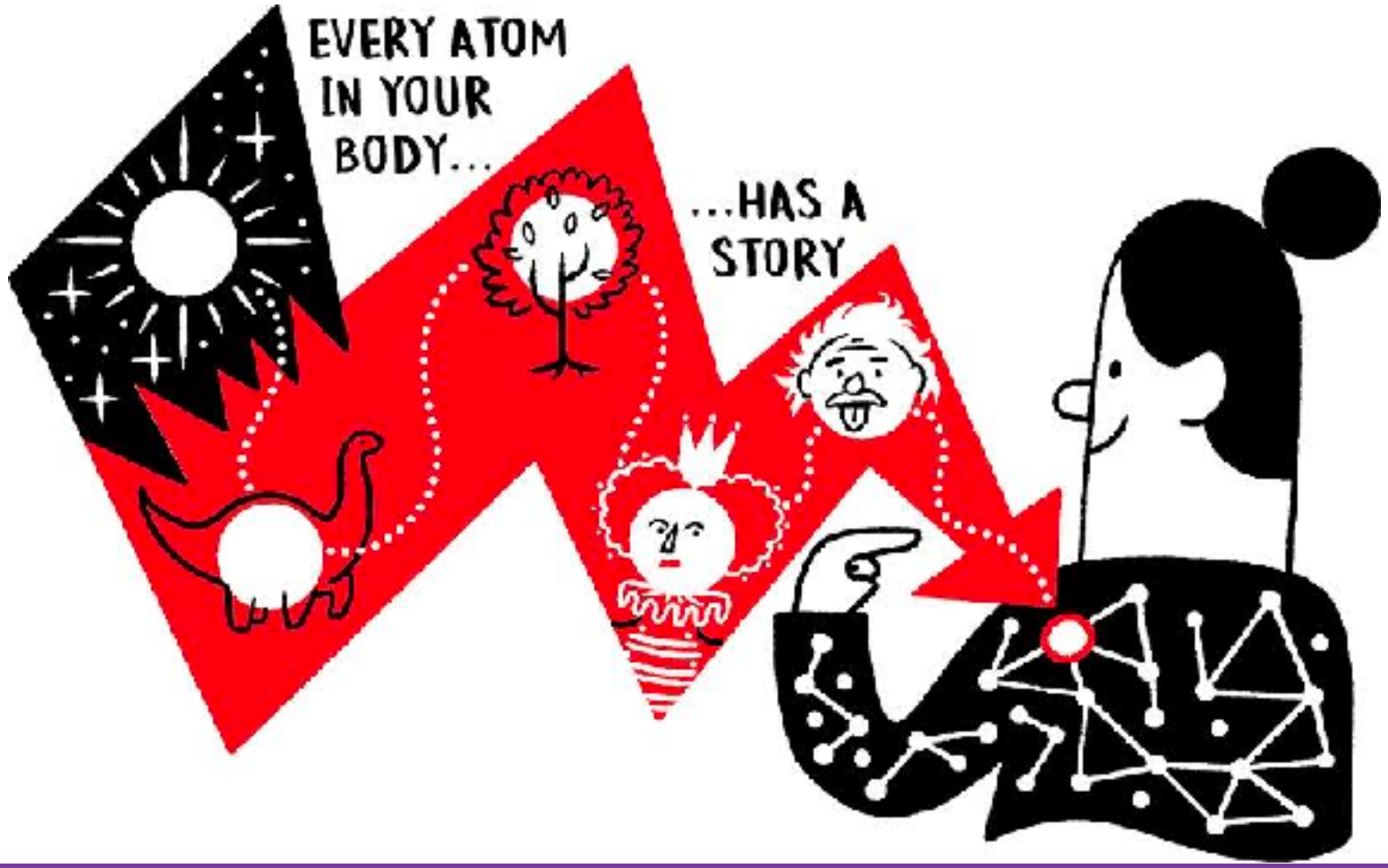
Atomic Physics

Introduction



Class requirements

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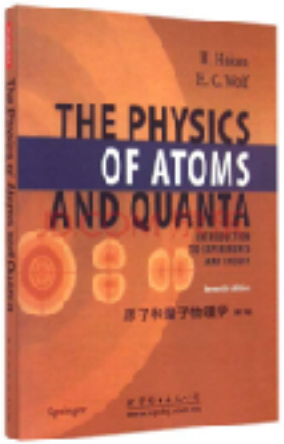
- ✓ Quiz+Homework (40%)
- ✓ Final examination (60%)
- ✓ References

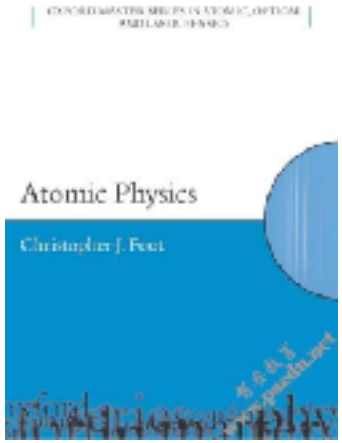
H. Haken and H. C. Wolf, The physics of Atom and Quanta

C. J. Foot, Atomic Physics

杨福家，原子物理学

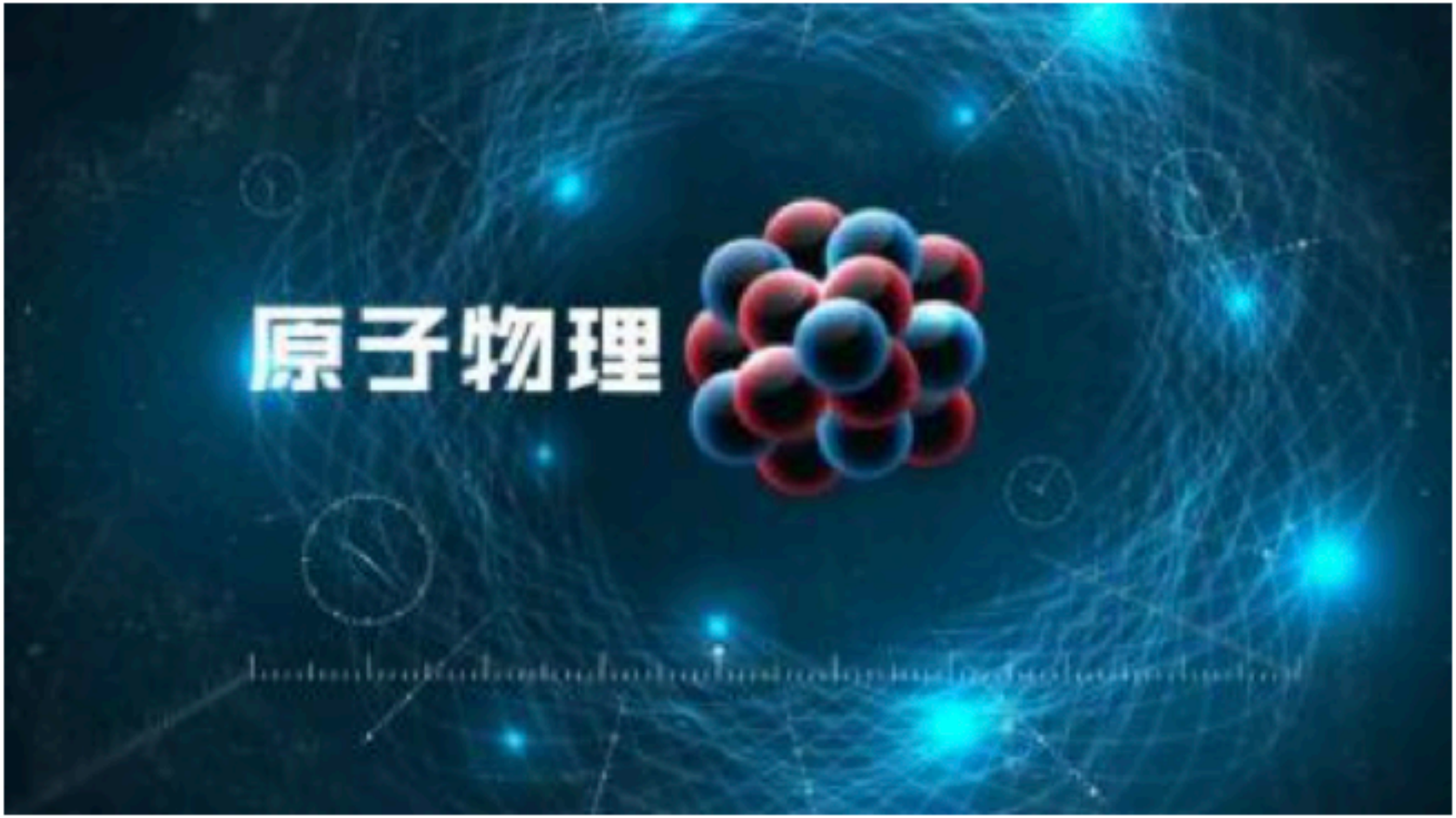
朱林繁 彭新华，原子物理学



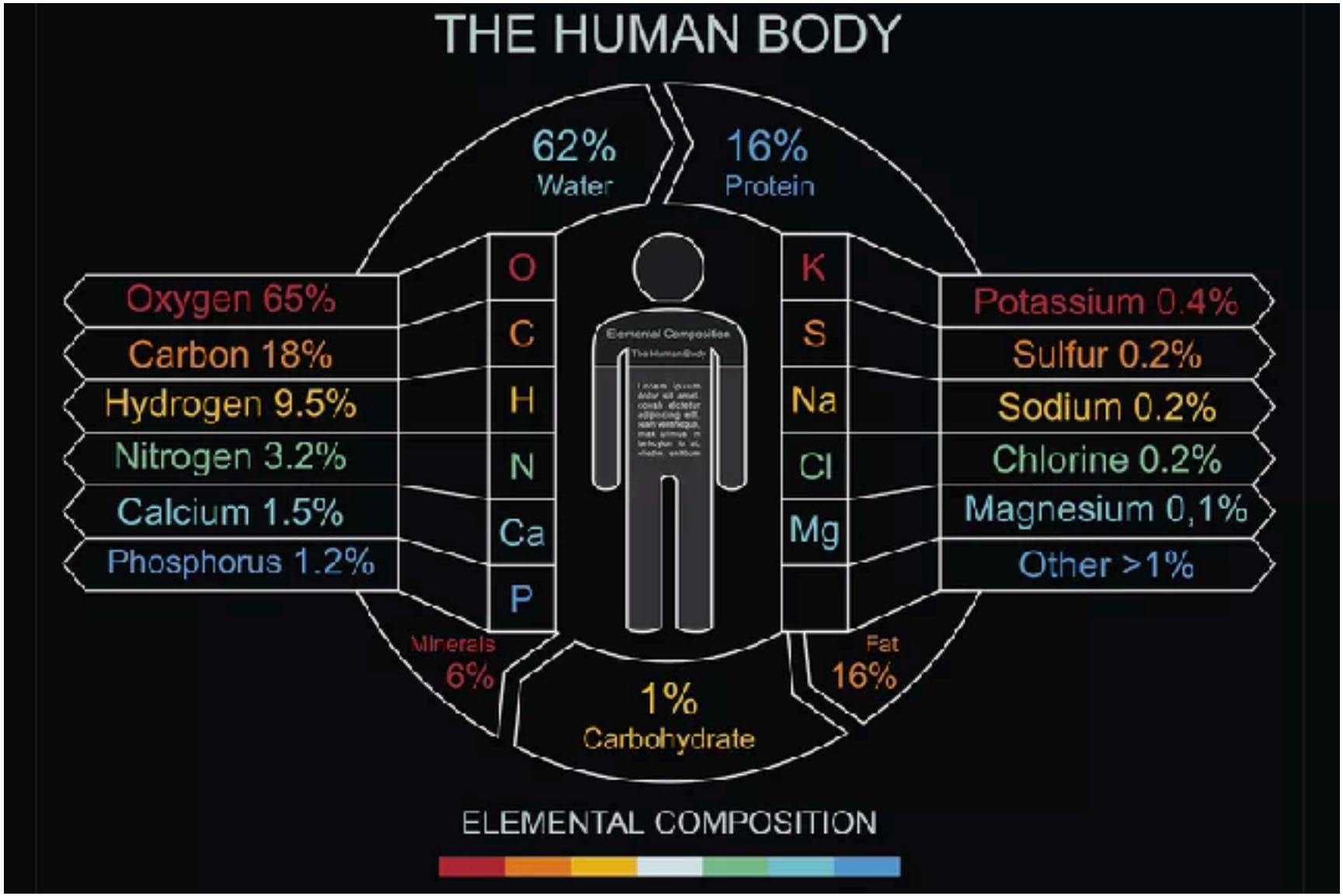


Class requirements

http://coursehome.zhihuishu.com/courseHome/1000008969#teachTeam



The elements in human body



Every atom in your body came from a star that exploded.

And, the atoms in your left hand probably came from a different star than your right hand.

It really is the most poetic thing I know about physics:

You are all stardust.

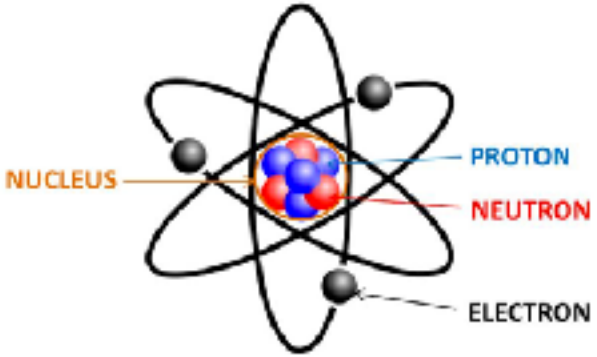
——— Lawrence Maxwell Krauss

What is an atom

An atom is the smallest unchangeable component of a chemical element.

1. Unchangeable means in this case by chemical means

2. Moderate temperatures: kT < eV



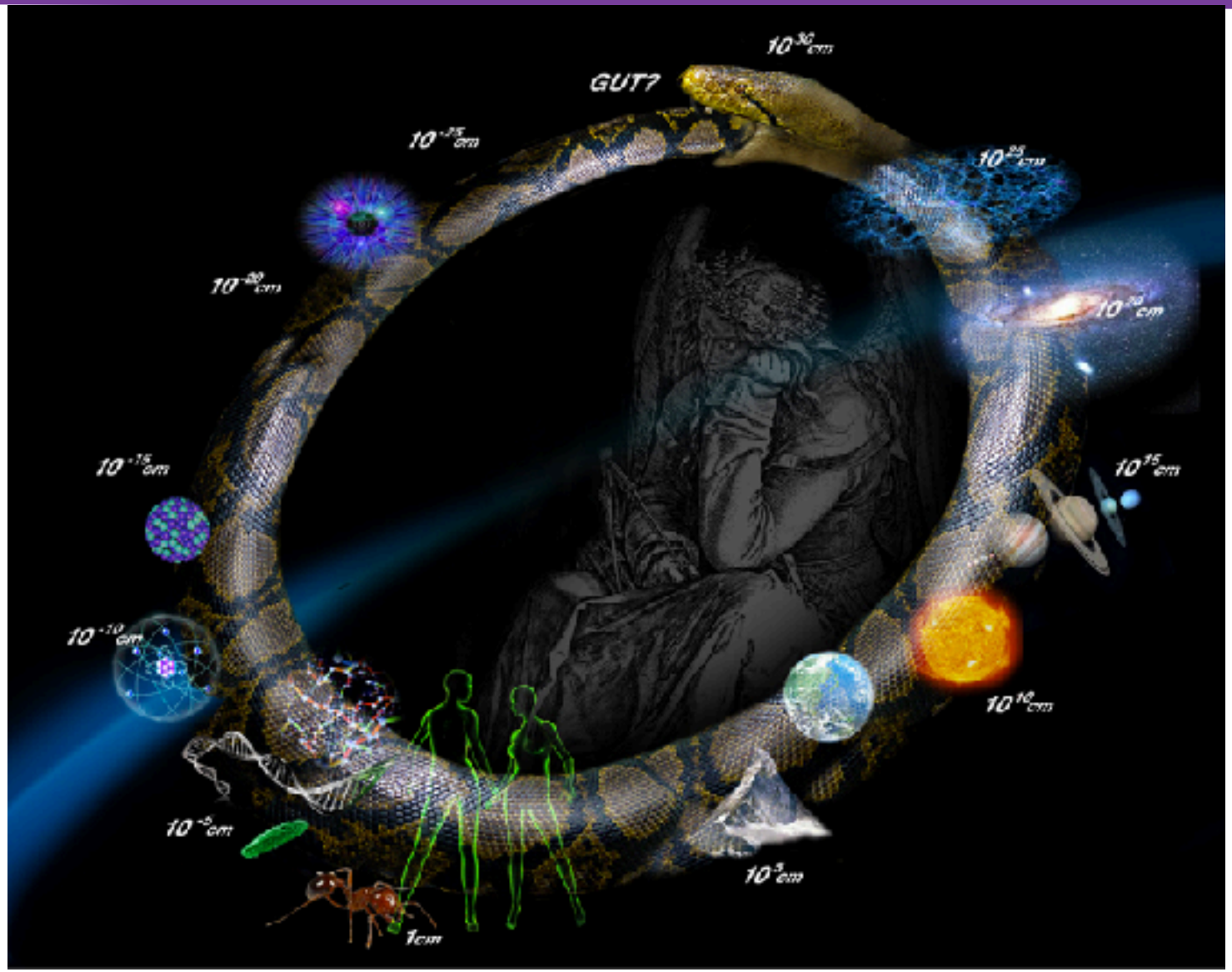
Mass range: 1.67×10^{-27} to 4.52×10^{-25} kg

Electric charge: zero (neutral), or ion charge

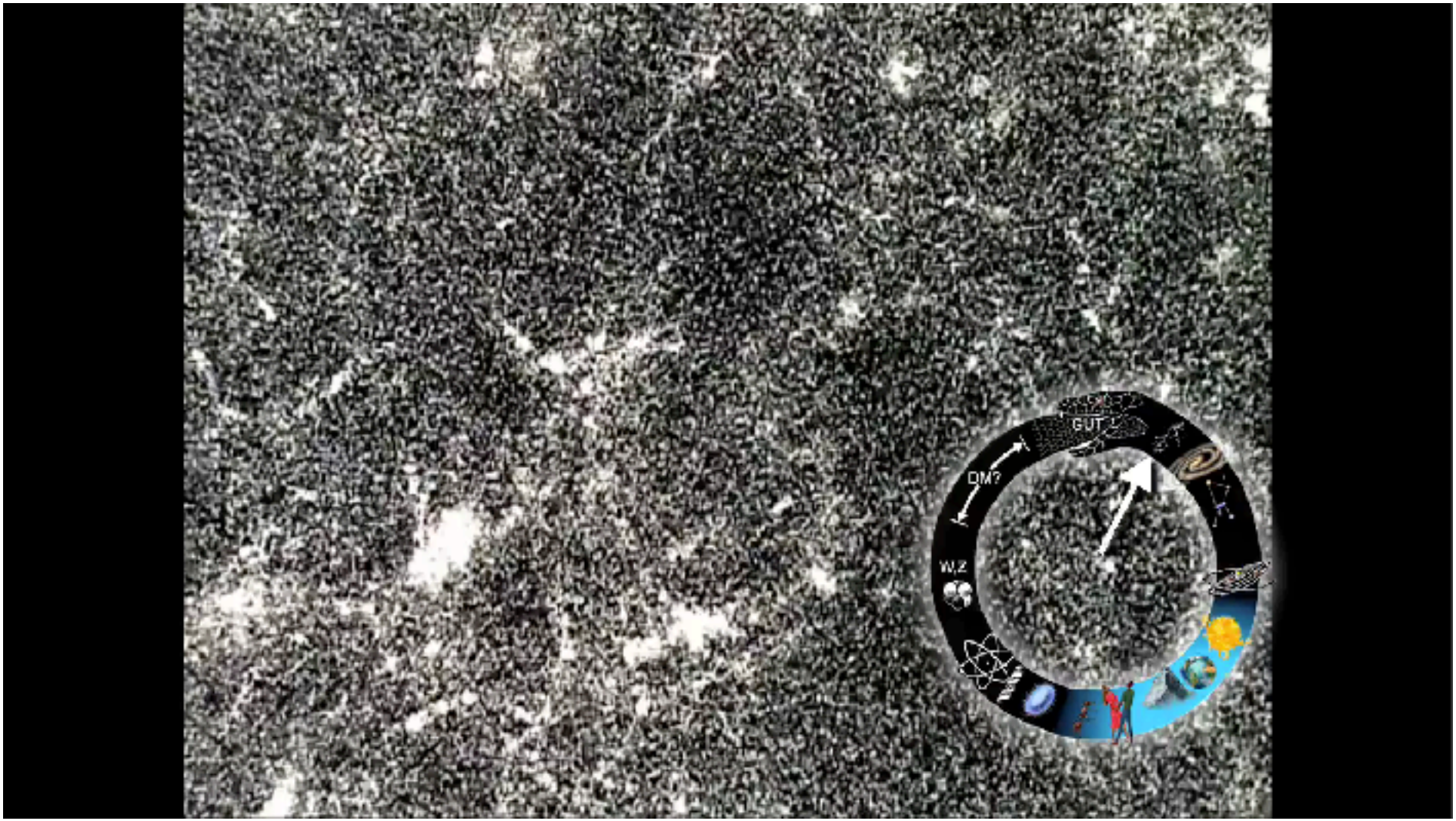
Diameter range: 62 pm (He) to 520 pm (Cs)

Components: Electrons and compact nucleus of protons and neutrons

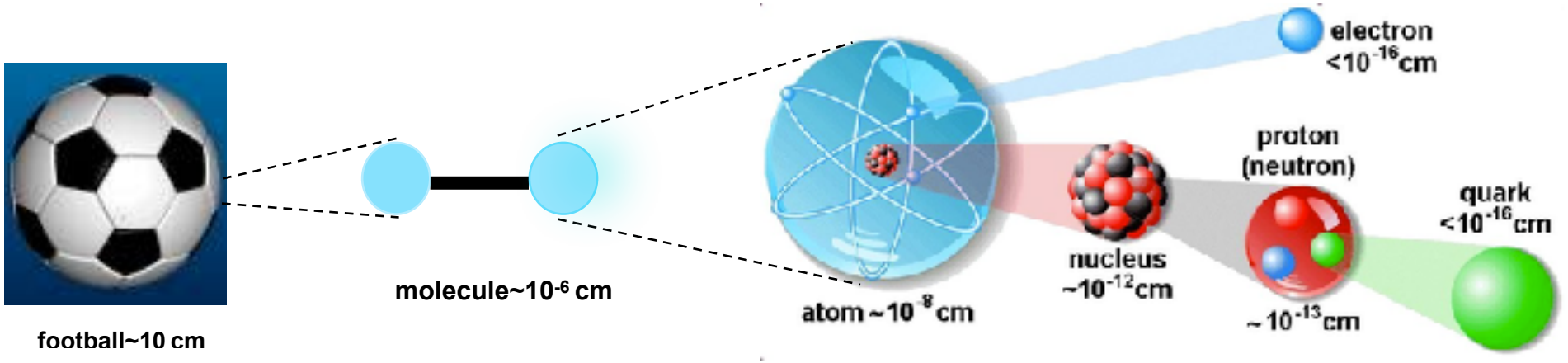
Cosmic Uroboros



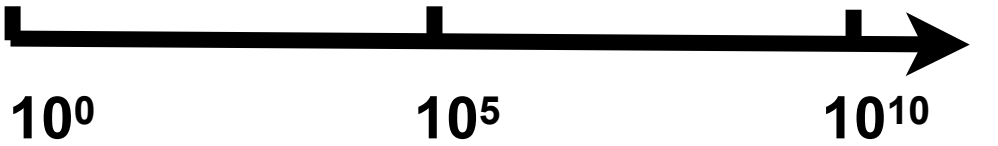
Cosmic Uroboros



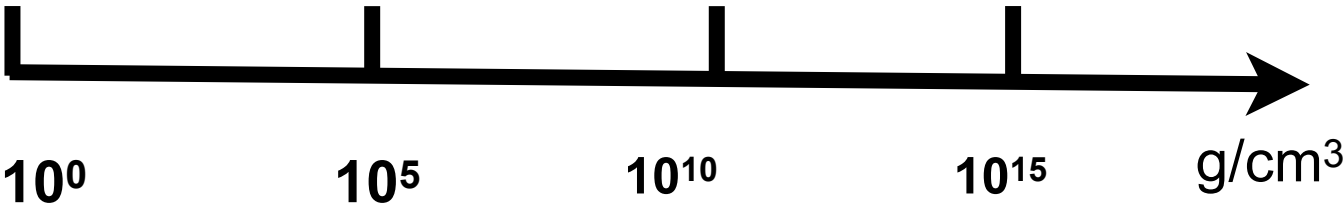
Atom size



Range of excitation energies



Range of densities



Short Historical Review

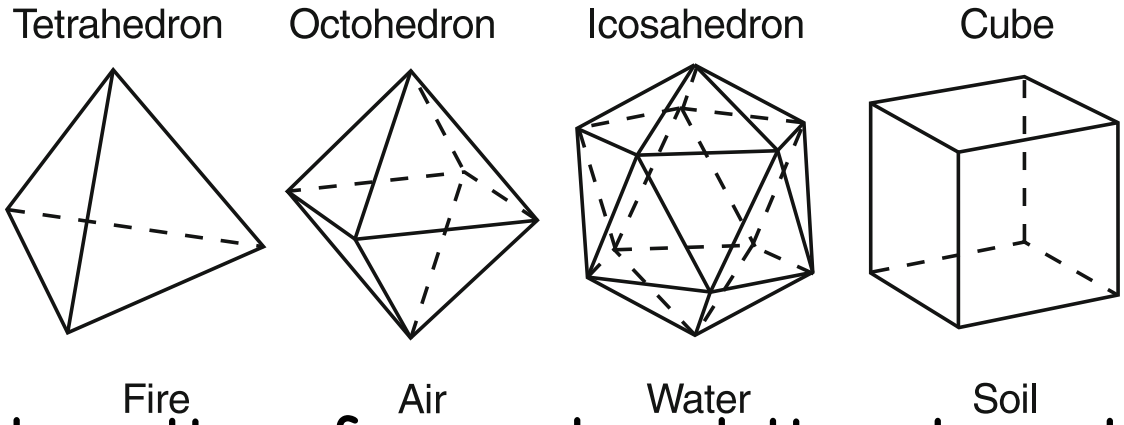
✓ Atom comes from the Greek and means "the indivisible", the smallest component of matter, which cannot be further divided.

✓The first atomic theories of the structure of matter were those of Democritus (460 - 370 B.C.), who both taught that all natural bodies consist of "infinitely small" particles that completely fill the volume of the bodies and are not further divisible. They called these particles "atoms".

Democracy

Short Historical Review

✓ The famous Greek philosopher Plato (427–347 B.C.) pushed the abstraction of the concept further. He used the hypothesis of the four "elements" fire, water, air, and soil but attributed to these elements four regular three-dimensional geometric structures, which are formed by symmetric triangles or squares.



✓ Plato's ideas therefore reduced the atoms to mathematical structures that are not necessarily based on the real existence of matter.

Short Historical Review

✓ Aristoteles (384–322 B.C.), a student of Plato, did not accept this concept of atoms since it contradicted his idea of a continuous space filled with matter. He also did not believe in the existence of empty space between the atoms. His influence was so great that Democritus' hypothesis was almost abandoned and nearly forgotten until it was revived and modified later by Epicurus (341–271 B.C.), who attributed atoms not only size but also a mass to explain why bodies fell down.

✓ After Epicurus the atomic theory was forgotten for many centuries. This was due to the influence of the Christian church, which did not accept the materialistic view that everything, even human beings, should be composed of atoms.

The ancient atomic theories

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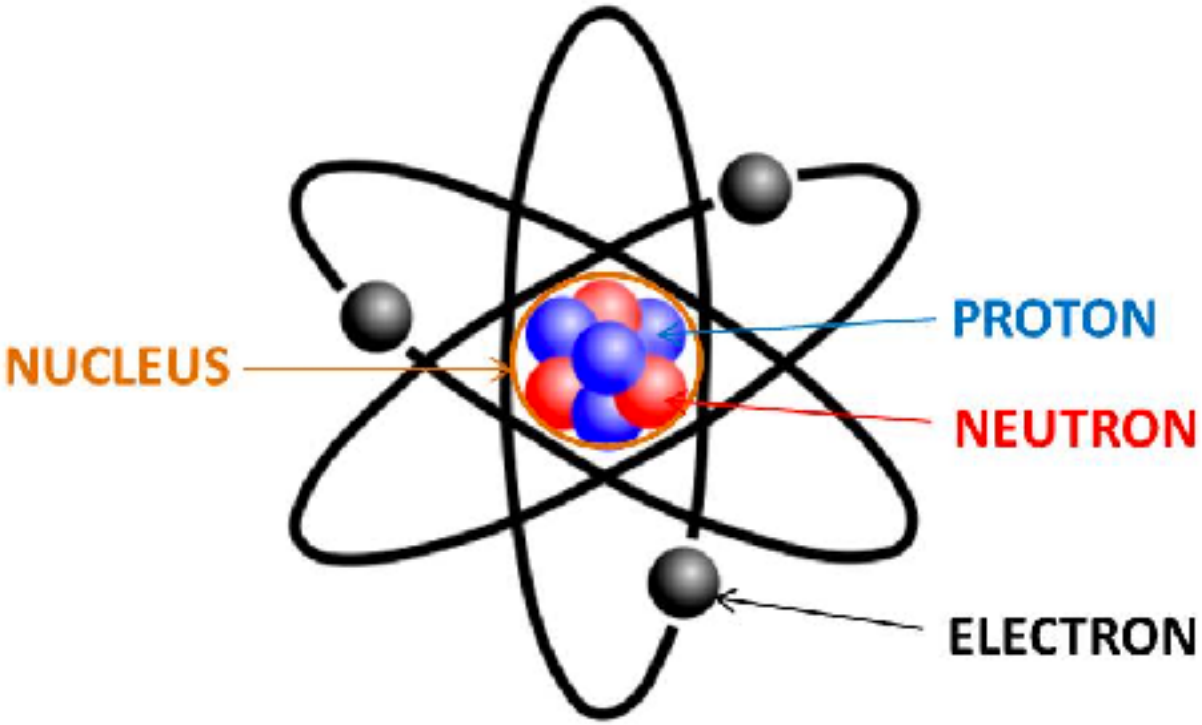
✓"端：体之无序最前者也"　　《墨经》

✓"语小，天下莫能破焉"。　　《中庸》

✓"一尺之棰，日取其半，万世不竭"　　《庄子·天下篇》

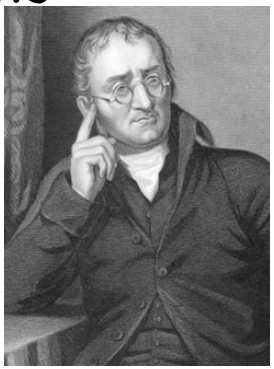
Short Historical Review

✓ The meaning of the word "atom" becomes less subject to misinterpretation if it is translated into Latin: an individuum （不可分） is the smallest unit of a large set which possesses all the essential characteristics of the set.



Short Historical Review

✓ All the chemical elements are composed of atoms were recognized from **chemical investigations**.



✓ The laws of constant and multiple proportions: (J. L. Proust and Dalton)

In a mixture of non-reacting gases, the total pressure exerted is equal to the sum of the partial pressures of the individual gases. （在组分之间不发生化学反应的前提下，理想气体混合物的压强等于各组分的分压之总和）

✓1815 The first atomic model (W. Prout):

The atoms of all elements are put together out of hydrogen atoms.

Short Historical Review

✓ Dalton published his ideas in the paper "A New System of Chemical Philosophy", which contains the three important postulates:

All chemical elements consist of very small particles (atoms), which can not be further divided by chemical techniques.

All atoms of the same chemical element have equal size, mass and quality, but they differ from the atoms of other elements. This means that the properties of a chemical element are determined by those of its atoms.

When a chemical element A reacts with an element B to form a compound AB_n (n = 1,2,...) each atom of A recombines with n atoms of B and therefore the number ratio N_B/N_A is always a small integer, n.

Short Historical Review

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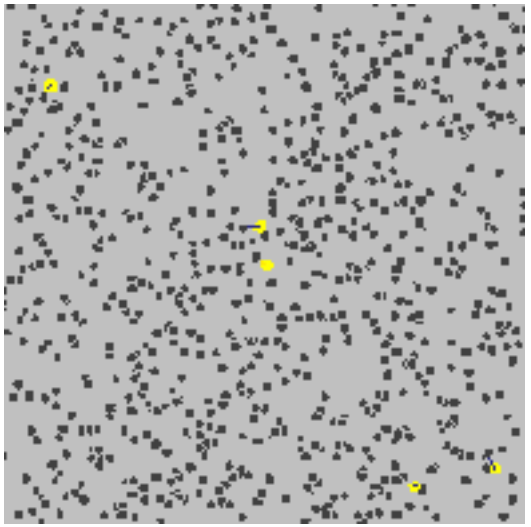
✓1808 The volume of gaseous reactants occur as ratios of small integers (Gay-Lussac) （在同温同压下，气体相互之间按照简单体积比例进行反应，并且生成的任一气体产物也与反应气体的体积成简单整数比）

✓1811 Hypothesis of Avogadro:

Equal volumes of gases under similar conditions contain equal numbers of molecules.

✓1826 Brown motion:

The random motion of particlessuspended in a fluid(a liquid or a gas) resulting from their collision with the fast-moving atoms or molecules in the gas or liquid.



Short Historical Review

✓ 1833, Faraday laws:

1. The quantity of an element which is separated is proportional to the quantity of charge transported in the process.
2. Various elements are separated into equivalent weights by the same quantity of charge.

1. 物质在电解过程中，参与电极反应的质量与通过电极的电量成正比。
2. 不同物质电解的质量则正比于该物质的化学当量。

Short Historical Review

✓ 1869, Periodic table (L. Meyer and D. I. Mendeleev)

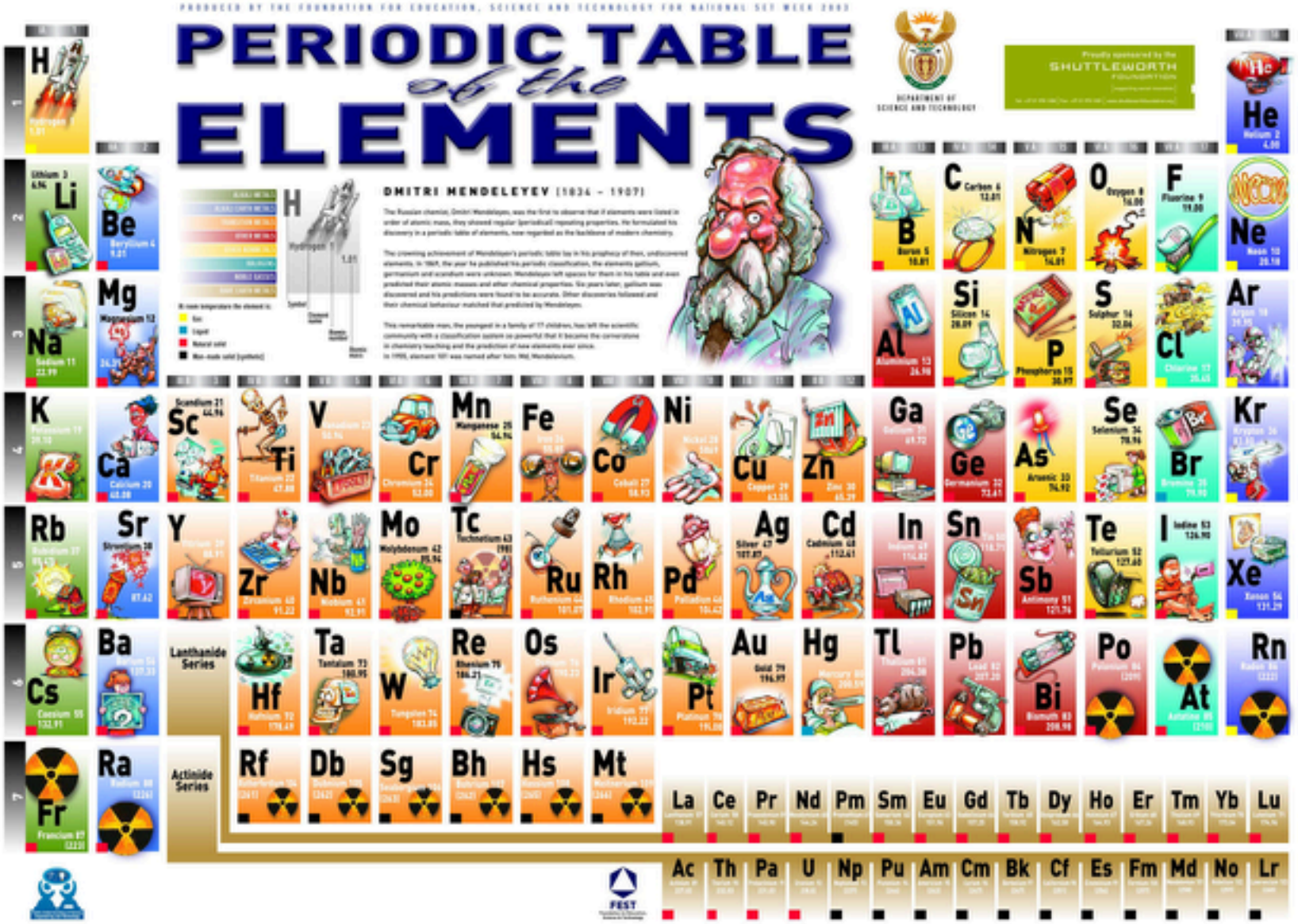
ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ,

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=197,1.
			Fe=56	Ru=104,4	Ir=198.
			Ni=Co=59	Pd=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=27,3	?=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

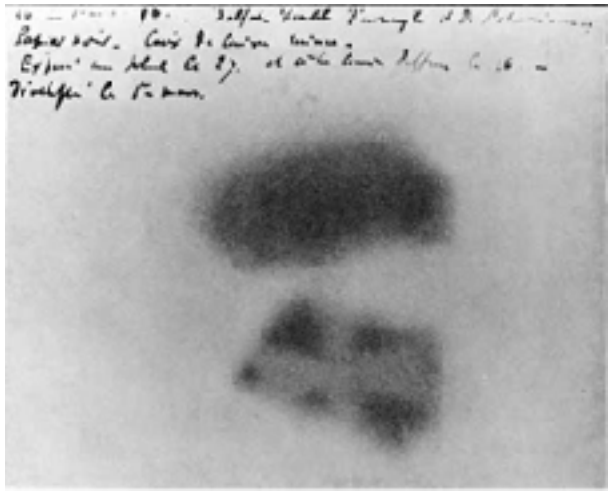
Periodic table

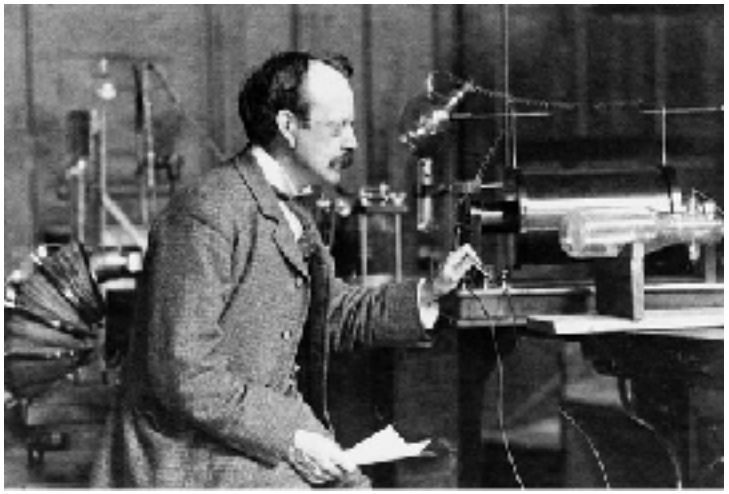


Periodic table song

Short Historical Review

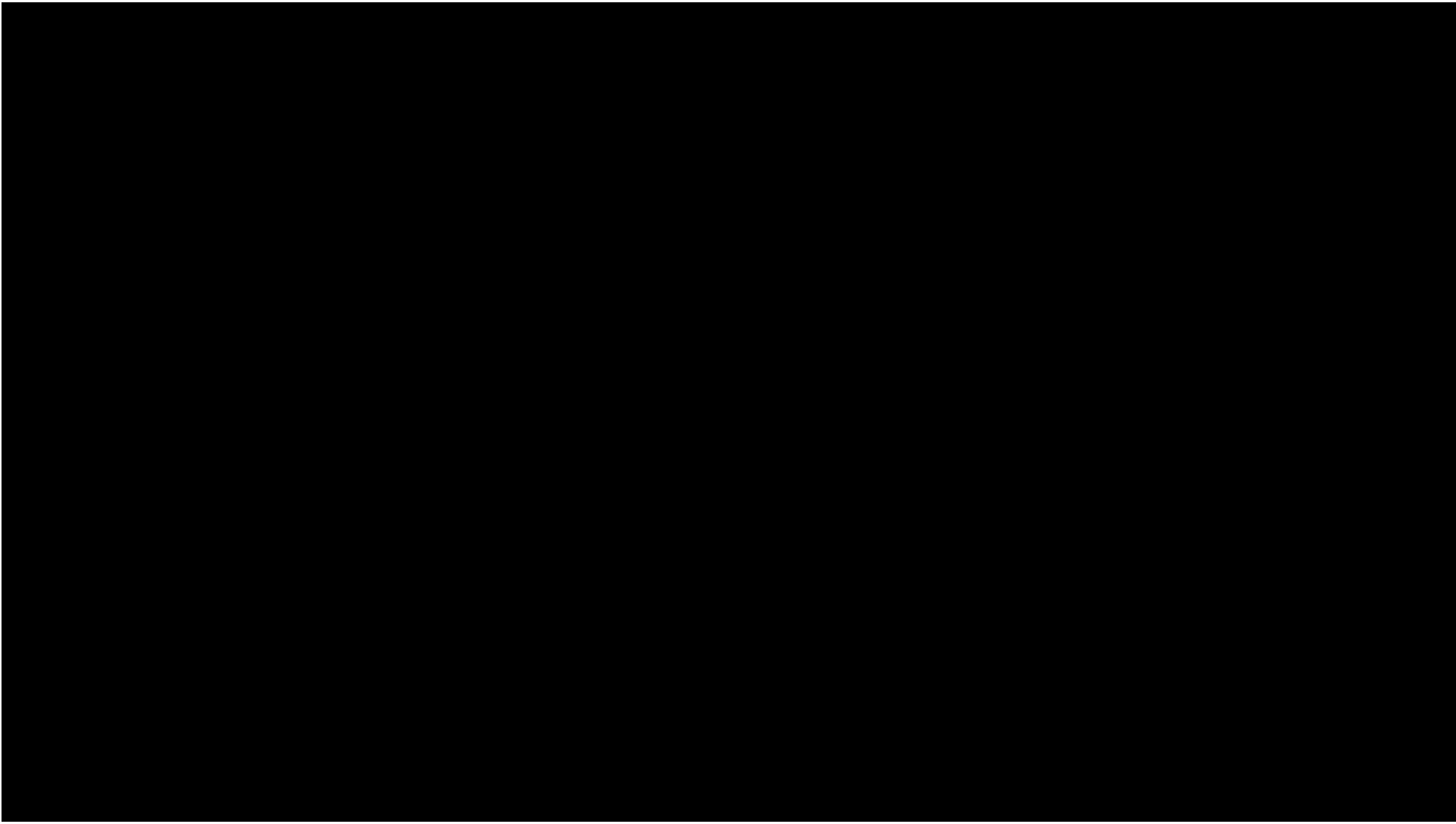
- ✓ 1885, Ordering principle in atomic spectra (J. Balmer)
- ✓ 1895, X ray (W. Roentgen)
- ✓ 1896, Radiation (A. H. Becquerel)
- ✓ 1897, The discovery of electron (J. J. Thomson)



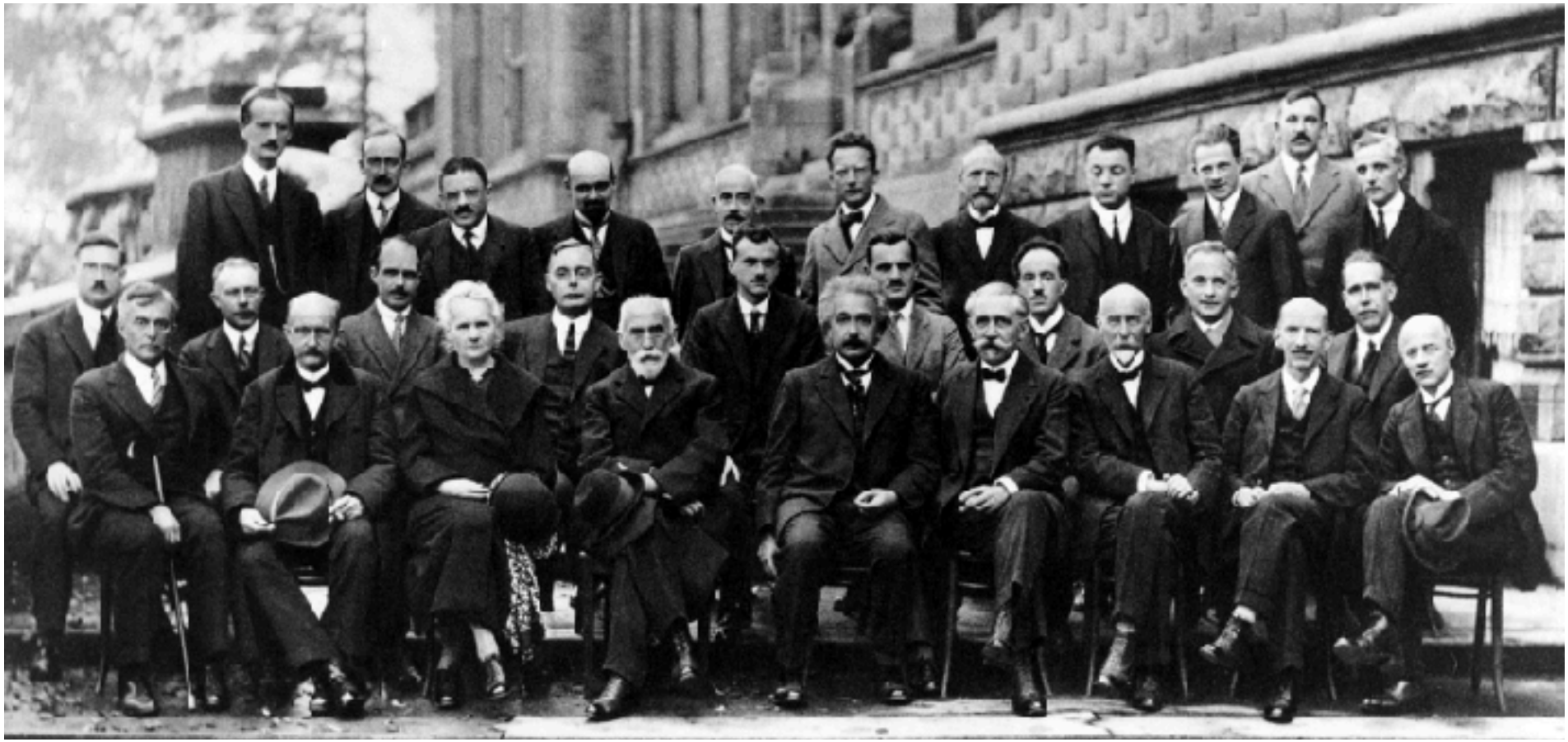


Short Historical Review

- ✓ 1885, Ordering principle in atomic spectra (J. Balmer)
- ✓ 1900, The laws of black body radiation (M. Plank)
- ✓ 1911, Planetary model of the atom (E. Rutherford)
- ✓ 1913, Bohr model for hydrogen
- ✓ 1925, Matter waves (De Broglie)
- ✓ 1926, Schroedinger equation (E. Schroedinger)
- ✓ 1928, Dirac equation (P. Dirac)

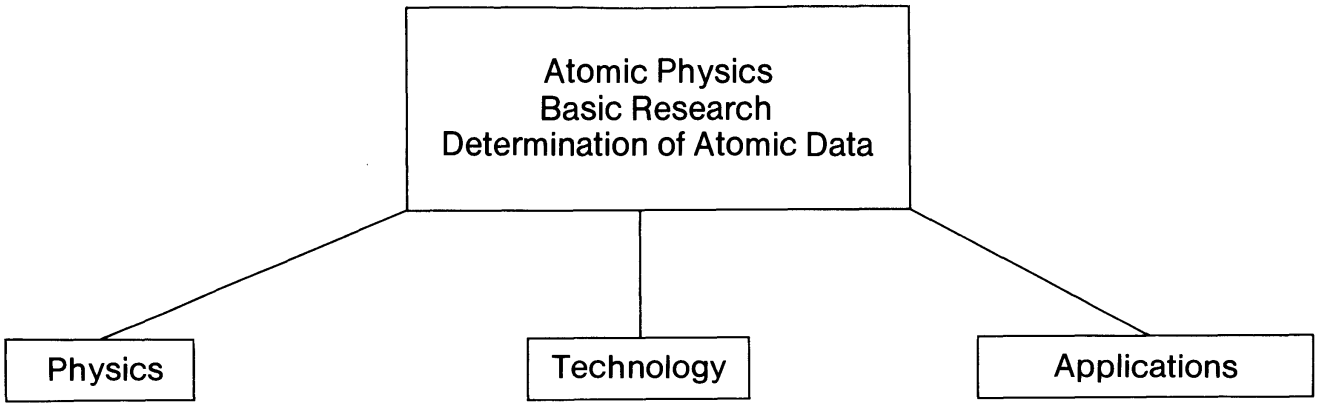


Solvay conference 1927



17 Nobel Prize winners! Niubility!

The application of atomic physics



Solid State Physics
Ideal and defect structures

Chemical Physics
Formation of molecules, chemical reactions

Astrophysics
Atomic spectroscopy

Plasma Physics
Excitation mechanisms

Biophysics
Complex molecular structures

Geophysics
Earth's magnetic field

Quantum Electronics
Lasers, frequency standards, navigation, geodetics

Medical Technology
Radiation effects

Communications Technology
Laser techniques, ionosphere

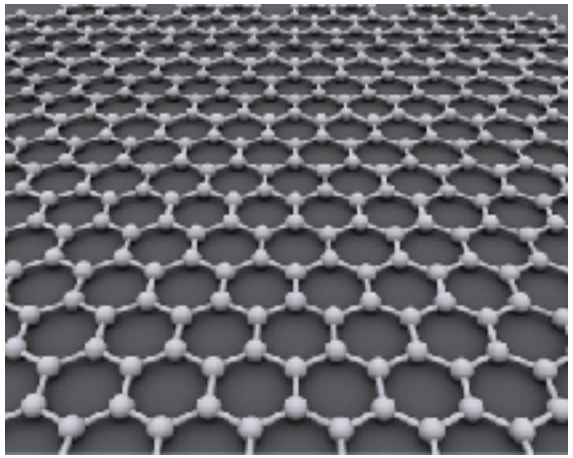
Determination of Units
Fundamental constants

Space Research
Earth and planetary atmospheres, weather

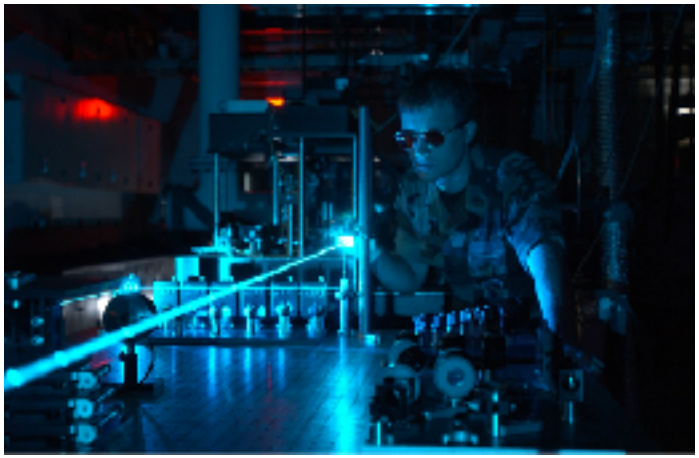
Environment
Detection of pollutants

Energy Problems
New methods of energy production

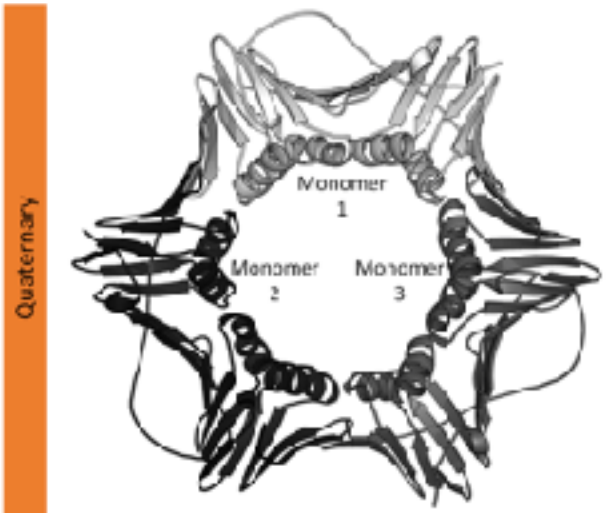
The application of atomic physics



Graphene



Laser



Biomolecular structure

CT Scan

The application of atomic physics

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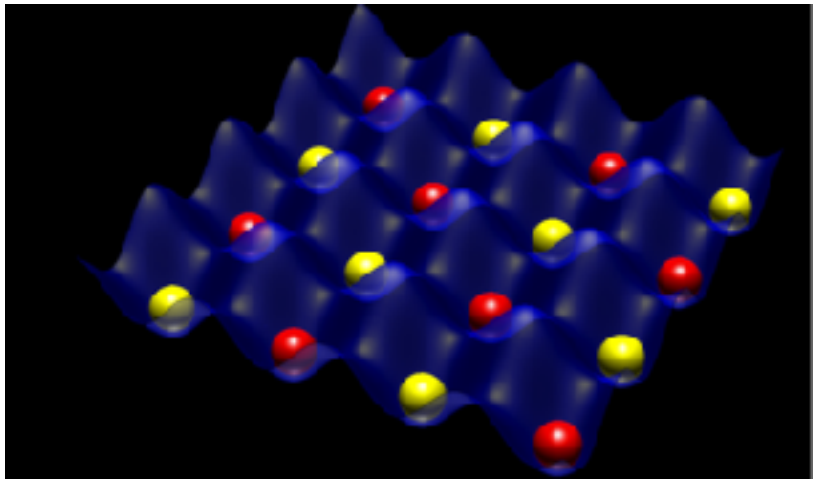
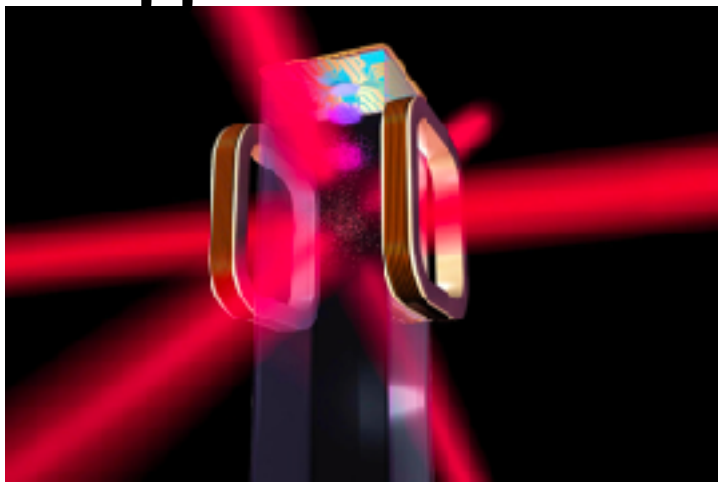
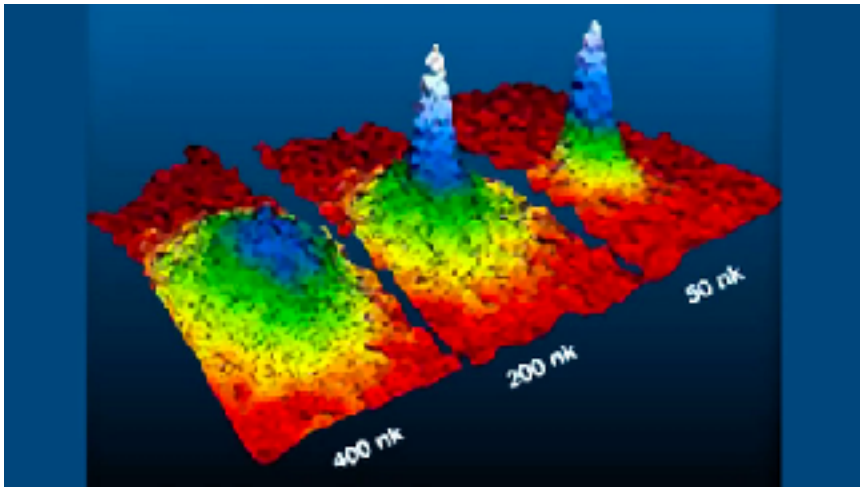
Optical lattice



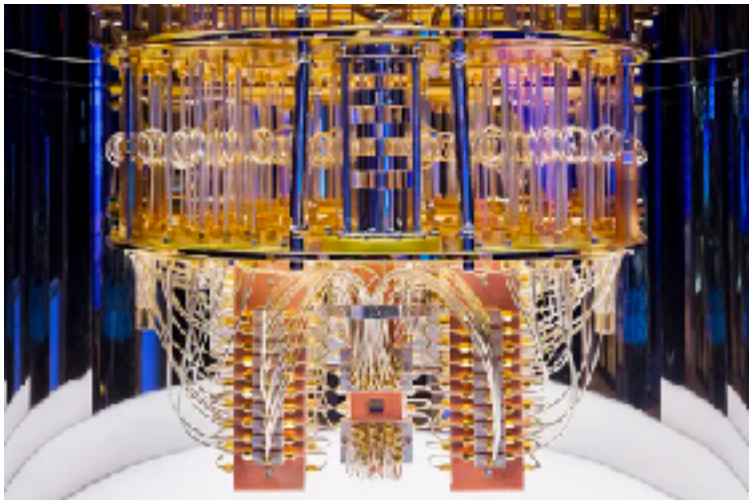
Trapped well



BEC condensation



Quantum computer



Class outline

- ✓ Introduction (2 classes)
- ✓ Basic Properties of Atom (8 classes)
- ✓ Bohr's Model of the Hydrogen Atom (8 classes)
- ✓ Quantum Mechanics of the Hydrogen Atom (12 classes)
- ✓ Fine structures of Atoms (12 classes)
- ✓ Many-Electron Atoms (12 classes)
- ✓ X-Ray (8 classes)
- ✓ Nuclear physics (6 classes)