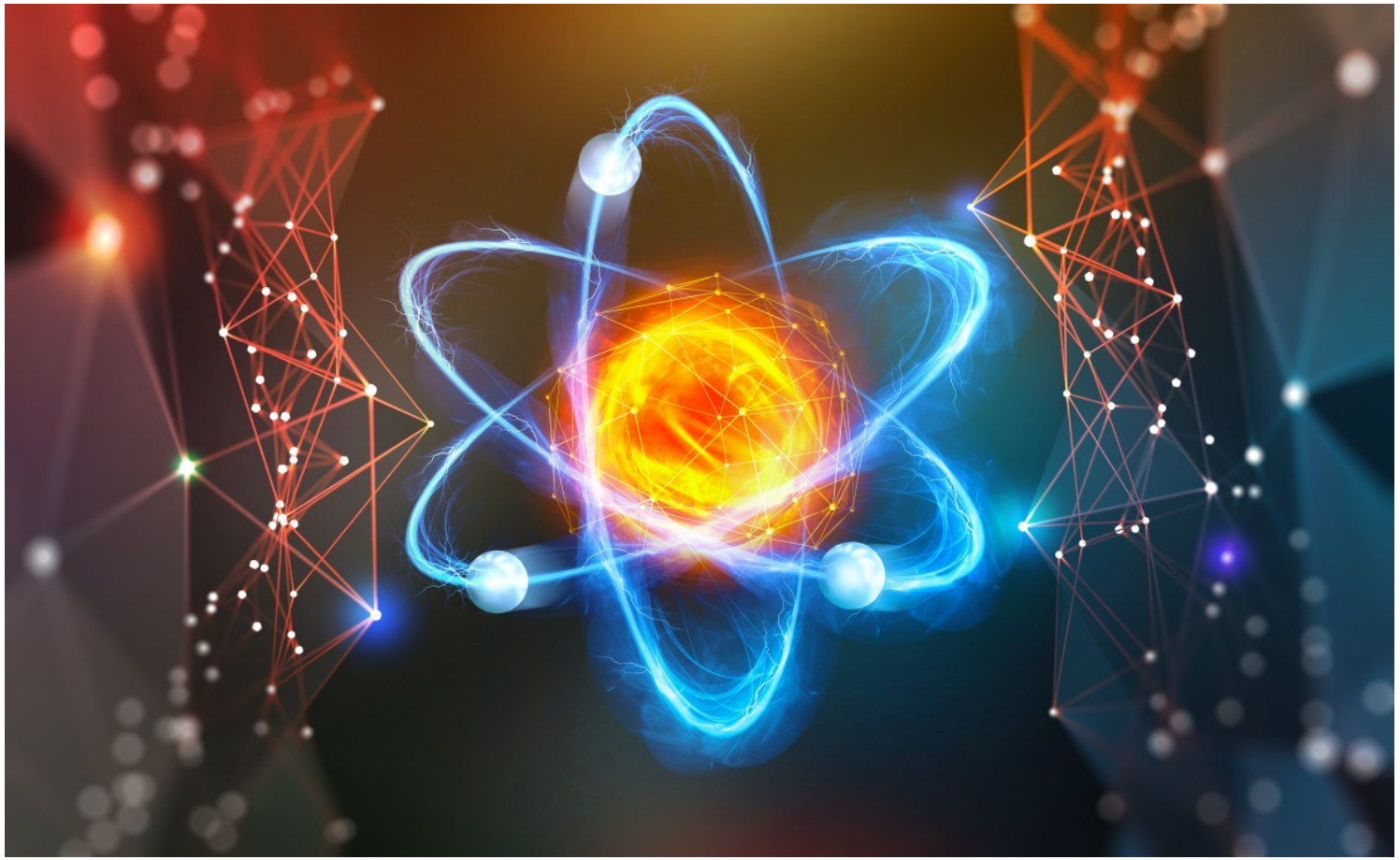
Atomic Physics

Introduction

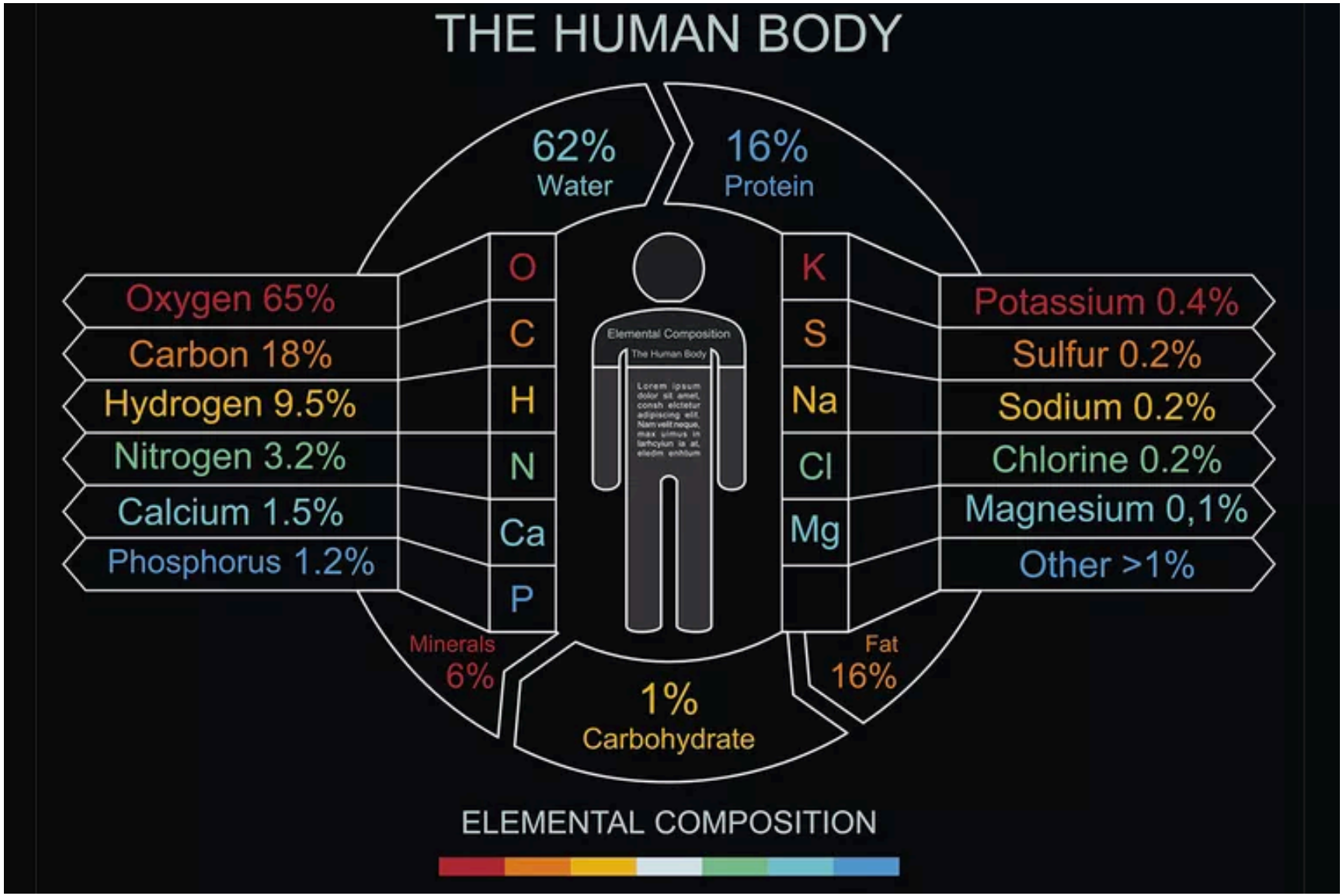


Class requirements

https://wisdomh5.zhihuishu.com/course/index/19885348917714616 32?courseId=1000008969&mapVersion=0



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

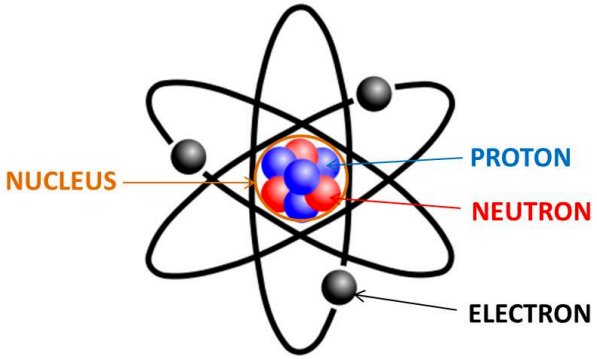


What is an atom

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



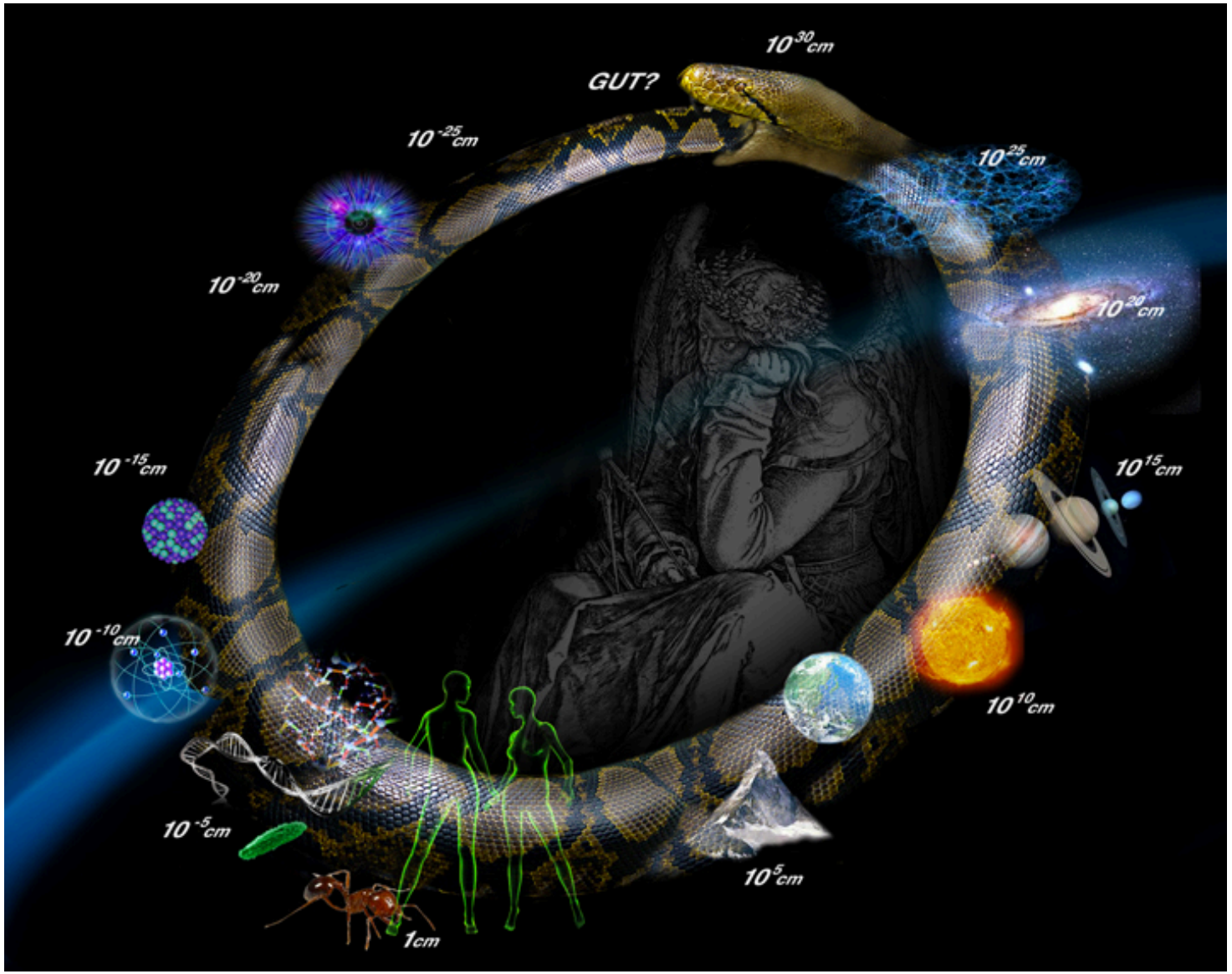
Mass range: 1.67×10^{-27} to 4.52×10^{-25} kg

Electric charge: zero (neutral), or ion charge

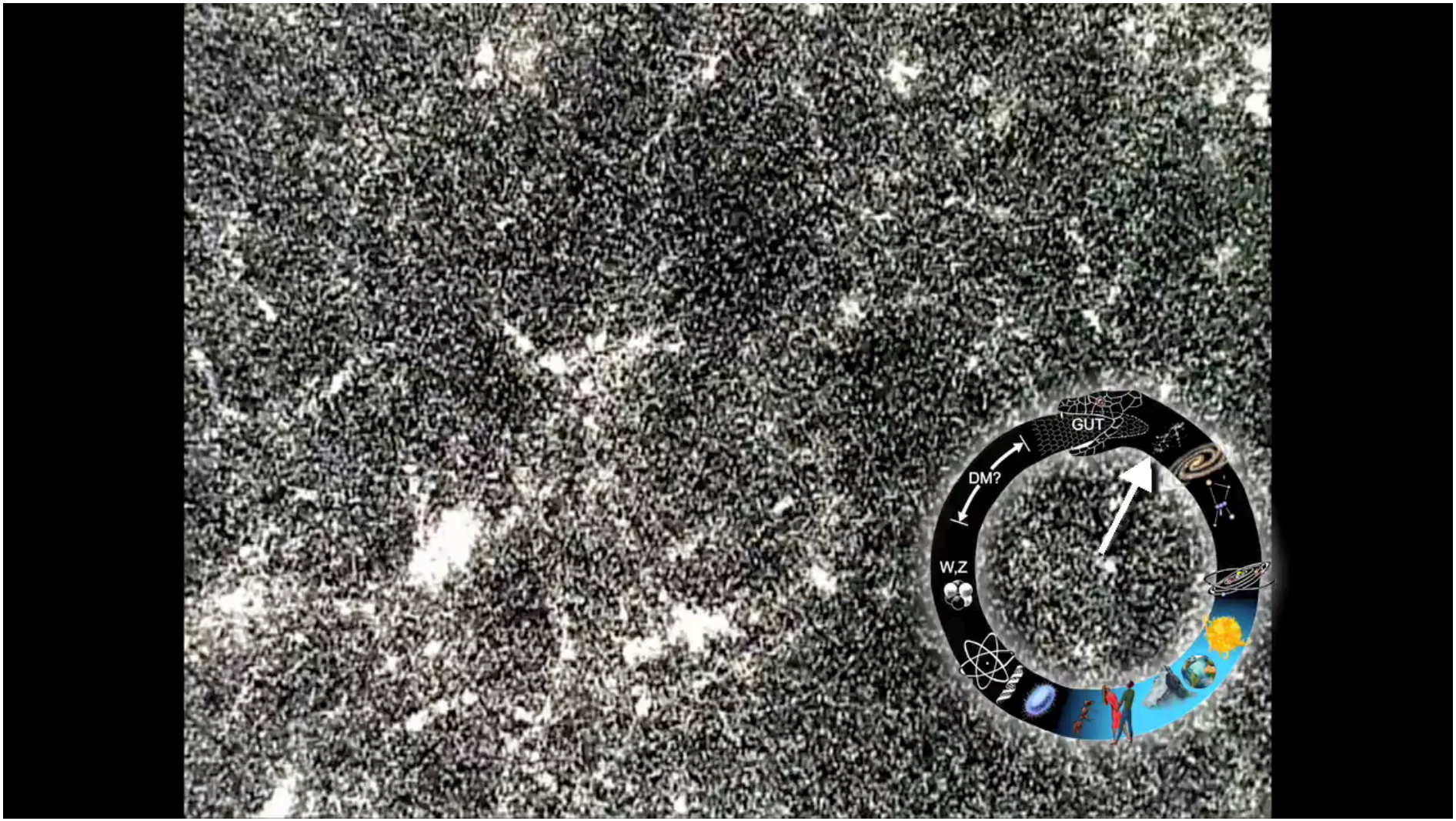
Diameter range: 62 pm (He) to 520 pm (Cs)

Components: Electrons and compact nucleus of protons and neutrons

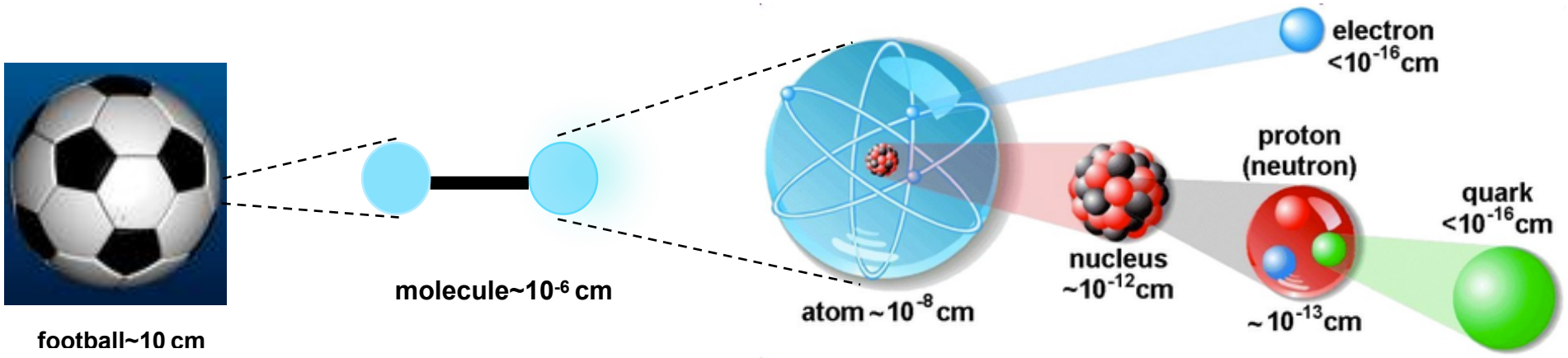
Cosmic Uroboros



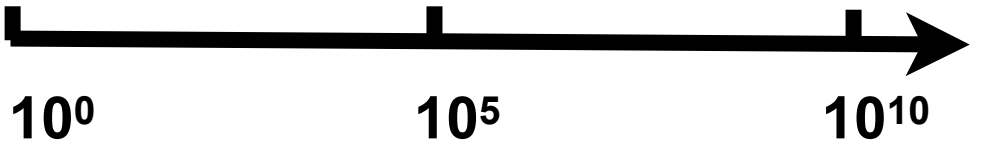
Cosmic Uroboros



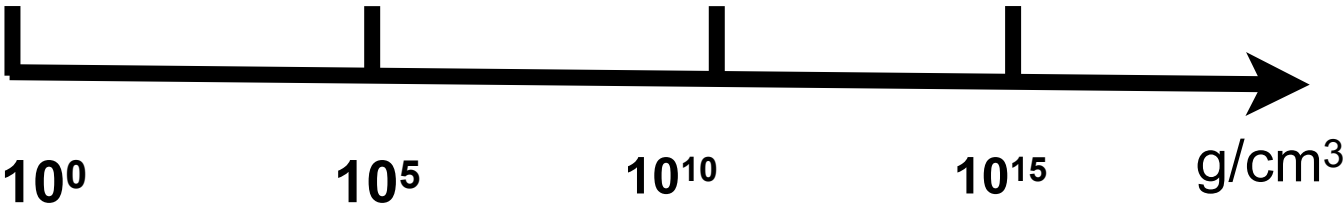
Atom size



Range of excitation energies



Range of densities



群聊：2026原子物理金牛班



该二维码7天内(3月9日前)有效，重新进入将更新

The introduction from deepseek

南開大學

请详细论述原子物理的发展历史，作为大学二年级物理专业必修课《原子物理》课程的导论

已深度思考（用时 35 秒）

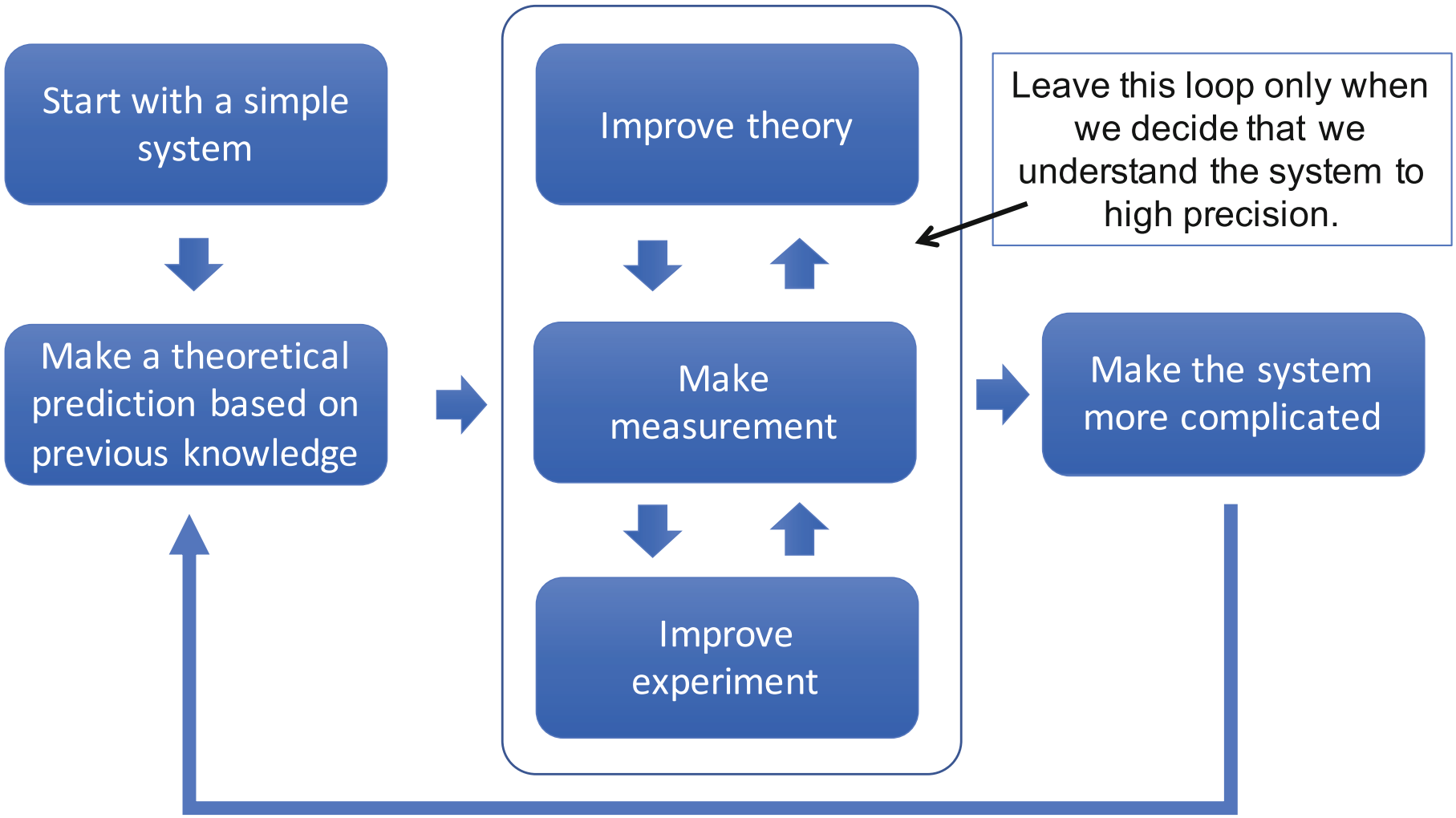
好的，用户让我详细论述原子物理的发展历史，作为大学二年级物理专业必修课《原子物理》课程的导论。首先，我需要确定用户的需求是什么。作为导论，应该要全面但简洁，适合刚接触原子物理的学生。需要涵盖从古代原子概念到现代发展的整个历程，同时要突出关键人物和实验，以及理论的发展脉络。

用户是物理专业大二学生，可能已经学过普通物理和一些基础量子力学，但原子物理课程可能更注重实验现象和经典理论。导论需要激发学生的兴趣，并为他们后续学习打下基础。因此，我需要将历史发展分成几个阶段，每个阶段的重要发现和理论突破，同时强调这些发现如何推动学科发展。

首先，我应该从古希腊的原子论开始，说明早期的哲学思想如何影响后来的科学。然后是19世纪的化学原子论，道尔顿的贡献，接着是气体动理论和统计力学的萌芽，这为原子物理奠定了基础。

接下来是经典物理时期的实验发现，比如阴极射线、电子的发现（汤姆逊）、α粒子散射实验（卢瑟福的核模型），以及经典理论的局限性，比如黑体辐射问题和紫外灾难，引出量子论的诞生。

How to understand the world



Short Historical Review

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

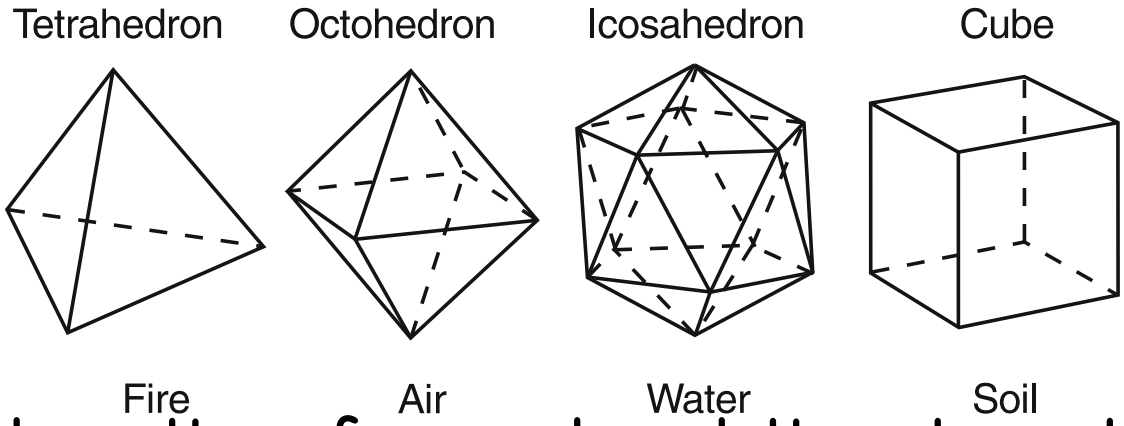
✓The first atomic theories of the structure of matter were those of Democritus (460 - 370 B.C.), who both taught that all natural bodies consist of "infinitely small" particles that completely fill the volume of the bodies and are not further divisible. They called these particles "atoms".



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

南開大學

✓"端：体之无序最前者也"　　《墨经》

✓"语小，天下莫能破焉"。　　《中庸》

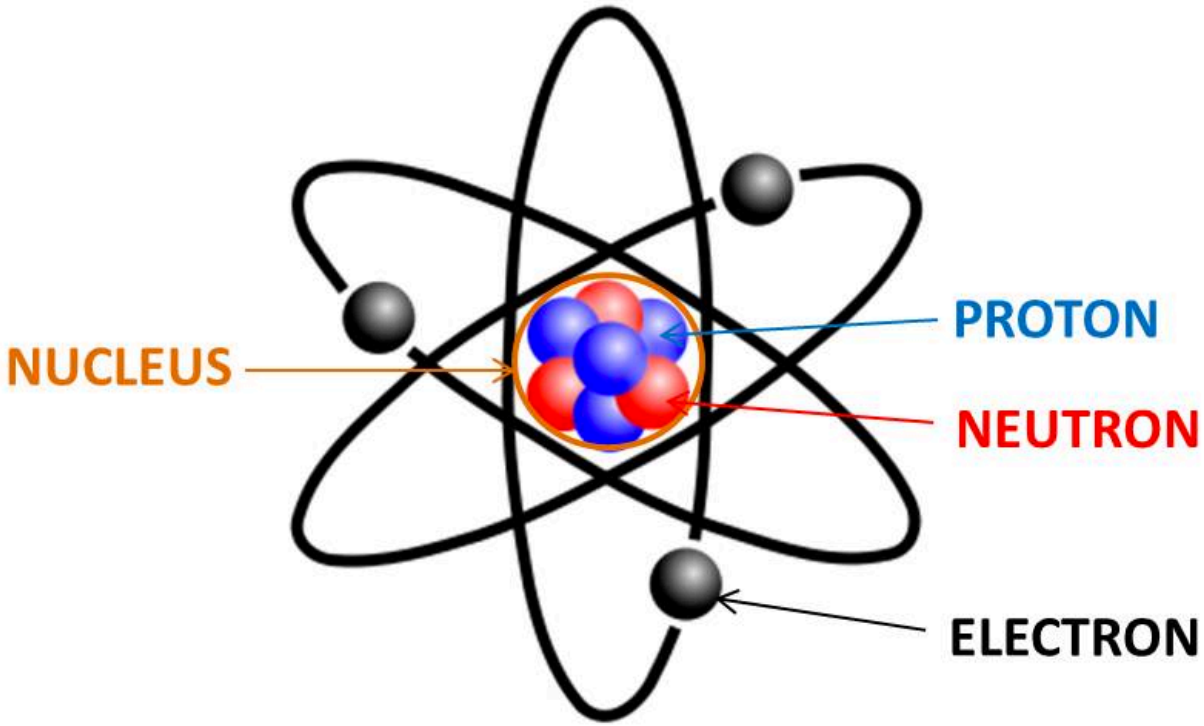
✓"一尺之棰，日取其半，万世不竭"　　《庄子·天下篇》





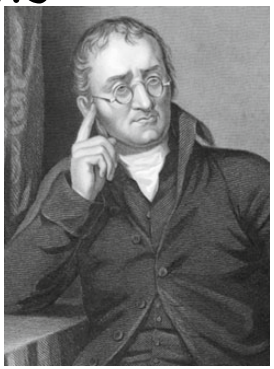
Short Historical Review

✓ 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

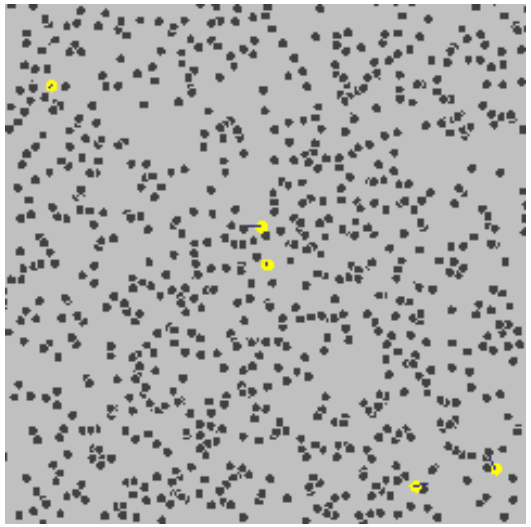
✓1808 The volume of gaseous reactants occur as ratios of small integers (Gay-Lussac) （在同温同压下，气体相互之间按照简单体积比例进行反应，并且生成的任一气体产物也与反应气体的体积成简单整数比）

✓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

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✓ 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)



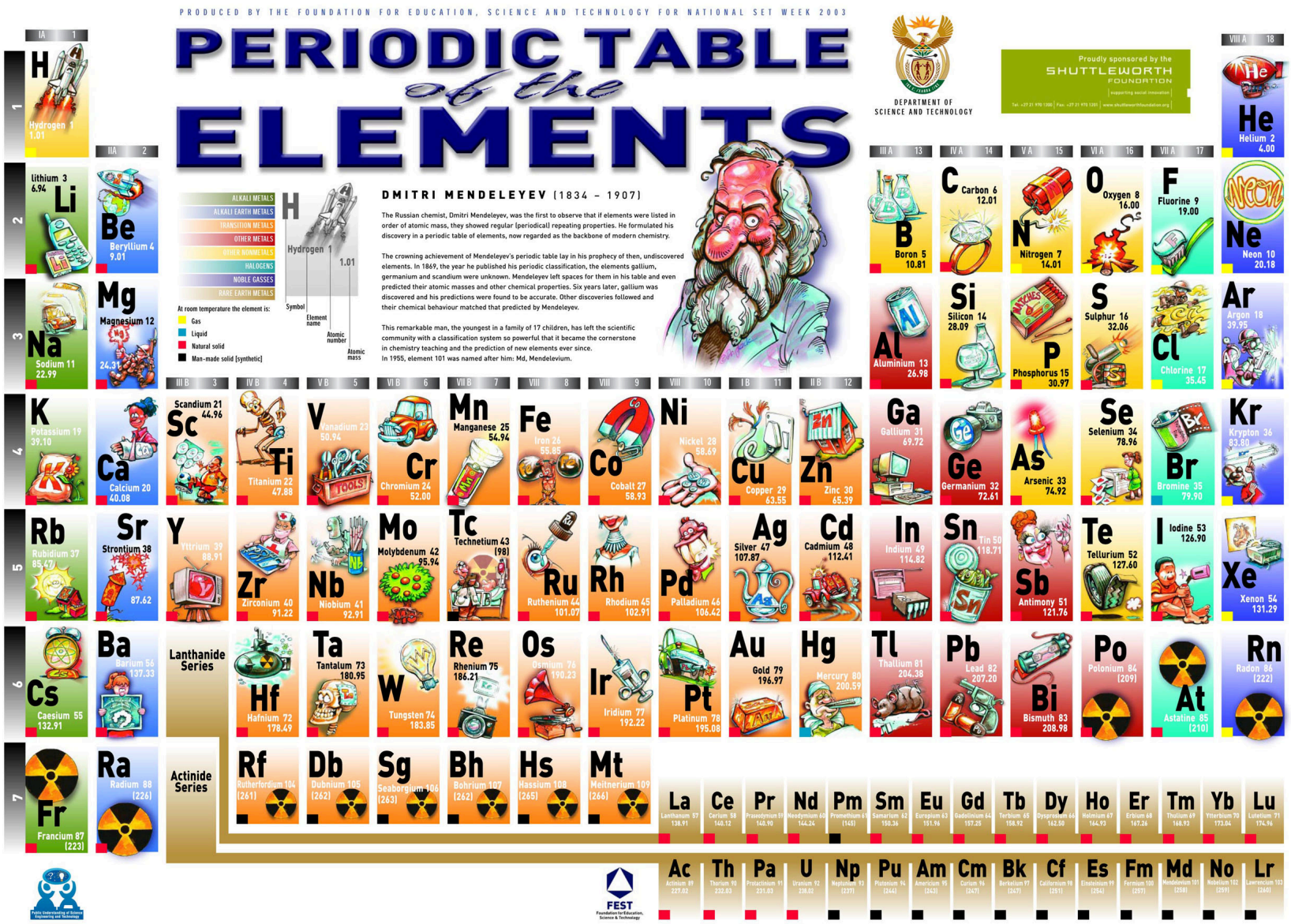
ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ,

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

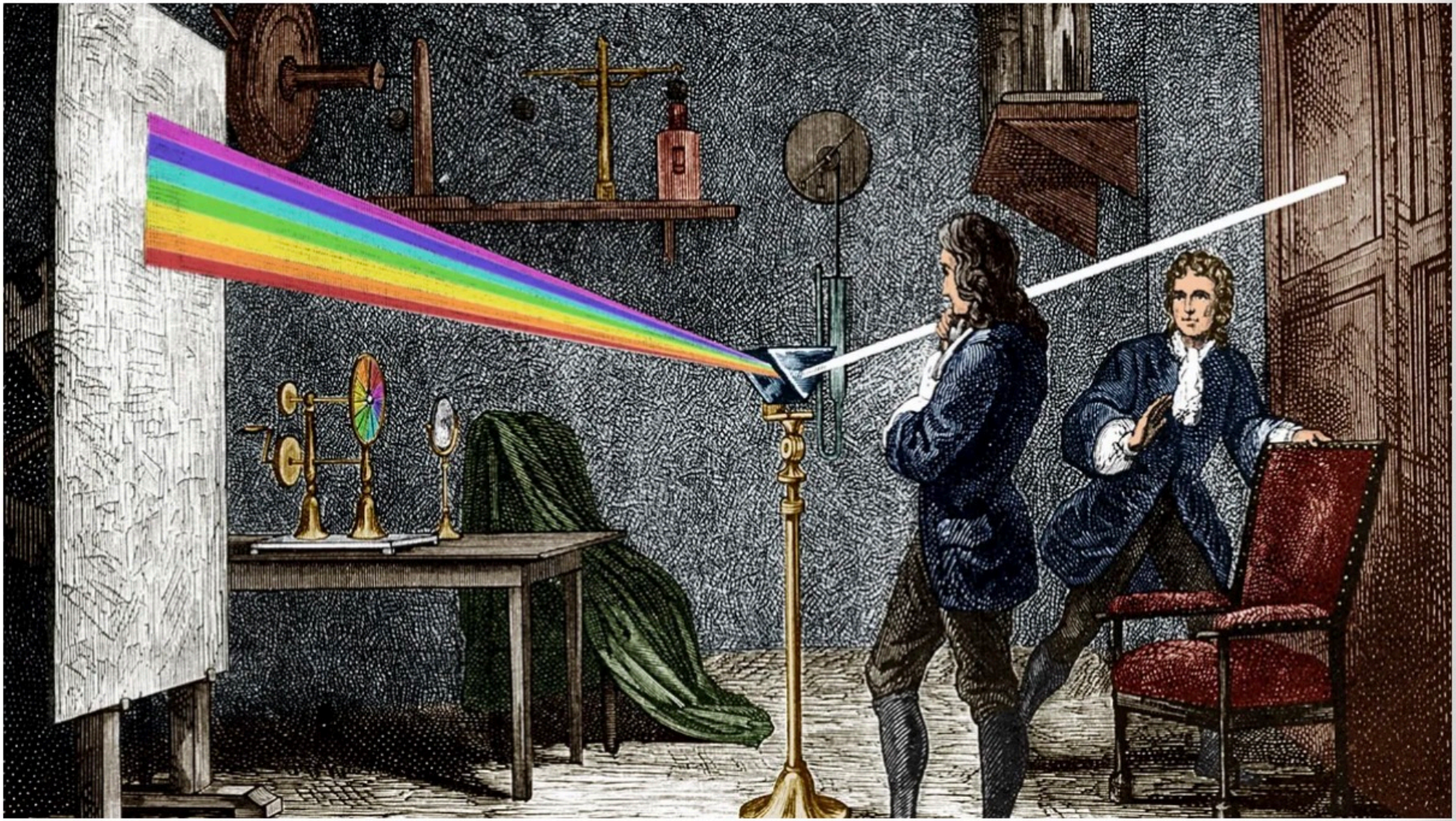
			Ti=50	Zr=90	?=180.
			V=51	Nb=94	Ta=182.
			Cr=52	Mo=96	W=186.
			Mn=55	Rh=104,4	Pt=197,1.
			Fe=56	Ru=104,4	Ir=198.
			Ni=Co=59	Pd=106,6	Os=199.
H=1			Cu=63,4	Ag=108	Hg=200.
	Be= 9,4	Mg=24	Zn=65,2	Cd=112	
	B=11	Al=27,3	?=68	Ur=116	Au=197?
	C=12	Si=28	?=70	Sn=118	
	N=14	P=31	As=75	Sb=122	Bi=210?
	O=16	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

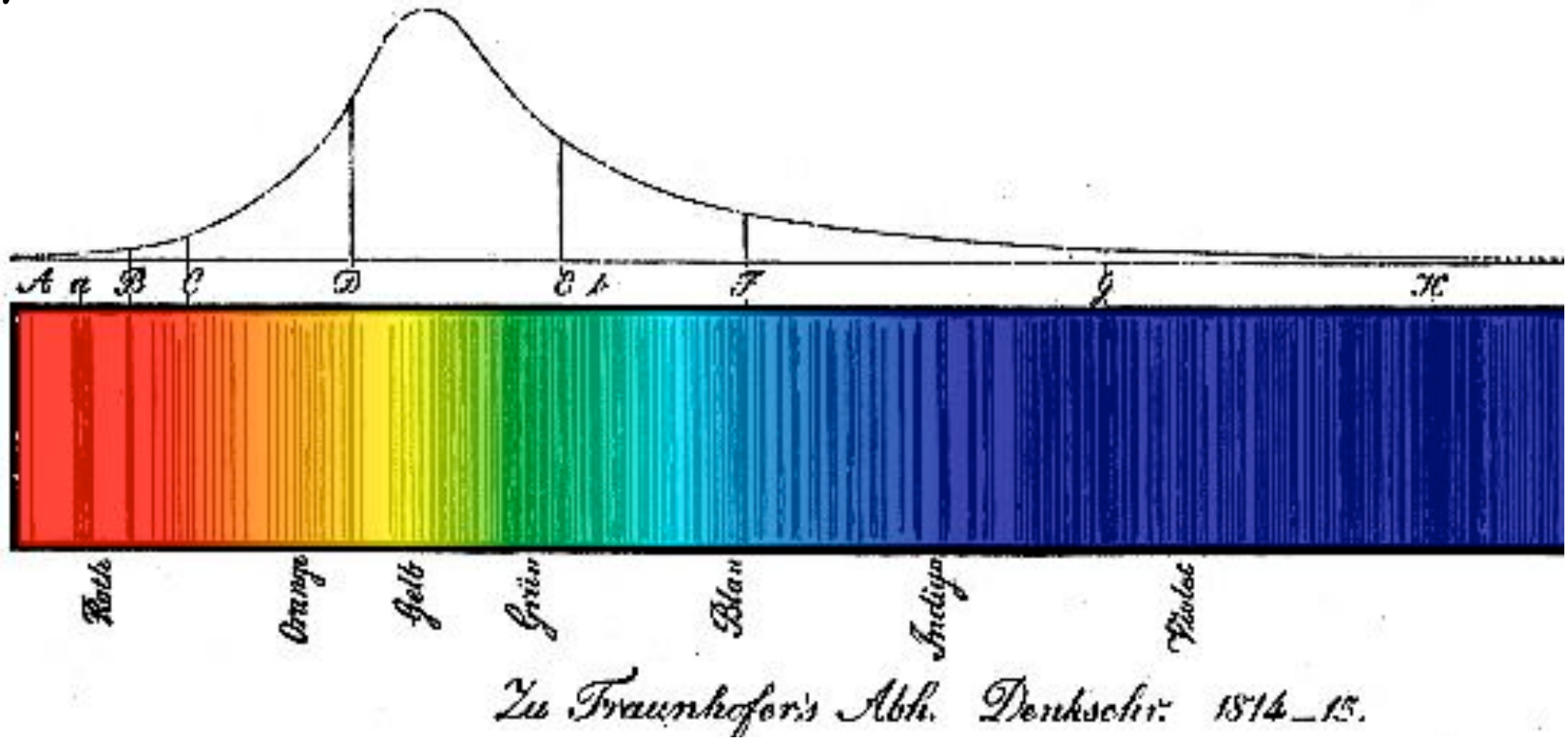


Light spectrum



Light spectrum

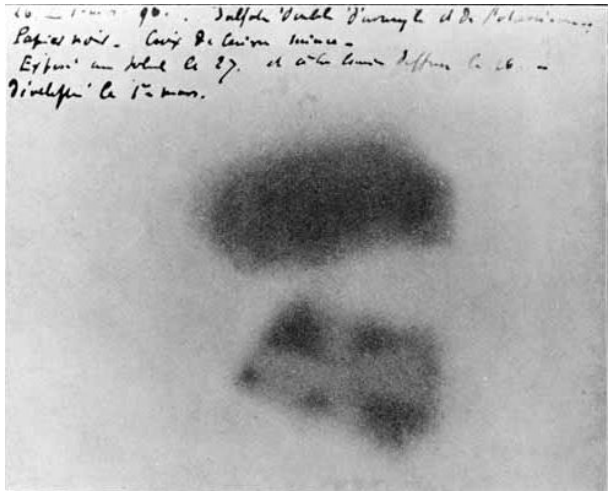
✓ In 1814, Fraunhofer's setup stretched (dispersed) the spectrum from the Sun, to reveal over 600 dark, absorption lines. He named the most distinct of these lines A, B, C...H and he counted some 574 lines between B and H.

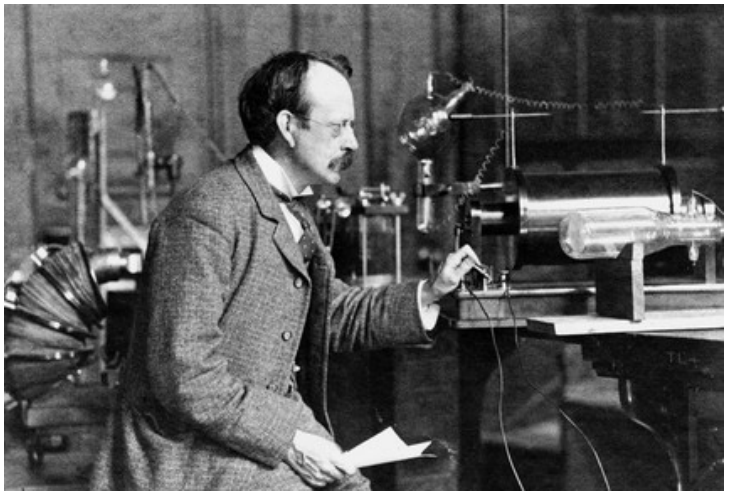


Short Historical Review

- ✓ 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)





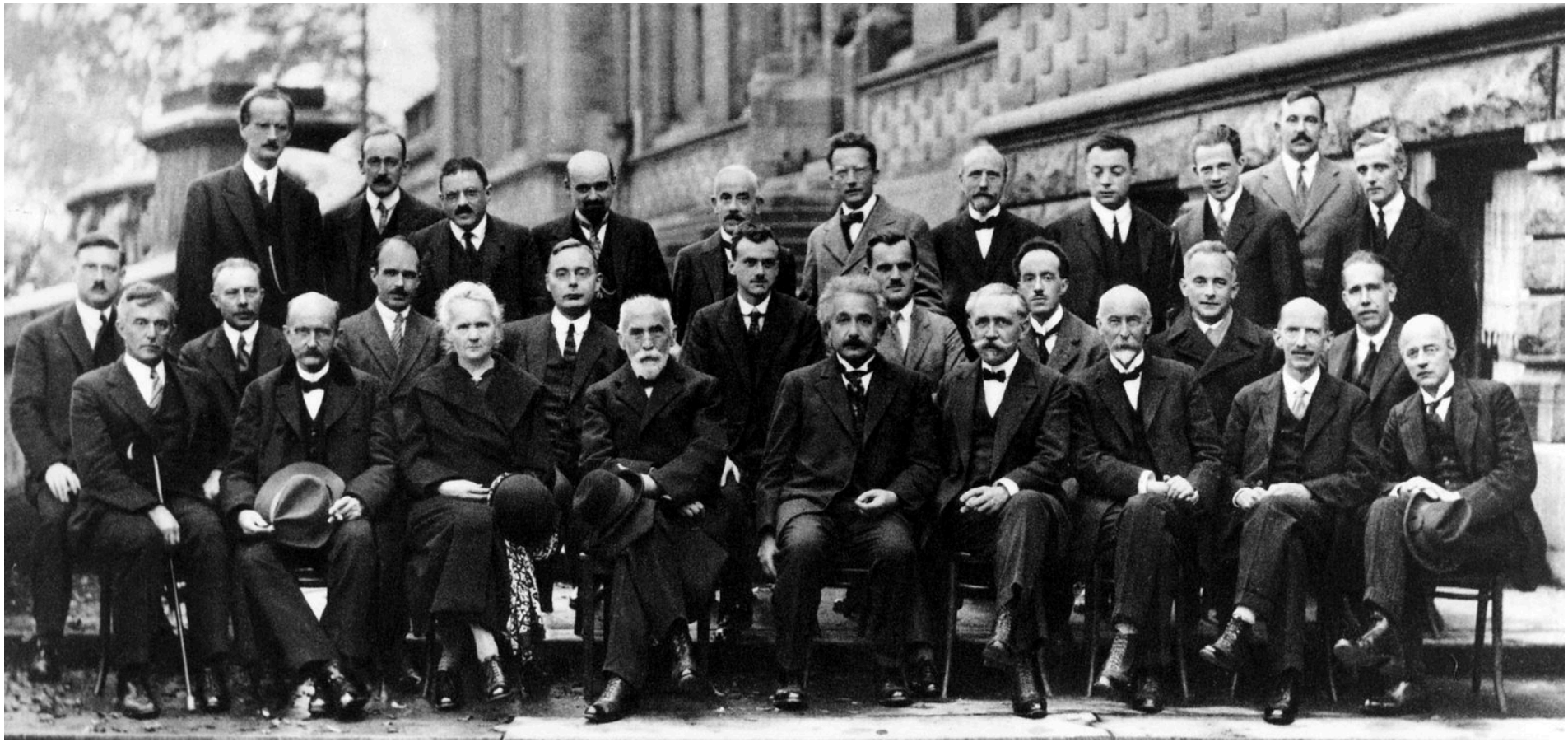


Short Historical Review

南開大學

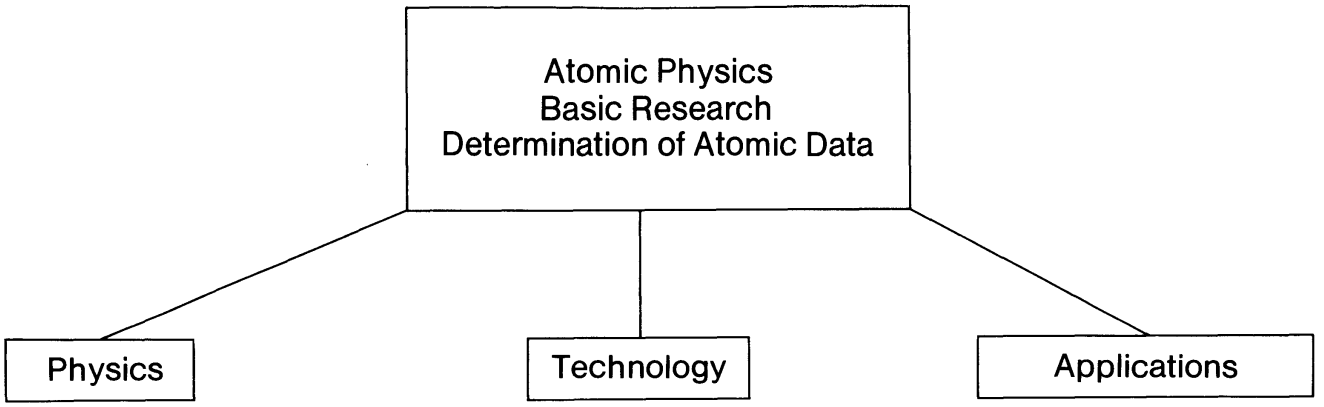
- ✓ 1885, Ordering principle in atomic spectra (J. Balmer)
- ✓ 1900, The laws of black body radiation (M. Plank)
- ✓ 1911, Planetary model of the atom (E. Rutherford)
- ✓ 1913, Bohr model for hydrogen
- ✓ 1925, Matter waves (De Broglie)
- ✓ 1926, Schroedinger equation (E. Schroedinger)
- ✓ 1928, Dirac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

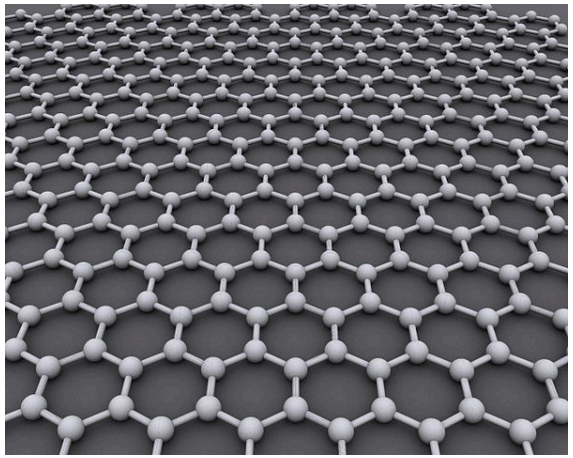
Determination of Units
Fundamental constants

Space Research
Earth and planetary atmospheres, weather

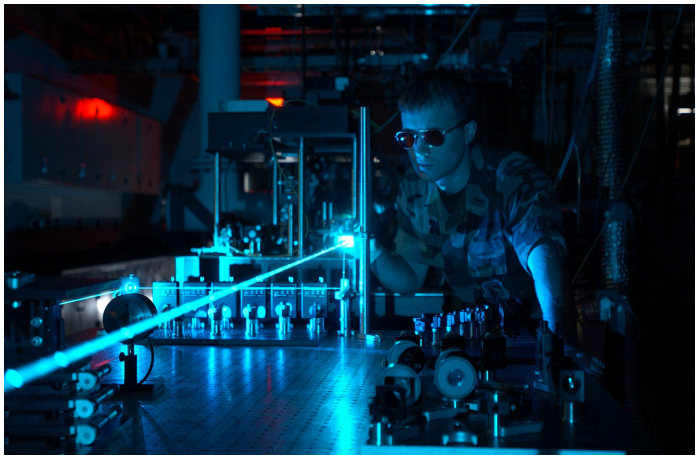
Environment
Detection of pollutants

Energy Problems
New methods of energy production

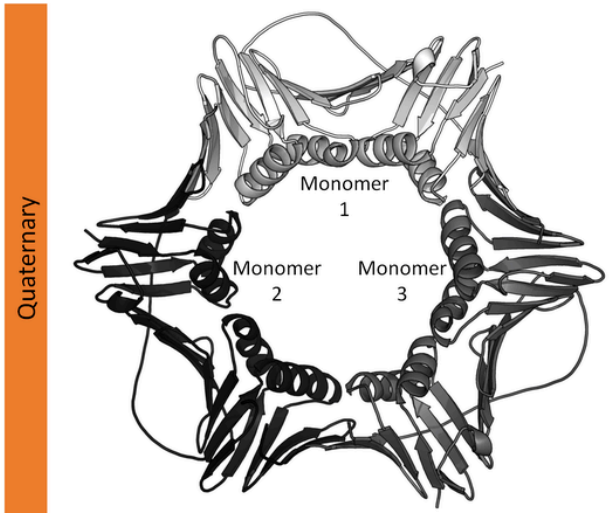
The application of atomic physics



Graphene



Laser



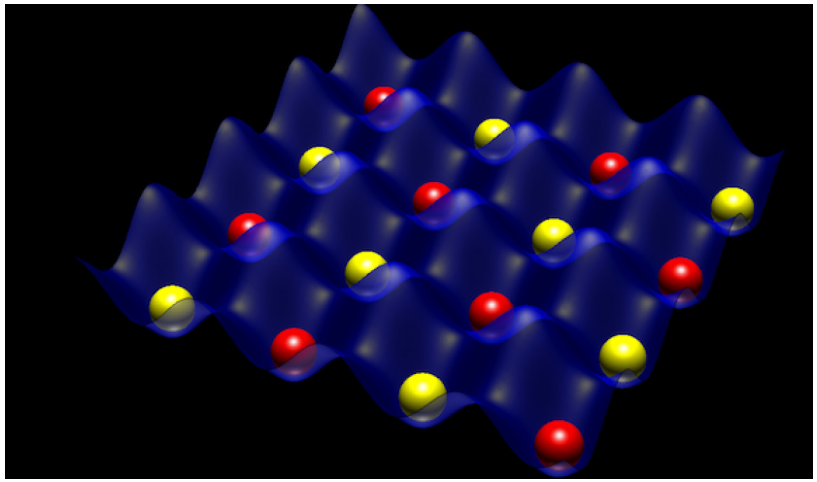
Biomolecular structure



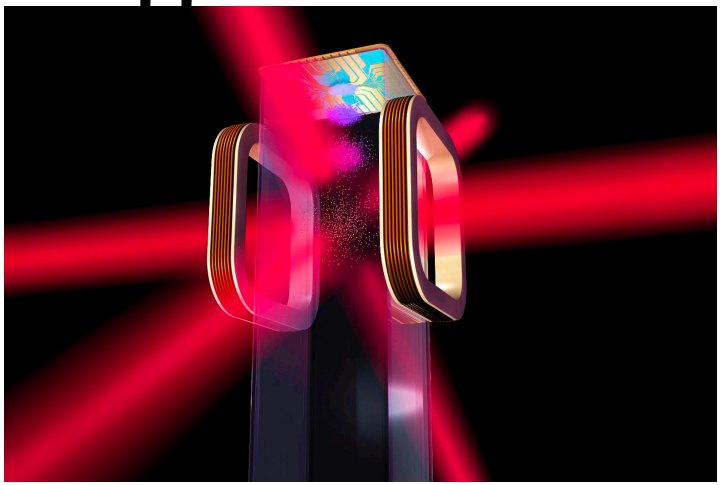
CT Scan

The application of atomic physics

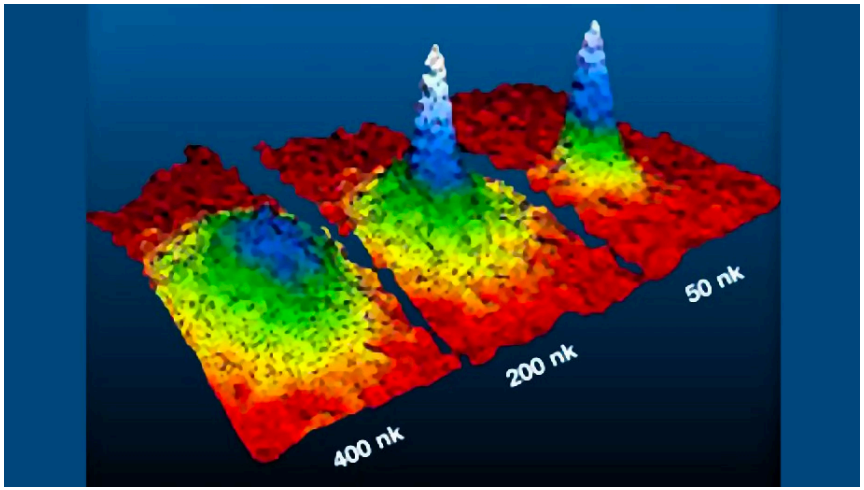
Optical lattice



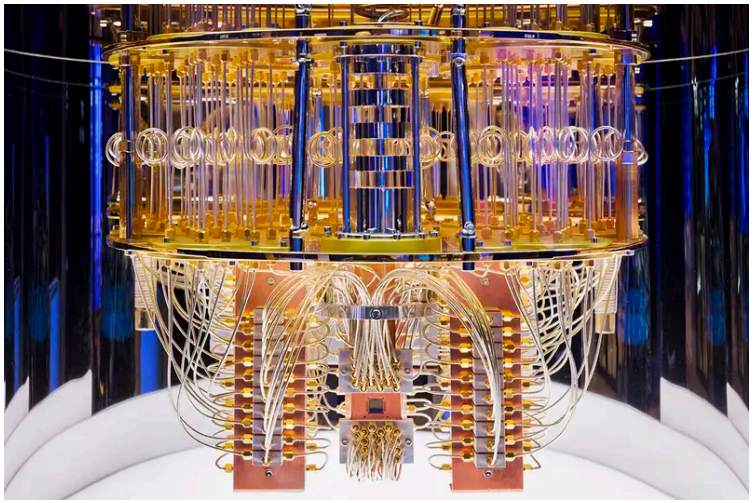
Trapped well



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)

- ✓ The light spectrum experiment
- ✓ The Thomson's Cathode Ray Experiment
- ✓ The black-body radiation experiment
- ✓ The photoelectric Effect experiment
- ✓ The Franck-Hertz experiment
- ✓ The Davisson-Germer Experiment
- ✓ The Stern-Gerlach experiment
- ✓ The Zeeman effect experiment
- ✓ The X-ray experiments
- ✓ The Compton experiments

施特恩—格拉赫实验其人其事

林志忠†
(台湾交通大学物理研究所及电子物理系)

2020－08－19收到
† email: jjlin@mail.nctu.edu.tw
DOI: 10.7693/wl20210207

如果你想从整体吸取力量，必须从细微之中看到整体。
——歌德

1 引言

1922年2月7日晚上至8日清早，德国中部城市气温低寒，下雪，法兰克福大学施特恩—格拉赫实验(Stern—Gerlach experiment)首次成功测量到了电中性银原子束在非均匀磁场中的双重分裂现象，明确印证了微观尺度世界的量子化特性本质，这是近代物理学史上的重大一笔!

实验是由格拉赫(Walther Gerlach，1889—1979)独自进行的，因子，以便可以清楚显影。在漫漫长夜里，如果仪器运转顺利，尤其是真空系统与装置的准直都维持正常平稳，格拉赫便会在一旁阅读文献、撰写论文，或是准备上课讲义，与今日的科学研究者的专注工作形式无异。

2 分子束方法的庞大威力

1911年，法国科学家Louis Dunoyer首度演示钠原子在真空中的运动，的确有如光子般沿直线前进，一颗原子都拥有同样的线性动量[1)]。由于原子束的速度可以精确调控，因此施特恩马上想到了利用这项技术，在1920年验证了麦克斯韦—玻尔兹曼分子速率分布(Maxwell—Boltzmann distribution of molecular speeds)的理论函数。紧接着，他与格拉赫合作，在1922年检验了角动量空间量子化的理论预测——当时许多著名物理学家都认为空间量子化只是一种理论猜想(冥想)，或一种数学符号而已，无关物理真实。

验证原子能级量子化的里程碑：弗兰克—赫兹实验

林志忠†

(台湾阳明交通大学电子物理系　新竹　30010)

“他们发现了一个电子撞击一个原子时所遵循的定律”

——1925年弗兰克与赫兹获得诺贝尔物理学奖时的颁奖词

2024－05－06收到

† email: jjlin@nycu.edu.tw

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1　引言

古斯塔夫·赫兹(Gustav Hertz，1887—1975)于1911年从柏林洪堡大学获得博士学位之后，詹姆斯·弗兰克(James Franck，1882—1964)随即邀请他一起在柏林大学进行气体放电相关实验。他们的合作只持续了三年，到了1914年第一次世界大子论模型(发表于1913年7月)预测的电子能级分立(离散而不连续)，提供了坚实的测量证据，使该项革命性理论预测，从看似不可思议的异想天开(奇想)，摇身成为确凿的微观世界的“事实”，“弗兰克—赫兹实验(Franck—Hertz experiment)”一词，从此写入近代物理学课本中，他们两人并因这一项丰功伟绩，致力于测量低压气体放电管中的电子及离子平均自由程、离子迁移率、电子能量分布和电子结合能，其主要动机在于研究各种(惰性)气体及金属原子的电离势(ionization potential)或电离能(ionization energy)，希望了解电和物质的本质。弗兰克和赫兹则企盼建立一个关于气体中的电子的动力学理论(a