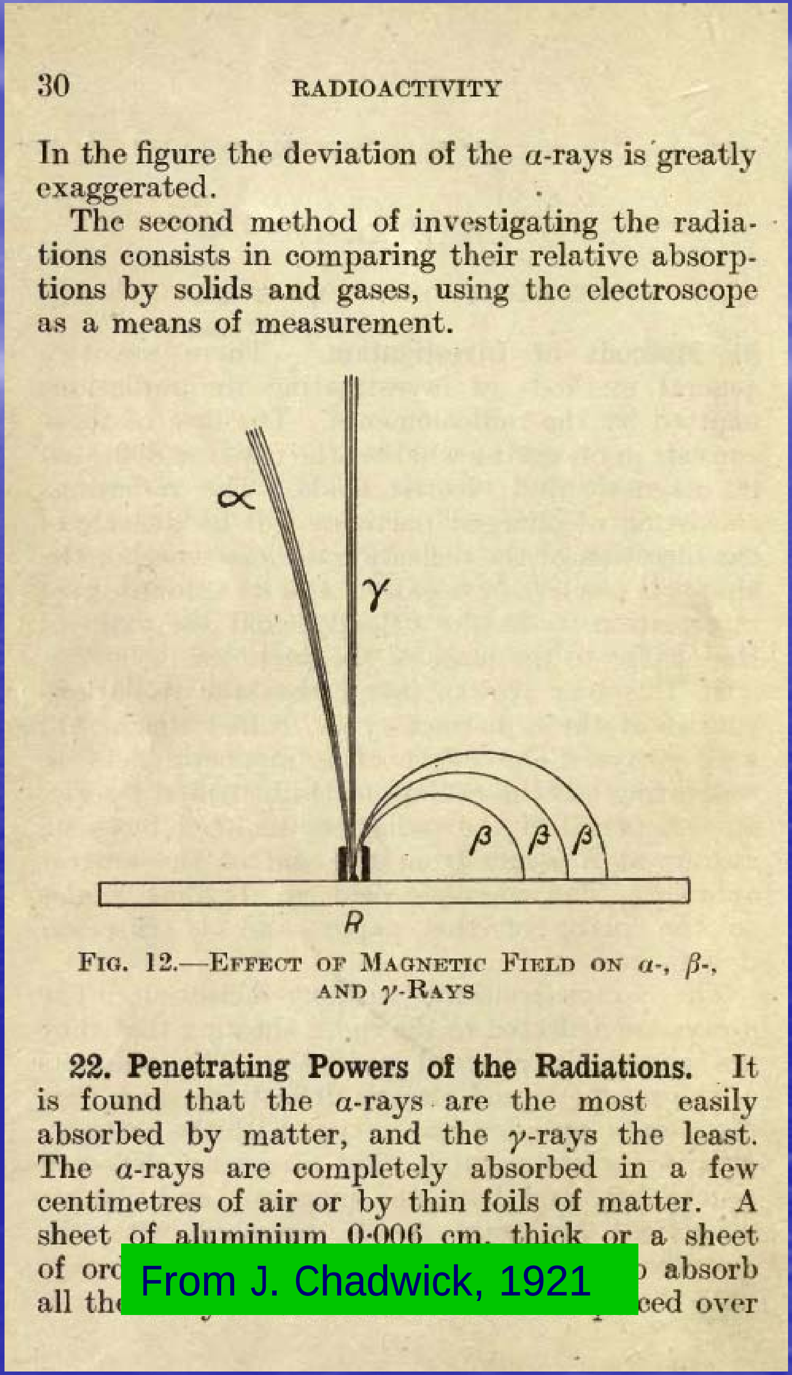
We have seen that radium releases heat "continuously " (app. 100 cal./hour).

We have, as well as others, investigated the rays emitted …

The nature of radiations

R.S.E.F.

1908 Rutherford’s Nobel Price for the discovery of He as the neutral element of the **α**-rays



30 RADIOACTIVITY

In the figure the deviation of the α-rays is greatly exaggerated.

The second method of investigating the radiations consists in comparing their relative absorptions by solids and gases, using the electroscope as a means of measurement.

FIG. 12.—EFFECT OF MAGNETIC FIELD ON α-, β-, AND γ-RAYS

22. Penetrating Powers of the Radiations. It is found that the α-rays are the most easily absorbed by matter, and the γ-rays the least. The α-rays are completely absorbed in a few centimetres of air or by thin foils of matter. A sheet of aluminium 0·006 cm. thick or a sheet of ord absorb all the ced over

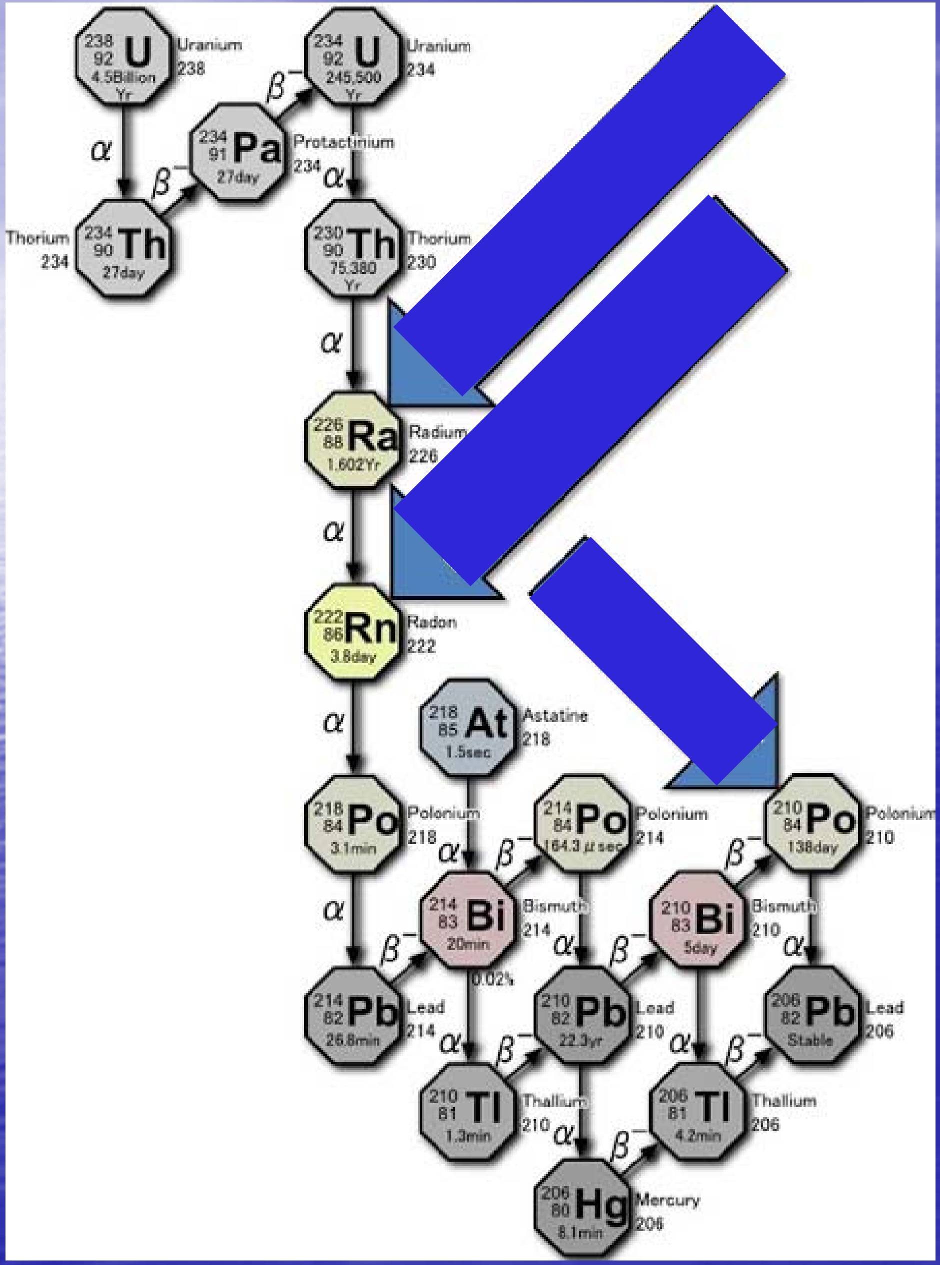
From J. Chadwick, 1921

Atomic weight determination of Radium

A first proof that the element radium existed was furnished by spectral analysis. The spectrum of a chloride enriched by crystallization exhibited a new line which Demarçay attributed to the new element. As the activity became more concentrated, the new line increased in intensity and other lines appeared while the barium spectrum became at the same time less pronounced. When the purity is very high the barium spectrum is scarcely visible.

I have repeatedly determined the average atomic weight of the metal in the salt subjected to spectral analysis. I have found that this method gives very good results even with quite small amounts of substance. The atomic weight increases with the enrichment of the radium as indicated by the spectrum. The results of a number of determinations are, 226.62; 226.31; 226.42.

Current View of U Rad. chain



Marie Nobel Lecture (1911)

…il semble prouvé que le radium est un derivé de l'uranium. Dans la famille du radium le dernier corps radioactif connu est le polonium dont la production par le radium est maintenant un fait prouvé…

Nous avons vu que le gaz hélium est un des termes de la désintégration du radium. Les 'atoms' d'hélium se détachent de ceux du radium et de ses dérivés au cours de la transformation.

U aprés 3 He done Ra;
Ra aprés 4 He donnerai Po…
La théorie que je viens de résumer est l'oeuvre de Rutherford et Soddy…

Within 14 years lots of questions had been answered. Many new elements were found (*by the new methods*) which seemed to be transforming into other ones emitting radiation.

But even harder questions were open.

How were (+) & (-) charges distributed in the atom?

Why the γ rays were so much more penetrating than **X**-rays?

Why were the rays coming off?

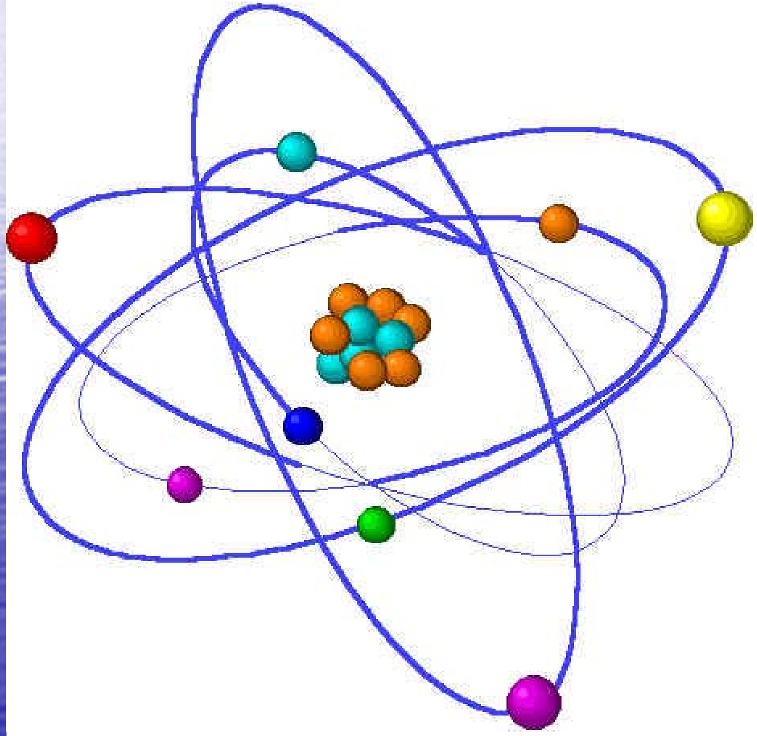
And, beyond all,
was the conservation of energy being violated?

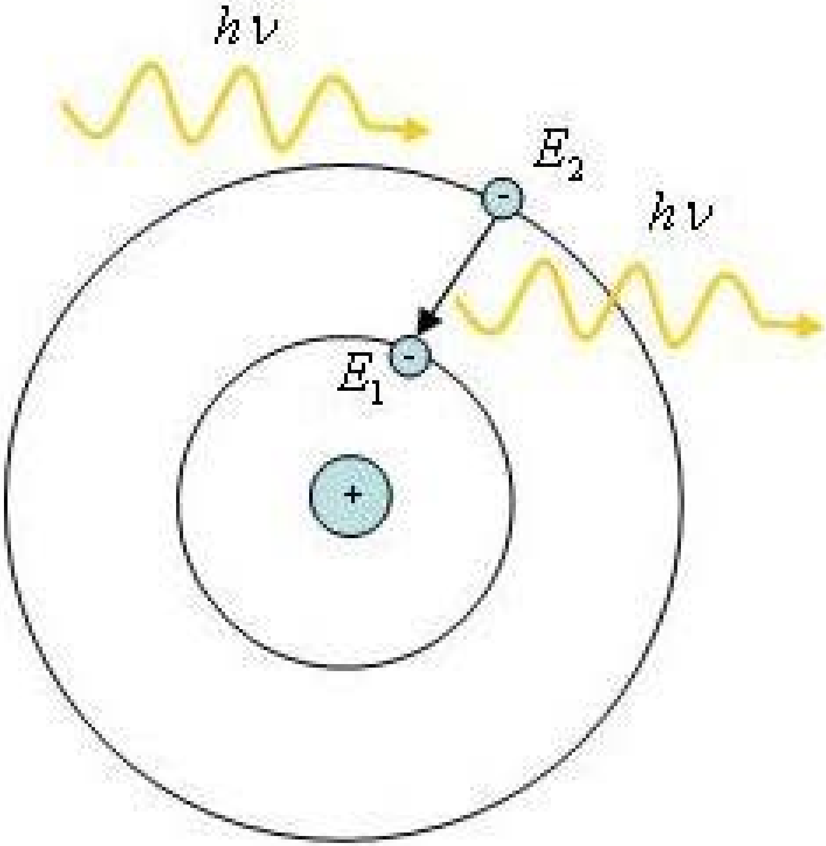
The New Nuclear Era had only started

The atom picture of Bohr & Rutherford

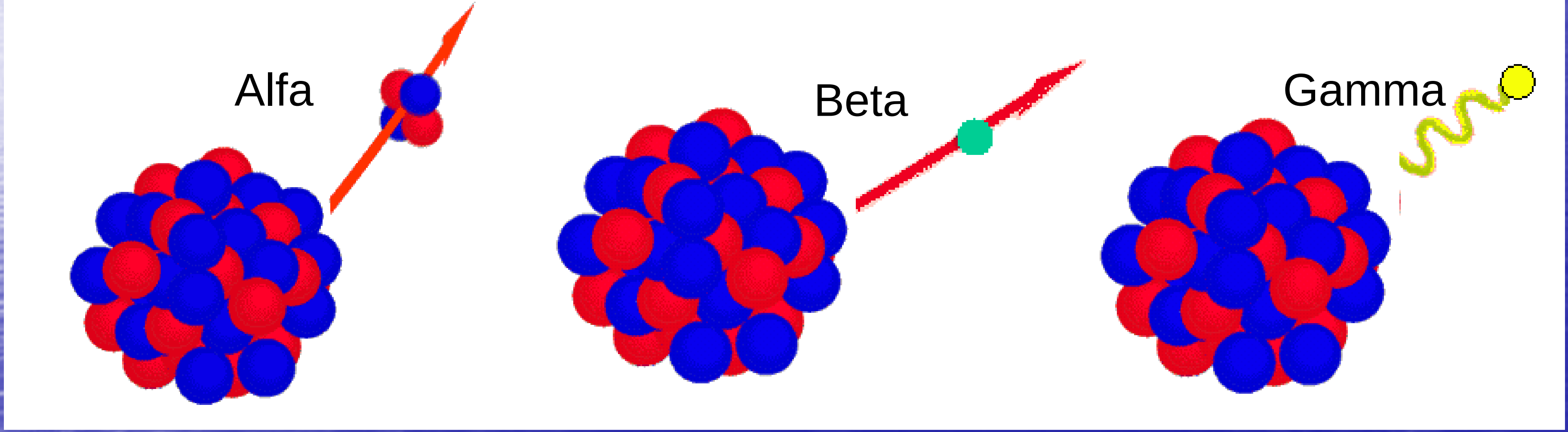
(after Rutherford’s discovery of the atomic nucleus 1911)

Nuclear radius is 10.000 to 100.000 times smaller than Atomic radius
Nucleus contains all (+) charge & most of the atomic mass.





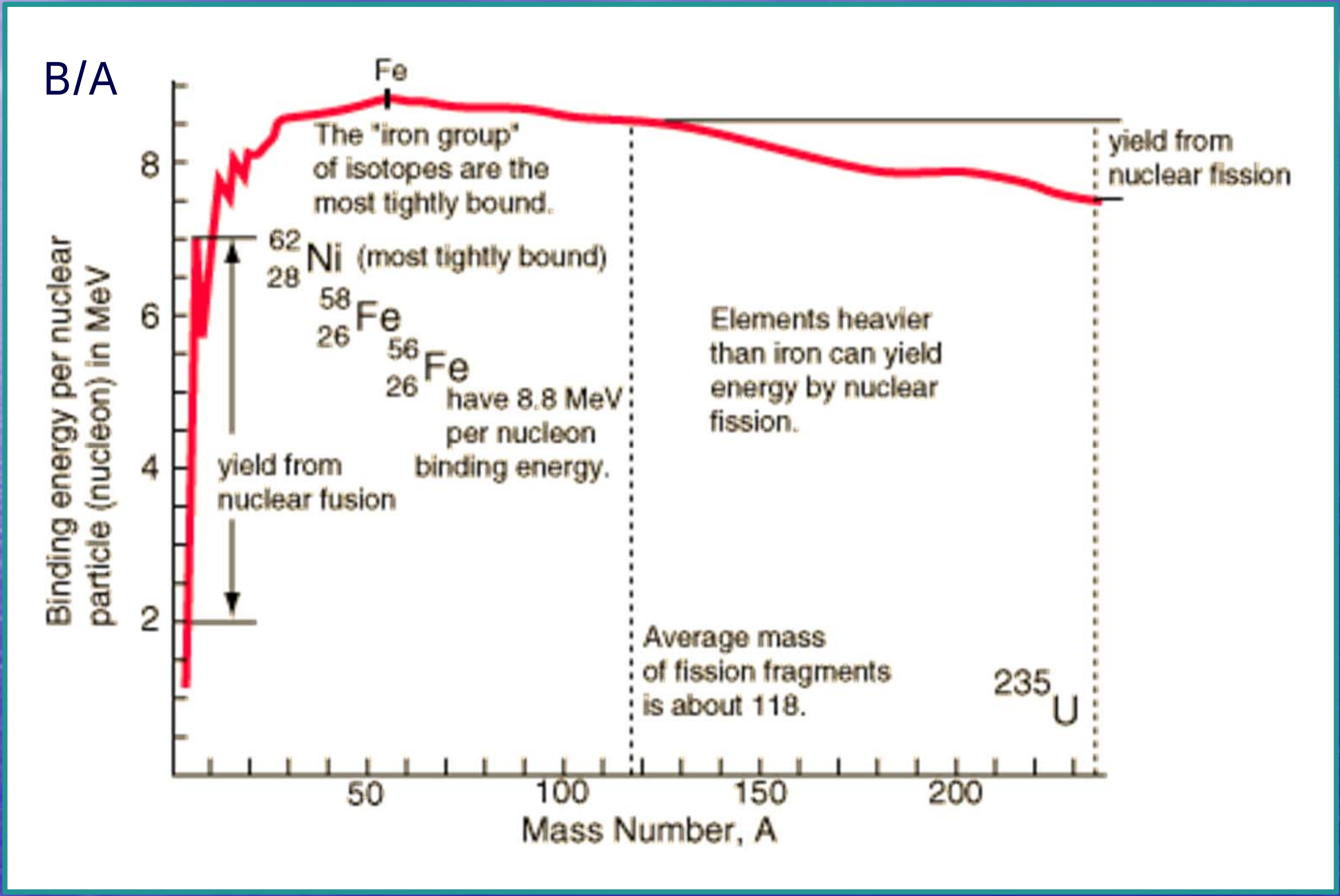
Nuclear α, β & γ decays



$$E = mc^2$$

$$M(A,Z) = A \times M(1,1) + (A-Z) \times M_n - B(A,Z)$$

Nuclear binding energies

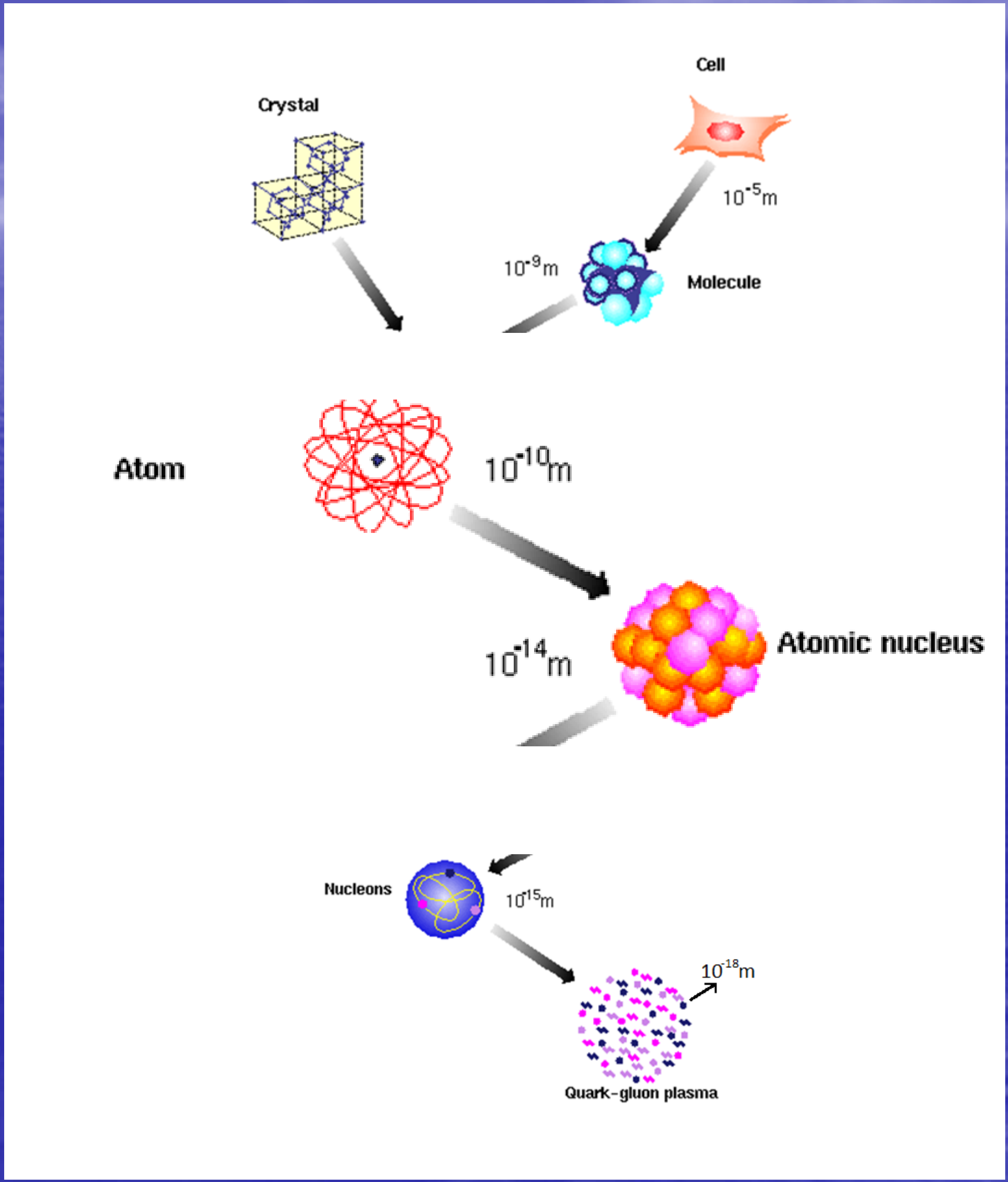


$$B/A = (M(A,Z) - Z\, m_p - (A-Z)\, m_n) \,/\, A$$

Current view of structure of matter

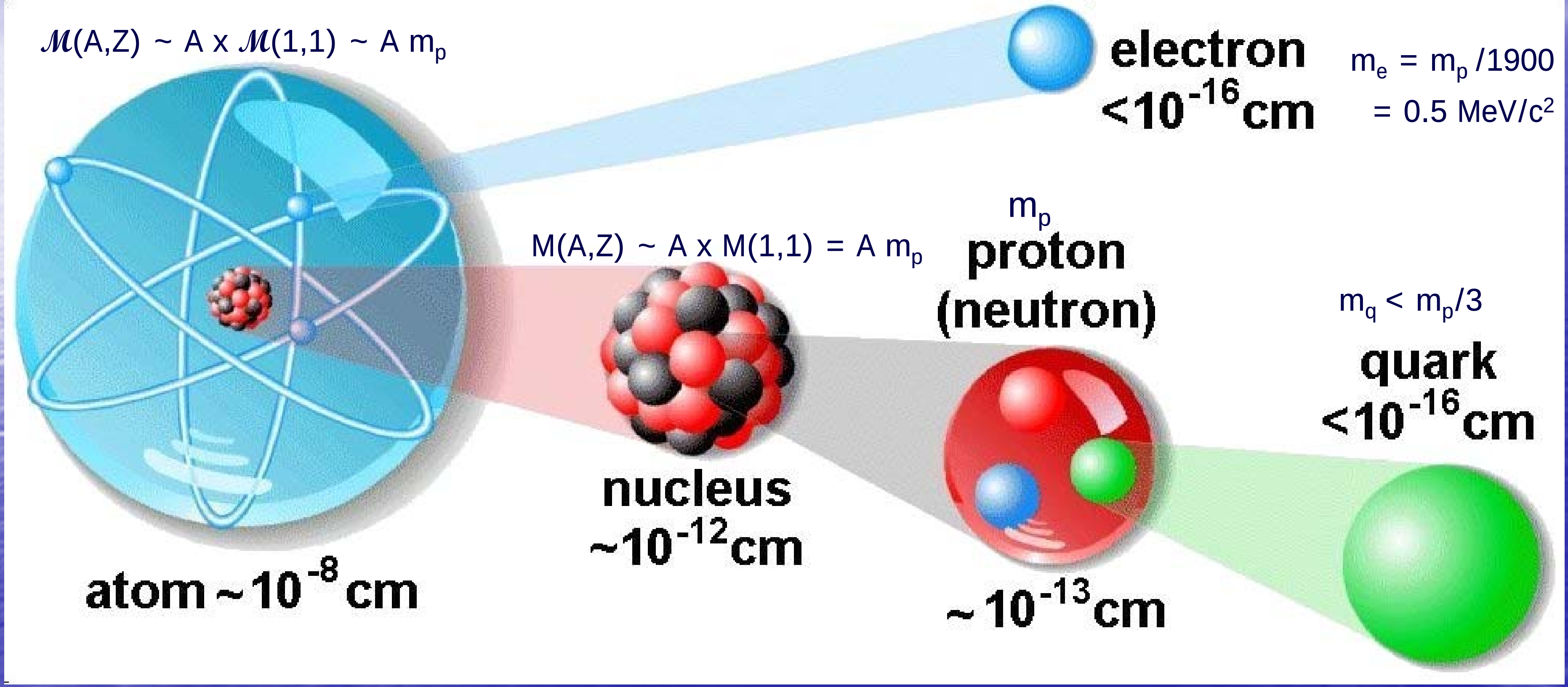
Over 99.95% of the known mass** of the Universe is contained in the atomic nuclei

α, β & γ rays come out directly from the **nucleus**



**From humans to viruses, from supernovae to peebles.

Structure of matter



$\mathcal{M}(A,Z) \sim A \times \mathcal{M}(1,1) \sim A\ m_p$

$m_e = m_p/1900$

$= 0.5\ MeV/c^2$

m_p

$M(A,Z) \sim A \times M(1,1) = A\ m_p$

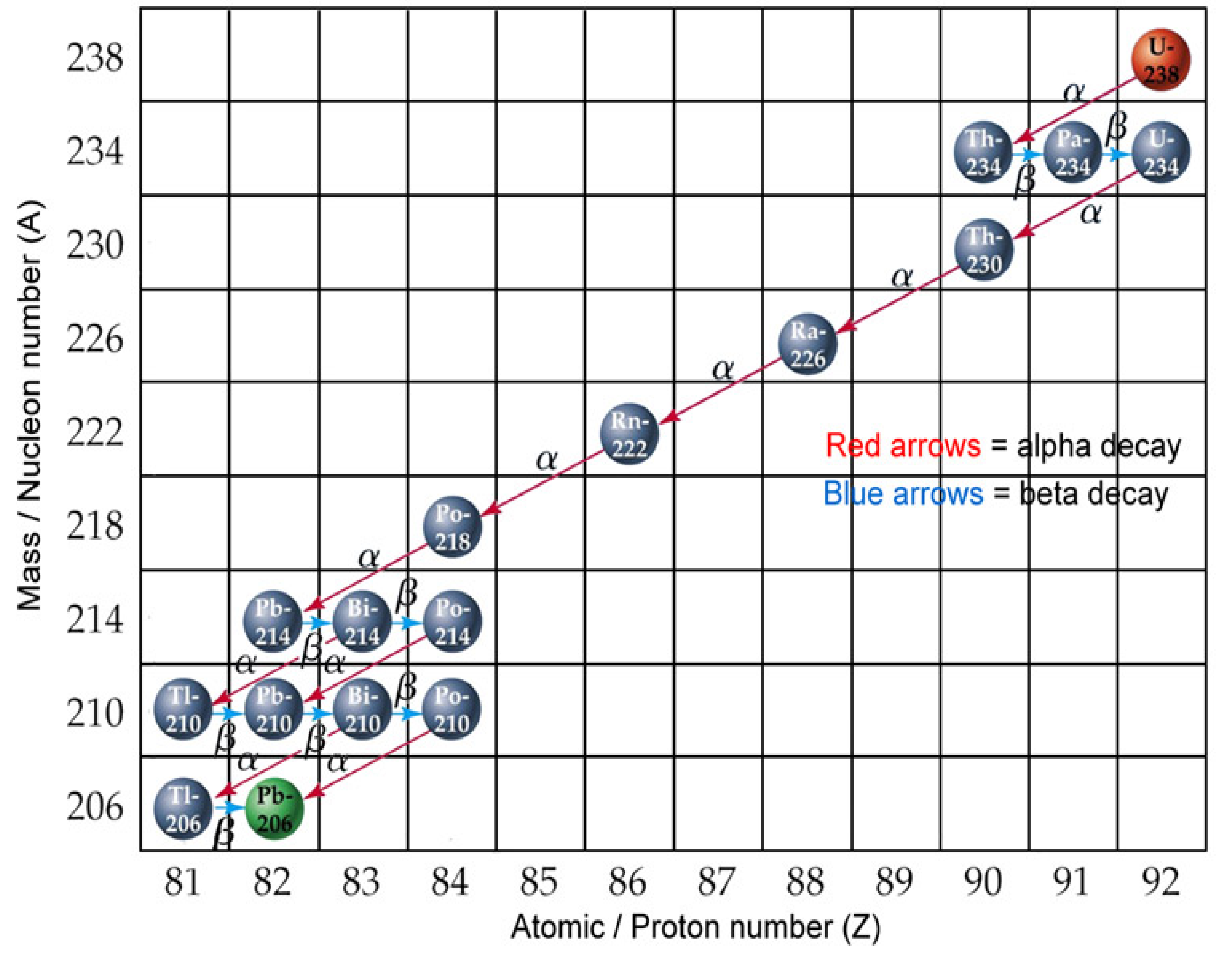
$m_q < m_p/3$

$$E = mc^2$$

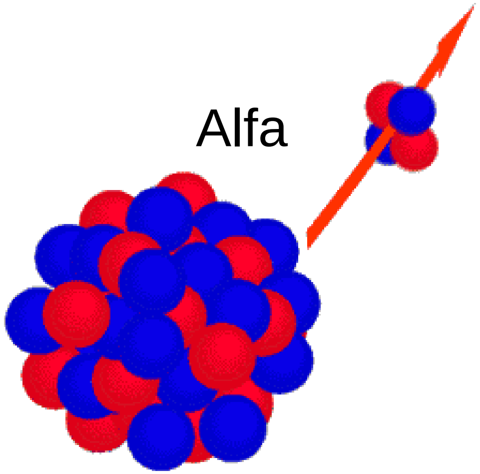
$1\ MeV/c^2 = 1.8 \times 10^{-27}\ g$

$1\ MeV = 1.6 \times 10^{-13}\ J$

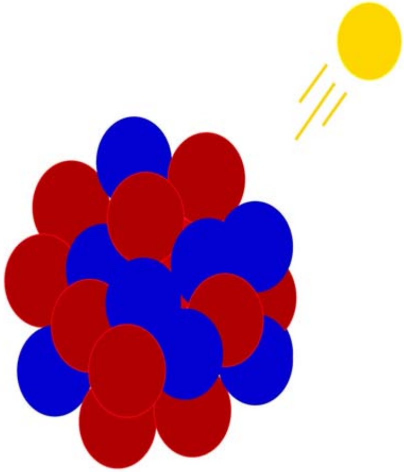
Theory of the ‘atomic’ radioactive transformations (modern ‘nuclear’ version)



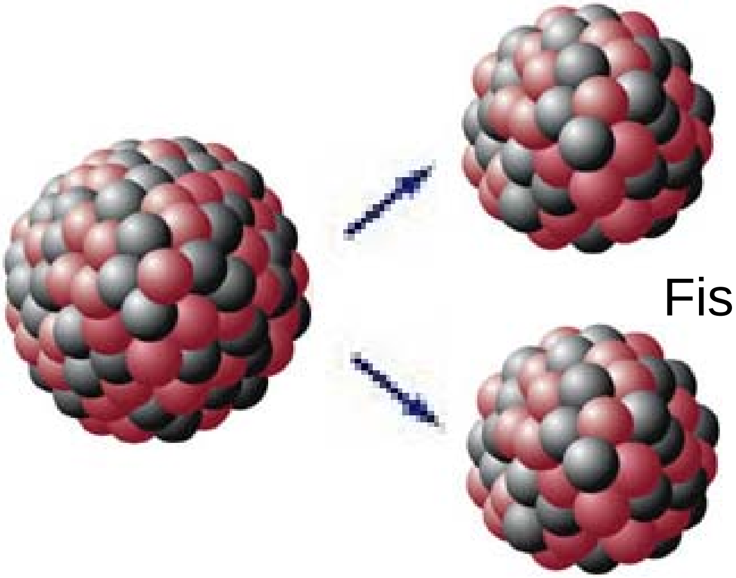
Other nuclear decay modes



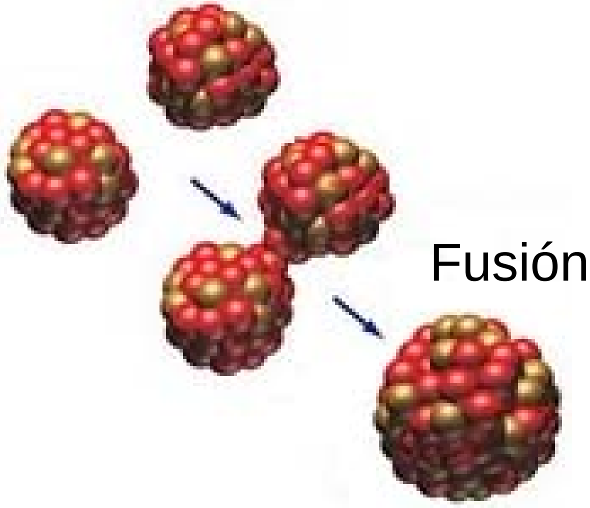
Alfa



Nucleon decay

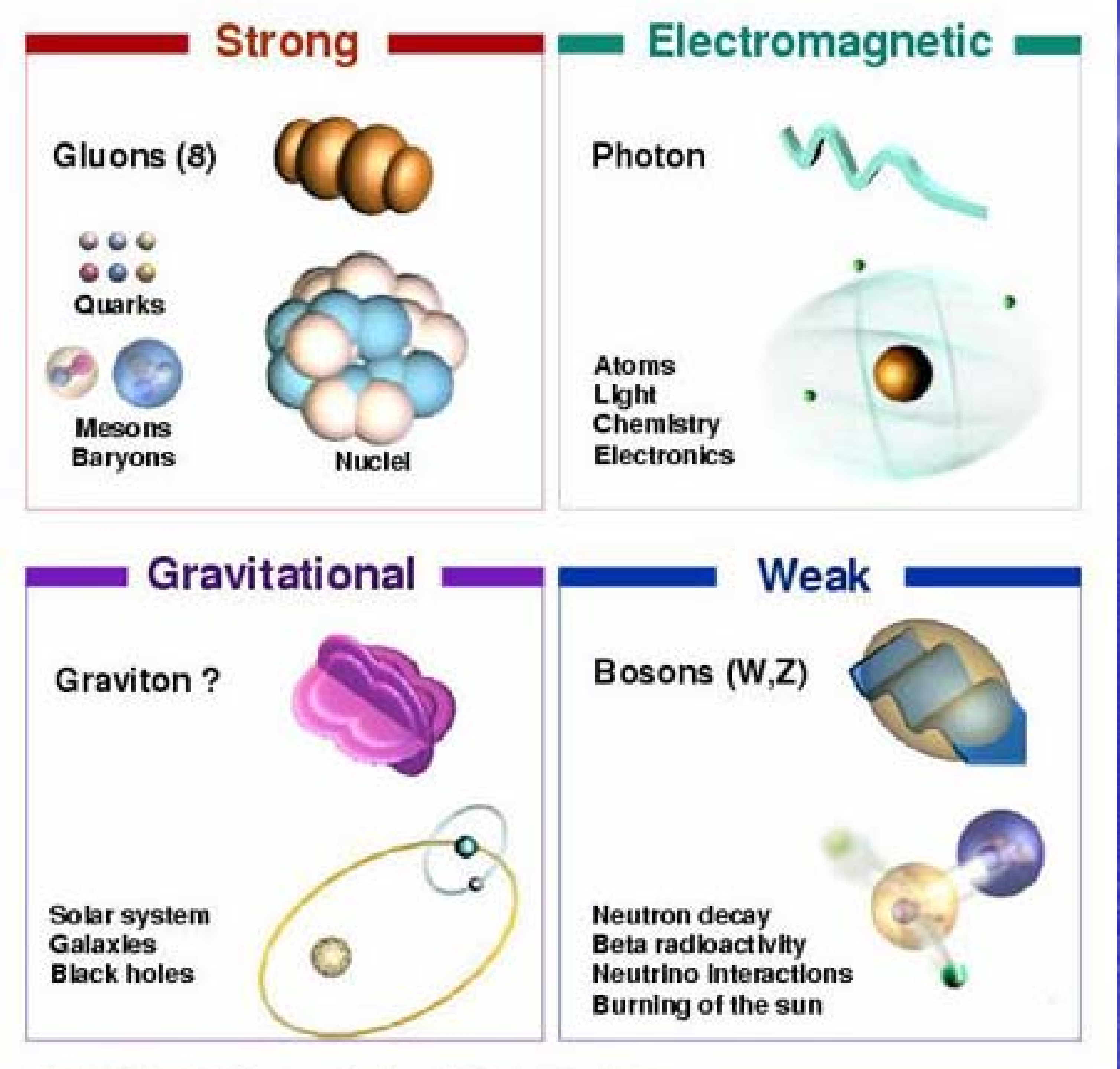


Fisión



Fusión

Nuclear forces



What did Mme. Curie do next?

The Radium Institute in Paris

Research on Physics, Chemistry and Medicine

1914 the Radium Institute is built in Paris which, once the war was finished, produced four more Nobel Prize winners (the Joliot-Curie couple, in particular)

Les petites curies

Through the war she was engaged intensively in equipping more than 20 vans that acted as mobile field hospitals and about 200 fixed installations with X-ray apparatus.

With her daughters and Missy Maloney in U.S.A. in 1921

With President Harding

Her visit to Madrid in 1931

The Radium Institute in Warsaw

Final remarks and impact

The pioneering work of the Curies and Becquerel gave birth to a new vigorous field, RADIOACTIVITY, which was revolutionary in many ways:

Conceptually it introduced the new idea that elements could be created and destroyed and could have an origin and an end. It opened up the big issue of the conservation of energy which on the other hand so much reinforced Einstein’s ideas. It gave an enormous push to the development of Science, particularly Physics, Chemistry and Medicine.

Radioactivity is in the origins of Quantum Mechanics, Nuclear Sciences and Particle Physics, as well as Modern Astrophysics and, to a lesser extent, Geophysics.

The applications in modern life range from industry to medicine, from agriculture to archaeology, from biology to geology, from energy sources for our everyday life to the space exploration.

MARIE CURIE ACTIONS

institutCurie
Together, let's beat cancer.

UNIVERSITE
PIERRE & MARIE CURIE
LA SCIENCE A PARIS

Marie Curie
Cancer Care

The Curies
A model for modern couples

The biggest discovery of the Curies was the discovery of each other

APPENDIX


1898. P. et M. CURIE DÉCOUVRENT LE RADIUM
CÔTE FR.çaise DES SOMALIS POSTES
R.F. 1f75 +50c
UNION INTERNATIONALE CONTRE LE CANCER
REPUBLIQUE FRANÇAISE 0,60 POSTES
1867 MARIE CURIE 1934
135F
Republique du Benin
FRANCE 0,87€
TÜRKİYE CUMHURİYETİ POSTALARI
MOLDOVA 3.70 L
Почта СССР 1987 5 к
Мария Склодовская-Кюри
120
MARIA SKŁODOWSKA CURIE 1867-1934
60 GR POLSKA
LES PREMIERS PRIX NOBEL 1901 2001
100ème ANNIVERSAIRE
भारत INDIA 20 P
1867-1934 MARIE CURIE
POLSKA
40 GR
POCZTA POLSKA
MARIE CURIE
SHARJAH
75
JERSEY
JERSEY POST
25
POSTA ROMANA 1.75 LEI
THE 50th ANNIVERSARY OF THE DEATH OF MARIE CURIE 1867-1934
DPR KOREA 1984
20000
NARODOWY BANK POLSKI
CORREOS
Marie Curie
Año Internacional de la QUÍMICA
ESPAÑA 0,35€
MADAME CURIE-SKŁODOWSKA (1867-1934)
Marie Curie 1867-1934
INTERNATIONAL WOMEN'S YEAR 1975
MARIE CURIE
LIBERIA 2c
DDR 10
MARIE CURIE

Pierre Curie’s Statements on good and evil from scientific discoveries

It can even be thought that radium could become very dangerous in criminal hands,
and here the question can be raised whether mankind benefits from knowing the secrets of Nature,
whether it is ready to profit from it or
whether this knowledge will not be harmful for it.
The example of the discoveries of Nobel is characteristic,
as powerful explosives have enabled man to do wonderful work.
They are also a terrible means of destruction in
the hands of great criminals who are leading the peoples towards war.
I am one of those who believe with Nobel that mankind will
derive more good than harm from the new discoveries.

Marie Curie Nobel Lecture (1911)

Radium is the higher homologue of barium in the family of alkaline-earth metals; it has been entered in Mendeleev's table in the corresponding column, on the row containing uranium and thorium. The radium spectrum is very precisely known. These very clear-cut results for radium have convinced chemists ...

In chemical terms radium differs little from barium; the salts of these two elements are isomorphic, while those of radium are usually less soluble than the barium salts. It is very interesting to note that strong radioactivity of radium involves no chemical anomalies and that the chemical properties are actually those which correspond to the position in the Periodic System indicated by its atomic weight. The radioactivity of radium in solid salts is ca. 5 million times greater than that of an equal weight of uranium. Owing to this activity its salts are spontaneously luminous. I also wish to recall that radium gives rise to a continuous liberation of energy which can be measured as heat, being about 118 calories per gram of radium per hour.

Radium has been isolated in the metallic state (M. Curie and A. Debierne, 1910). The method used consisted in distilling under very pure hydrogen the amalgam of radium formed by the electrolysis of a chloride solution using a mercury cathode. The metal obtained melts at about 700°C, above which temperature it starts to volatilize. Is it very unstable in the air and decomposes water vigorously.