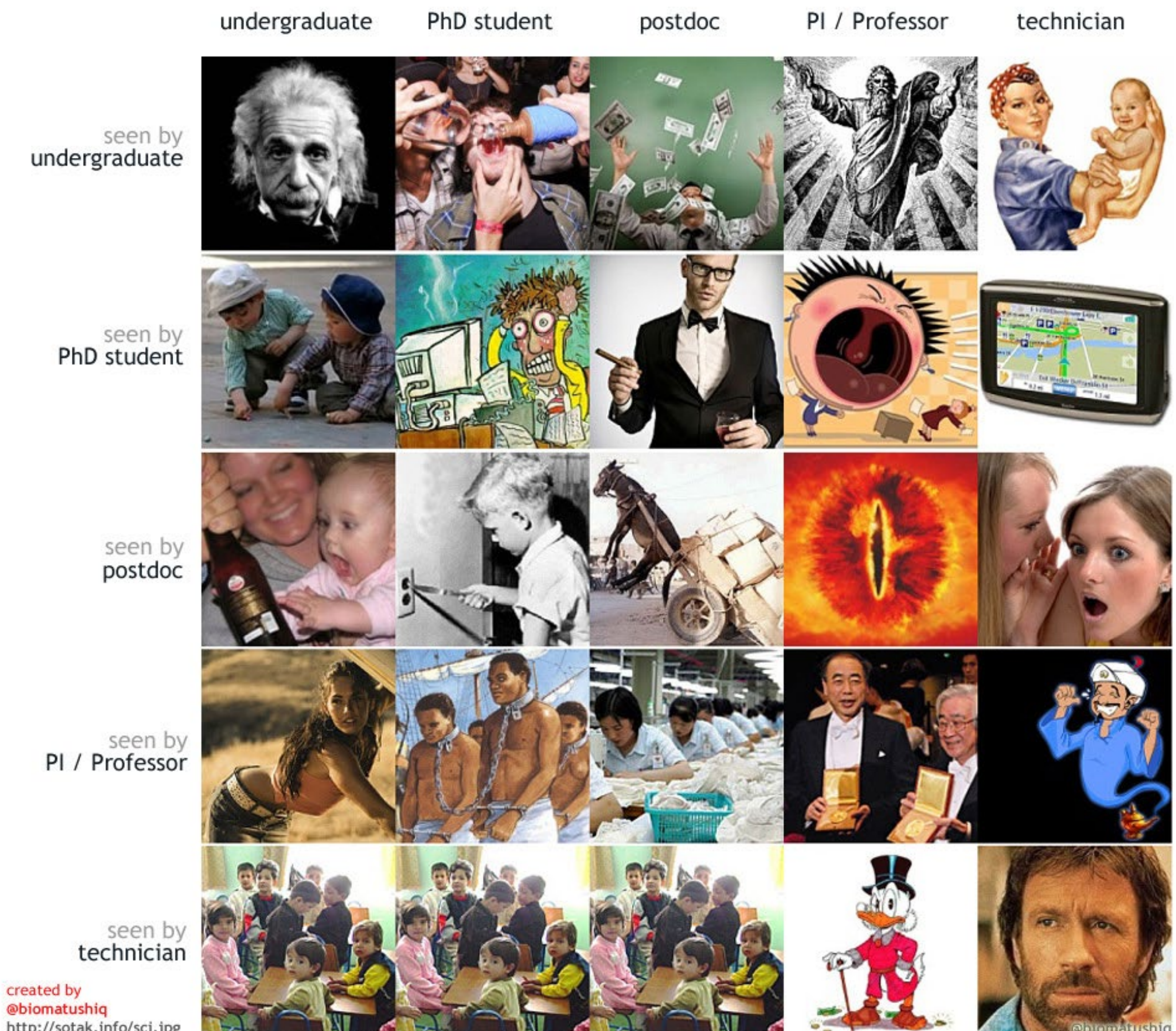
TABLE OF INFORMATION

| | |
|---|---|
| Rest mass of the electron | $m_e = 9.11 \times 10^{-31}$ kilogram $= 9.11 \times 10^{-28}$ gram |
| Magnitude of the electron charge | $e = 1.60 \times 10^{-19}$ coulomb $= 4.80 \times 10^{-10}$ statcoulomb (esu) |
| Avogadro's number | $N_A = 6.02 \times 10^{23}$ per mole |
| Universal gas constant | $R = 8.31$ joules/(mole • K) |
| Boltzmann's constant | $k = 1.38 \times 10^{-23}$ joule/K $= 1.38 \times 10^{-16}$ erg/K |
| Speed of light | $c = 3.00 \times 10^{8}$ m/s $= 3.00 \times 10^{10}$ cm/s |
| Planck's constant | $h = 6.63 \times 10^{-34}$ joule • second $= 4.14 \times 10^{-15}$ eV • second |
| | $\hbar = h/2\pi$ |
| Vacuum permittivity | $\epsilon_0 = 8.85 \times 10^{-12}$ coulomb$^2$/(newton • meter$^2$) |
| Vacuum permeability | $\mu_0 = 4\pi \times 10^{-7}$ weber/(ampere • meter) |

**在科学家座谈会上的讲话**
（2020年9月11日）
习近平

现在，我国经济社会发展和民生改善比过去任何时候都更加需要科学技术解决方案，都更加需要增强创新这个第一动力。同时，在激烈的国际竞争面前，在单边主义、保护主义上升的大背景下，我们必须走出适合国情的创新路子，特别是要把原始创新能力提升摆在更加突出的位置，努力实现更多“从0到1”的突破。希望广大科学家和科技工作者肩负起历史责任，坚持面向世界科技前沿、面向经济主战场、面向国家重大需求、面向人民生命健康，不断向科学技术广度和深度进军。

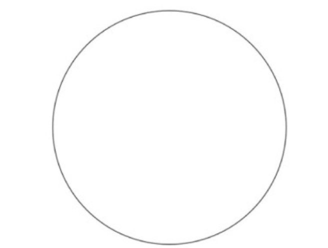
# How people in science see each other



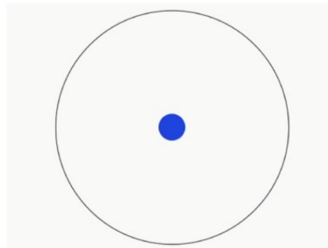

Chuck Norris

# The Illustrated Guide to a Ph.D by Matt Might

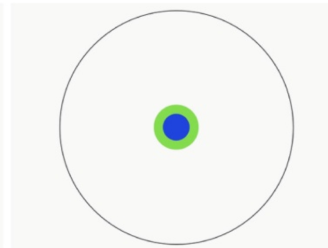
Imagine a circle that contains all of human knowledge:



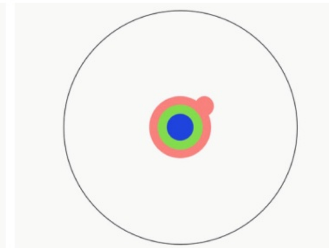
By the time you finish elementary school, you know a little:



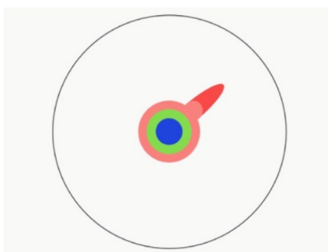
By the time you finish high school, you know a bit more:



With a bachelor's degree, you gain a specialty:

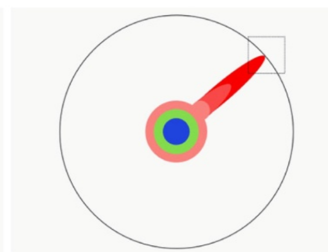


A master's degree deepens that specialty:

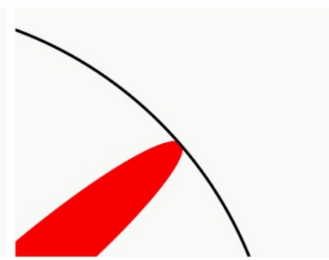


Reading research papers takes you to the edge of human knowledge:

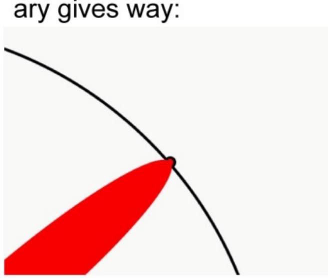
Once you're at the boundary, you focus:



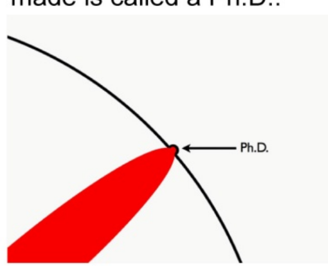
You push at the boundary for a few years:



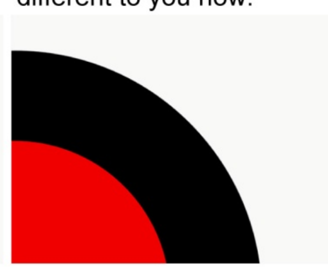
Until one day, the boundary gives way:



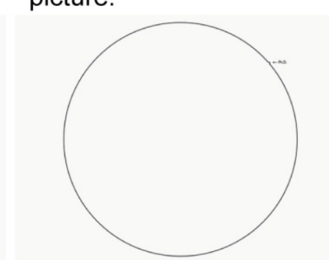
And, that dent you've made is called a Ph.D.:




Of course, the world looks different to you now:



So, don't forget the bigger picture:



Keep pushing.


5
10
20
50
100
200
500

*吾生也有涯，而知也无涯。以有涯随无涯，殆已！* —庄子

*学而不思则罔，思而不学则殆。* — Confucius

# Reference books

**Modern Atomic & Nuclear Physics, Fujia Yang and J. H. Hamilton, World Scientific Publishing Co., 2010**

**原子物理学（第四版），杨福家，高等教育出版社，2008**

**Introduction to Quantum Mechanics (2nd Edition), David J. Griffiths, 机械工业出版社 (reprint Edition)**

**量子力学 卷I 曾谨言，科学出版社**

**量子物理（新概念物理教程），赵凯华 罗蔚茵 高等教育出版社**

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**Chapter 1**
**The Configuration of the Atom: Rutherford Model**

**Chapter 2**
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**Chapter 3**
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**Fine Structure in Atomic Spectra: Electron Spin**

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**Chapter 6**
**X-rays**

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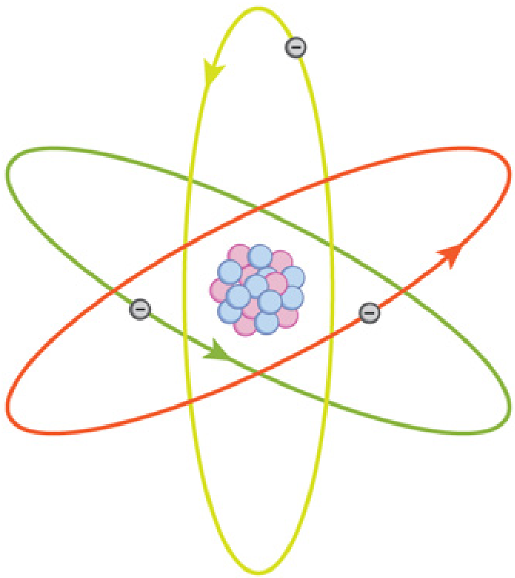
**The Configuration of the Atom: Rutherford Model**



atomic planetary model
Rutherford, 1911


USA Atomic Energy Commission
1946-1975

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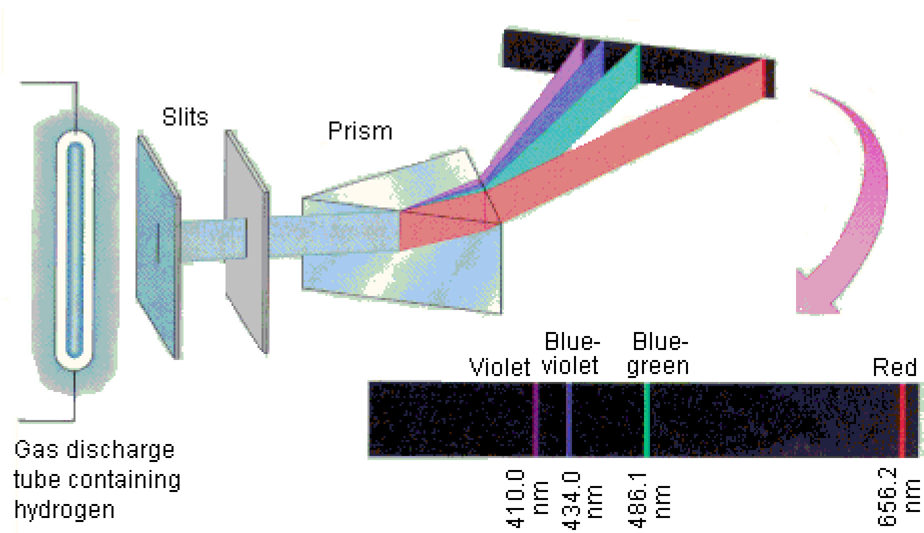
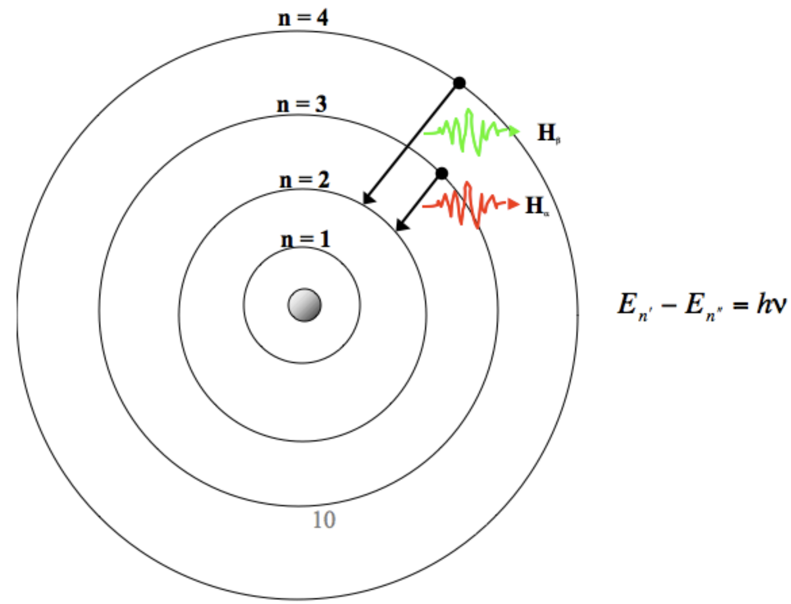
## Chapter 2
## Introduction of Quantum Concepts and the Bohr Model

### Spectrum of Atomic Hydrogen




**Chapter 3**
**Introductory Quantum Mechanics: Concepts and the Schrödinger Equation**

## Schrödinger equation

$$i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},t) = \hat{H}\Psi(\mathbf{r},t)$$

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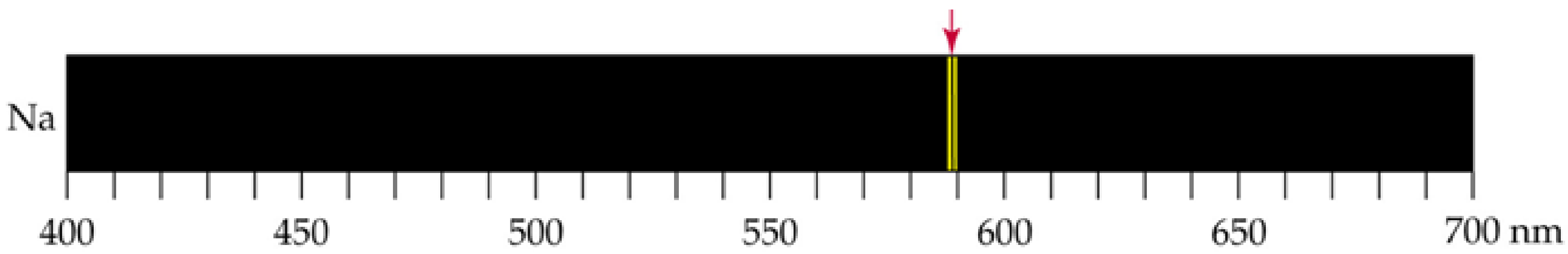
**Chapter 4**
**Fine Structure in Atomic Spectra: Electron Spin**




doublet lines of Alkali Metals

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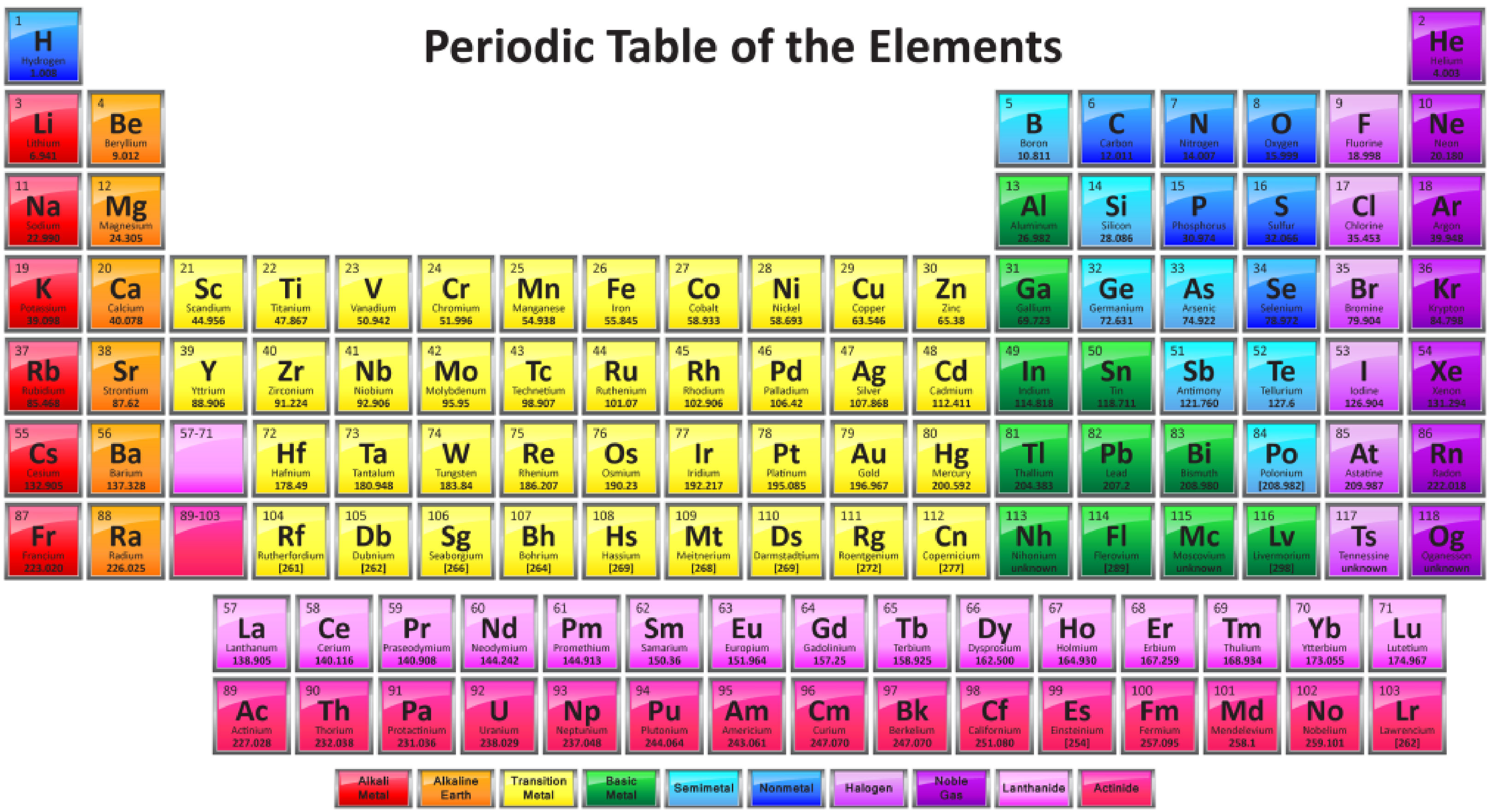
## Chapter 5
## Multi-Electron Atoms: The Pauli Exclusion Principle

Mendeleev (1869)



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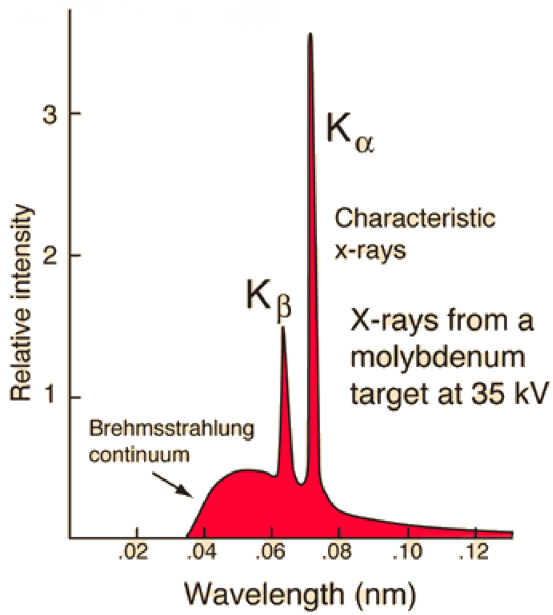
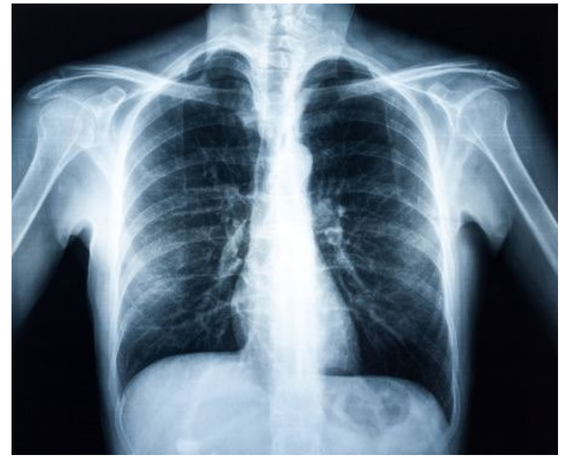
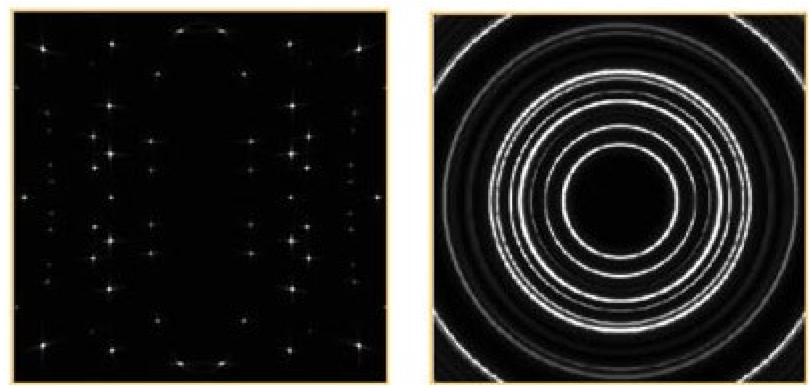
## Chapter 6
## X-rays




X-ray emission spectrum





X-ray Diffraction (XRD)

# Grading Policy

**Homework (30%)**
**Attendance (10%)**
**Final Exam (60%)**

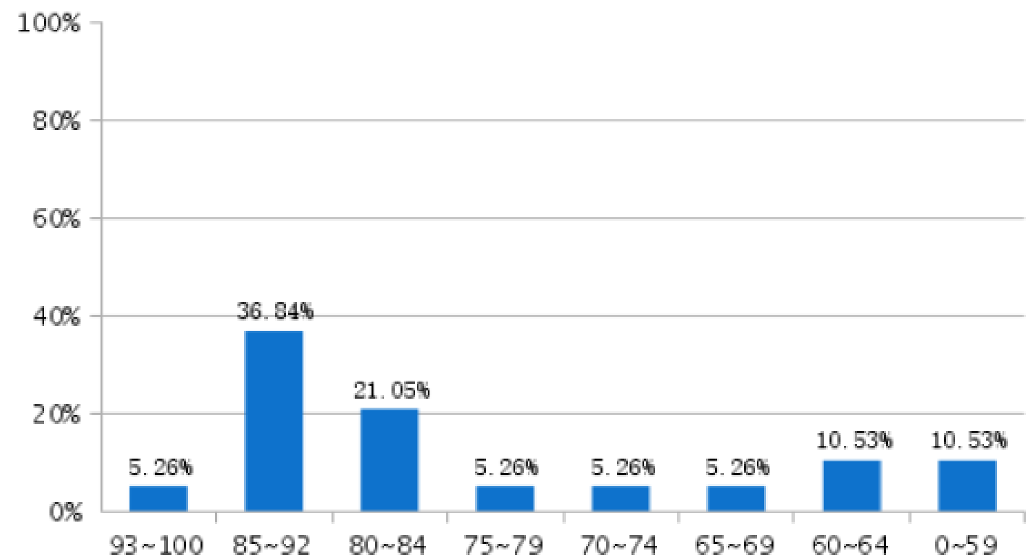
# 深圳大学期末考试试卷分析表

2018-2019学年第一学期

第1页， 共1页

| 课程编号 | 6400370002 | 课程名称 | 量子力学（1） |
|---|---|---|---|
| 课序号 | 01 | 课程类别 | 专业选修课 |
| 课程学分 | 4 | 考核表样式 | 期末考试(有附加题) |
| 考试方式 | 闭卷 | 主讲教师 | 李武 |
| 实考人数 | 19 | | |

| 期末基本题得分情况 | | | | | |
|---|---|---|---|---|---|
| 93～100: | 1 | 人， | 占总数: | 5.26% |
| 85～92: | 7 | 人， | 占总数: | 36.84% |
| 80～84: | 4 | 人， | 占总数: | 21.05% |
| 75～79: | 1 | 人， | 占总数: | 5.26% |
| 70～74: | 1 | 人， | 占总数: | 5.26% |
| 65～69: | 1 | 人， | 占总数: | 5.26% |
| 60～64: | 2 | 人， | 占总数: | 10.53% |
| 0～59: | 2 | 人， | 占总数: | 10.53% |
| 最高分: | 93 | 最低分: | | 15 |
| 平均分: | 75.63 | 标准差: | | 18.28 |
| 附加题有效得分: | 2 | 人， | 占总数: | 10.53% |



# A sample Exam Question

二. (10 points) When alpha particles are directed onto atoms in a thin foil, some make very close collisions with the nuclei of the atoms and are scattered at large angles. If an alpha particle with an initial kinetic energy of 5MeV happens to be scattered through an angle of 180 degree, what is its distance of the closest approach to the scattering nucleus?(Assume that the metal foil is made of silver, with Z=50. $m_{Ag}$=107.9u, $m_{\alpha}$=4.0u)

群名称：IAS2020量子力学(I)
群　号：579464568

**Office hours:**
**4-6pm,**
**Wednesday,**
**Office 341**

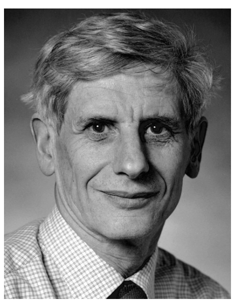
# Academic Family Tree

Arnold Sommerfeld
(1868–1951)

Werner Heisenberg (1901-1976)
(**Nobel Prize 1932**)

Hans Bethe (1906-2005)
(**Nobel Prize 1967**)

Rudolf Peierls(1907–1995)



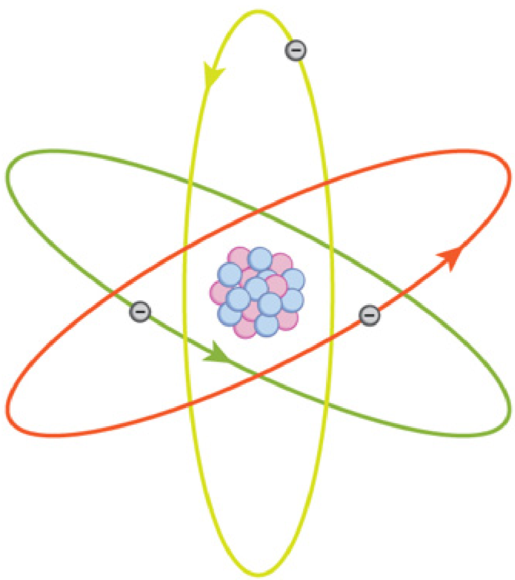
David J. Thouless, (1934-2019)
(**Nobel Prize 2016**)

牛谦(UT Austin)

吴飙(PKU)

李武(SZU)

# Chapter 1
# The Configuration of the Atom: Rutherford Model



atomic planetary model
Rutherford, 1911

# Lecture 02　Background

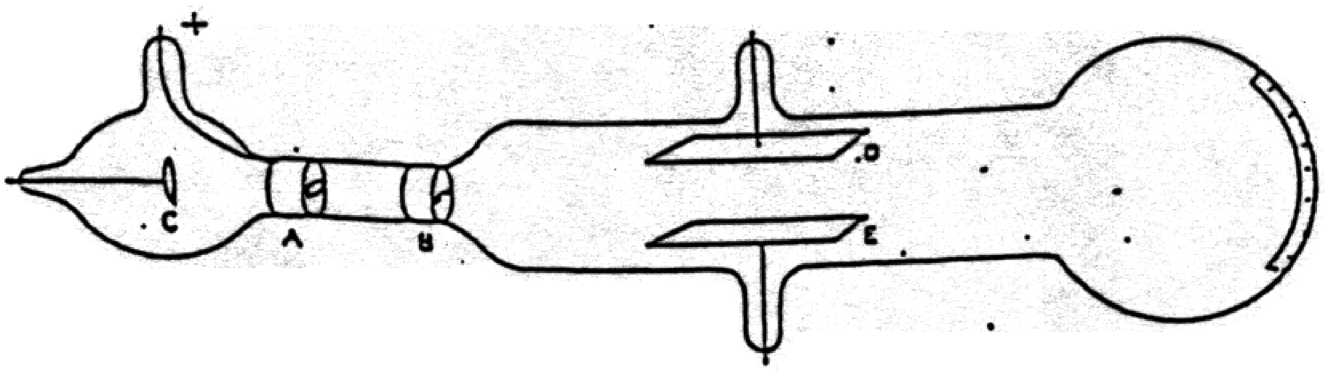
# 3 discoveries in the late 19th century

X-ray (Rontgen, 1895)
**Radioactivity (Becquerel, 1896)** **beginning of nuclear physics**
Electron (Joseph J. Thomson, 1897)

# Electron Discovery Experiment

In 1874 G. J. Stoney introduced the concept "*fundamental unit quantity of electricity*", and proposed the term "*electron*" in 1891.

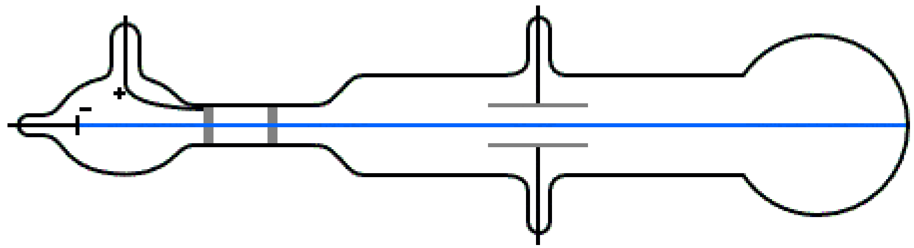
In 1897, Thomson discovered and identified electron in Crookes tube (discharge tube)




Cathode rays were emitted from the cathode C, passed through slits A (the anode) and B ([grounded](grounded)), then through the electric field generated between plates D and E, finally impacting the surface at the far end.

# Electron Discovery Experiment

Cathode rays could be deflected electrically => Cathode rays are negatively charged.

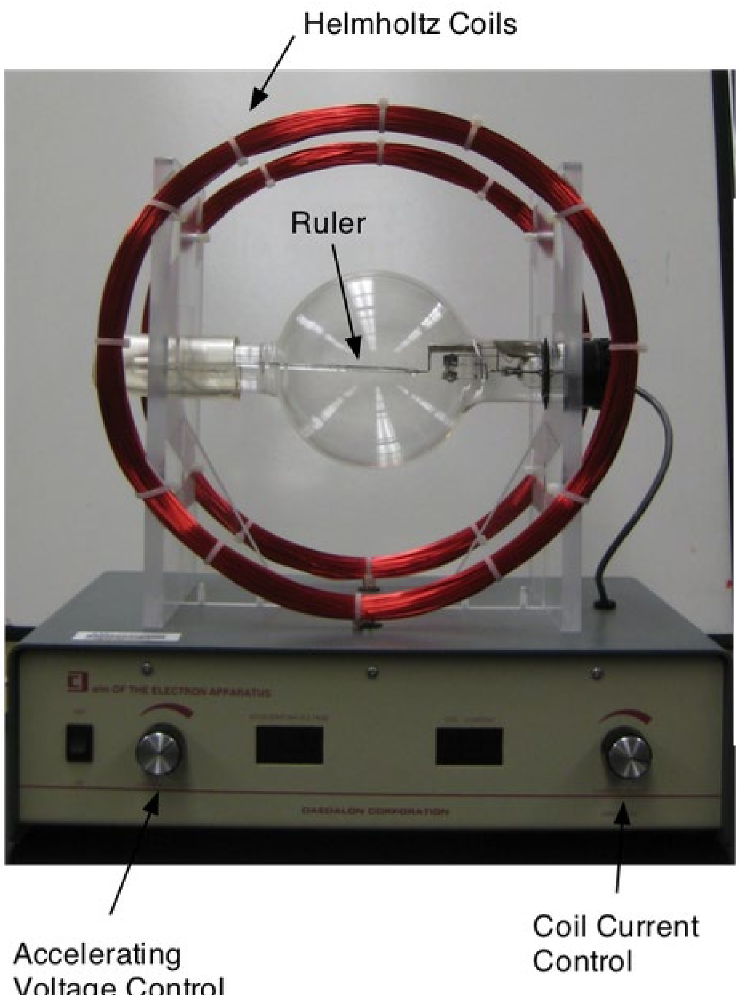


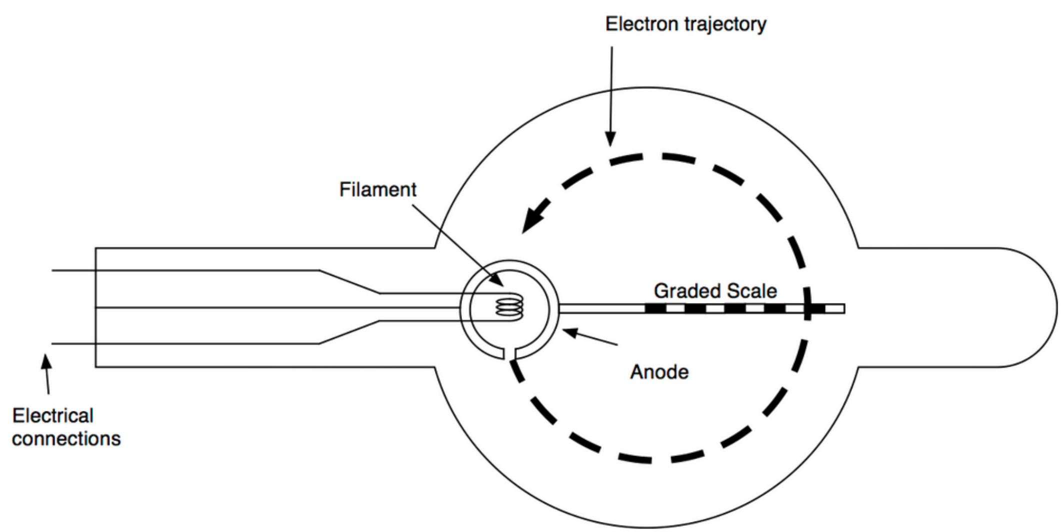

If further applying magnetic field H normal to screen,

$$v=E/H$$

# Electron Discovery Experiment

In the absence of electrical field and presence of magnetic field, the particles will travel along a circular arc.



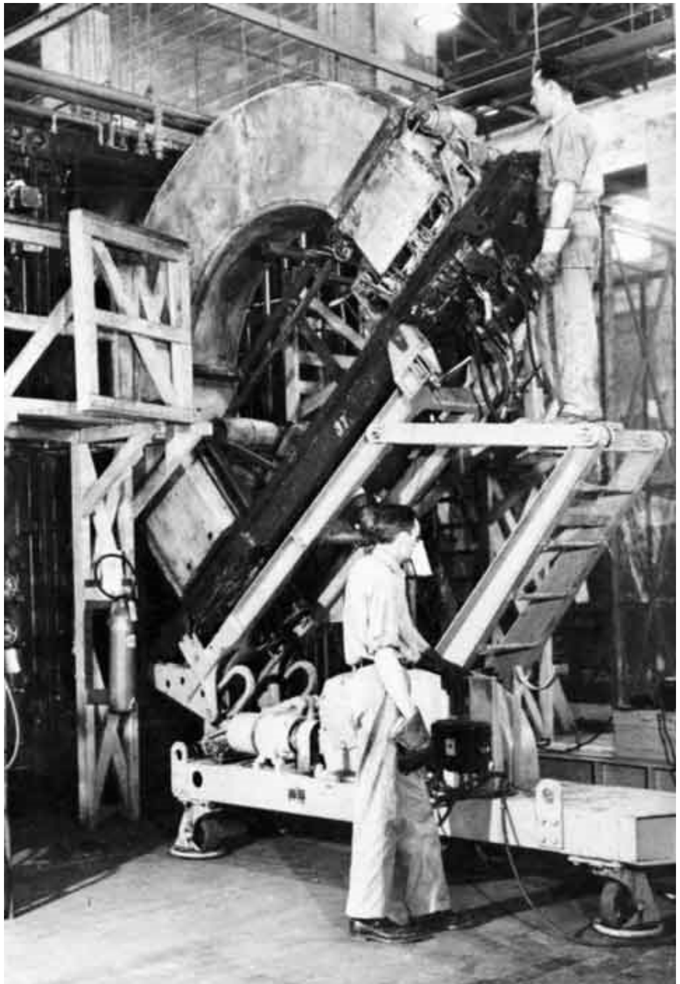
# Electron Discovery Experiment

In 1890, A. Shuster observed a much larger charge-to-mass ratio for the cathode ray than that of $H^+$ (referred to as *proton* in 1920 by Rutherford).

In 1897, W. Kaufman obtained much more accurate charge-to-mass ratio than J. Thomson did, and also discovered the velocity dependence of mass of the electron.

# Mass Spectrometry

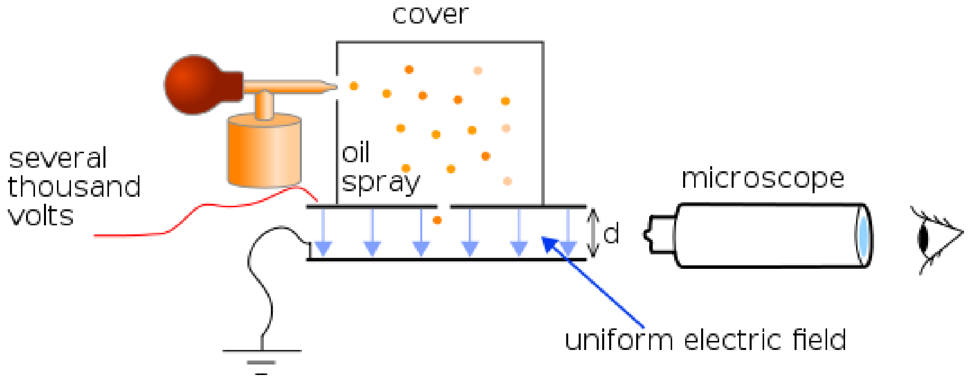
**principle: mass to charge ratio**



Calutron mass spectrometers were used in the Manhattan Project for uranium enrichment.


Inductively coupled plasma mass spectrometry

# Charge and Mass of the Electron




The drag force from Stokes's law

$$F_d = 6\pi r\eta v_1$$

and the effective weight

$$\boldsymbol{w} = \frac{4\pi}{3} r^3 (\rho - \rho_{air}) \boldsymbol{g}$$

should cancel out, suggesting

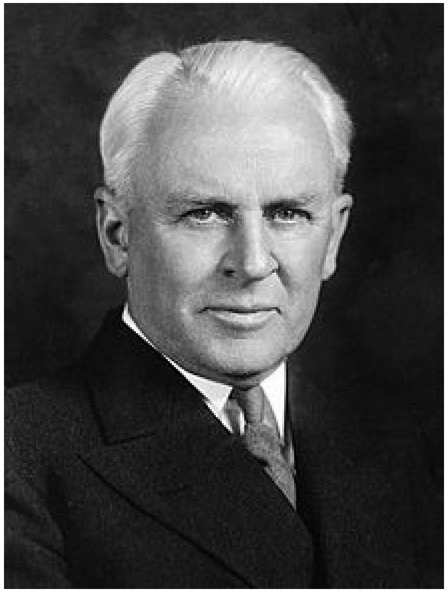
$$r^2 = \frac{9\eta v_1}{2g(\rho - \rho_{air})}.$$

Turn on an electric field E, so that a new upwards terminal velocity is reached. Then

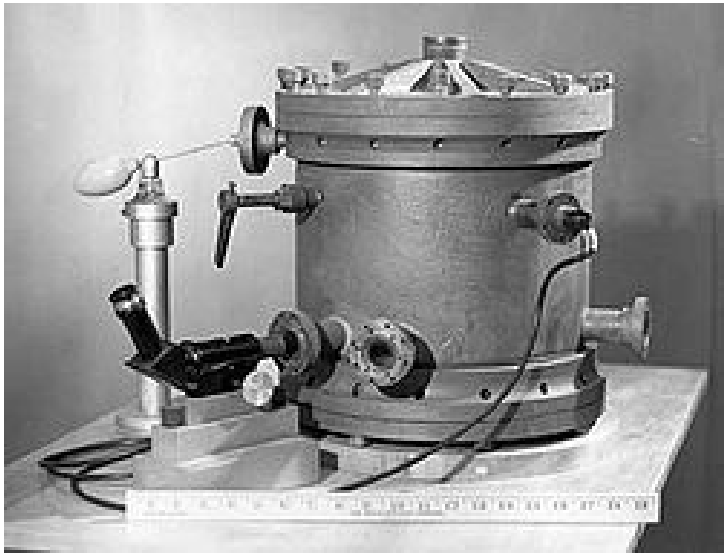
$$q\boldsymbol{E} - \boldsymbol{w} = 6\pi\eta(\boldsymbol{r}\cdot\boldsymbol{v_2}) = \left|\frac{\boldsymbol{v_2}}{\boldsymbol{v_1}}\right| \boldsymbol{w}.$$

# Charge and Mass of the Electron

1910, Robert A. Millikan, Oil-drop experiment
Nobel prize in 1923



(1868-1953)



Student: Chung-Yao Chao (赵忠尧), anomalously high scattering cross-section of Gamma rays (1930).

# Charge and Mass of the Electron

Electron charge reported by Robert A. Millikan:

e=1.59E-19 C,

Which is 1% less than the modern value:

e=1.60217662E-19 C.

Further from measured mass-to-charge ratio, one can obtain the **rest mass energy**

$m_e$ =9.10938215(45)E-31kg

**approximately 0.51 MeV/c2**

# Other things we learn from oil-drop experiments

**Quote from Richard Feynman**:

We have learned a lot from experience about how to handle some of the ways we fool ourselves. One example: Millikan measured the charge on an electron by an experiment with falling oil drops, and got an answer which we now know not to be quite right. It's a little bit off because he had the incorrect value for the viscosity of air. It's interesting to look at the history of measurements of the charge of an electron, after Millikan. If you plot them as a function of time, you find that one is a little bit bigger than Millikan's, and the next one's a little bit bigger than that, and the next one's a little bit bigger than that, until finally they settle down to a number which is higher.

Why didn't they discover the new number was higher right away? It's a thing that scientists are ashamed of—this history—because it's apparent that people did things like this: When they got a number that was too high above Millikan's, they thought something must be wrong—and they would look for and find a reason why something might be wrong. When they got a number close to Millikan's value they didn't look so hard. And so they eliminated the numbers that were too far off, and did other things like that...

# Other properties of the Electron

LETTER

Nature, 473, 493 (2011) doi:10.1038/nature10104

## Improved measurement of the shape of the electron

J. J. Hudson[1], D. M. Kara[1], I. J. Smallman[1], B. E. Sauer[1], M. R. Tarbutt[1] & E. A. Hinds[1]

**Shape:**
perfect sphere
radius smaller than 1E-17 cm (C.C. Ting).

作者：邱傲文 来源：澎湃新闻 发布时间：2016/9/2 13:38:54 选择字号：小 中 大

丁肇中：过去四十多年，我一直在找电子的半径


**Spin**
magnetic moment
spin-orbit interaction

# Avogadro constant

In 1811, A. Avogadro first proposed that the volume of a gas is proportional to the number of atoms or molecules regardless of the nature of the gas.

In 1909 Jean Perrin (Nobel laureate in 1926) proposed naming the constant in honor of Avogadro.

The earliest accurate method was based on **Coulometry**

$$N_{\mathrm{A}} = \frac{F}{e}$$

where F is Faraday constant (1833).

$k_B$ introduced by Planck (1900-1901) in *law of black body radiation*

It also links the gas constant R and Boltzmann constant:

$$R = k_{\mathrm{B}} N_{\mathrm{A}}$$

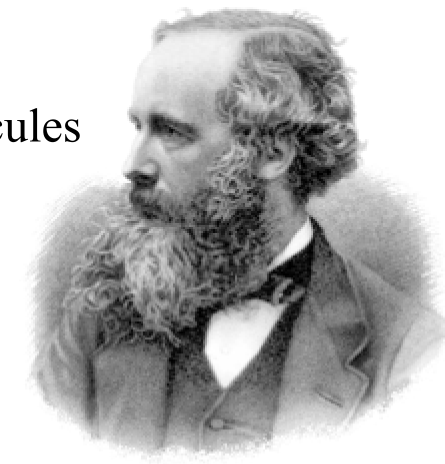
X-ray crystal density (XRCD) methods: the ratio of the molar volume $V_m$ to the atomic volume $V_{atom}$

International Avogadro Coordination

# (Further reading) Estimation of Avogadro constant

Loschmidt constant (number density in the ideal gas)

$$n_0 = \frac{p_0 N_A}{RT_0}$$ connection with $N_A$



James Clerk Maxwell
(1831–1879)

It can be estimated from the mean free path and diameter of molecules

$$\ell = \frac{3}{4 n_0 \pi d^2}$$

*Kinetic theory*

Its modern value $n_0 = 2.686\ 7805 \times 10^{25}\ \mathrm{m}^{-3}$

Loschmidt's estimate $n_0 = 1.81\times10^{24}\ \mathrm{m}^{-3}$

The diameter can be further related to the *condensation coefficient*

$$d = 8\frac{V_l}{V_g}\ell$$

yielding $$n_0 = \left(\frac{V_g}{V_l}\right)^2 \frac{3}{256\pi\ell^3}$$

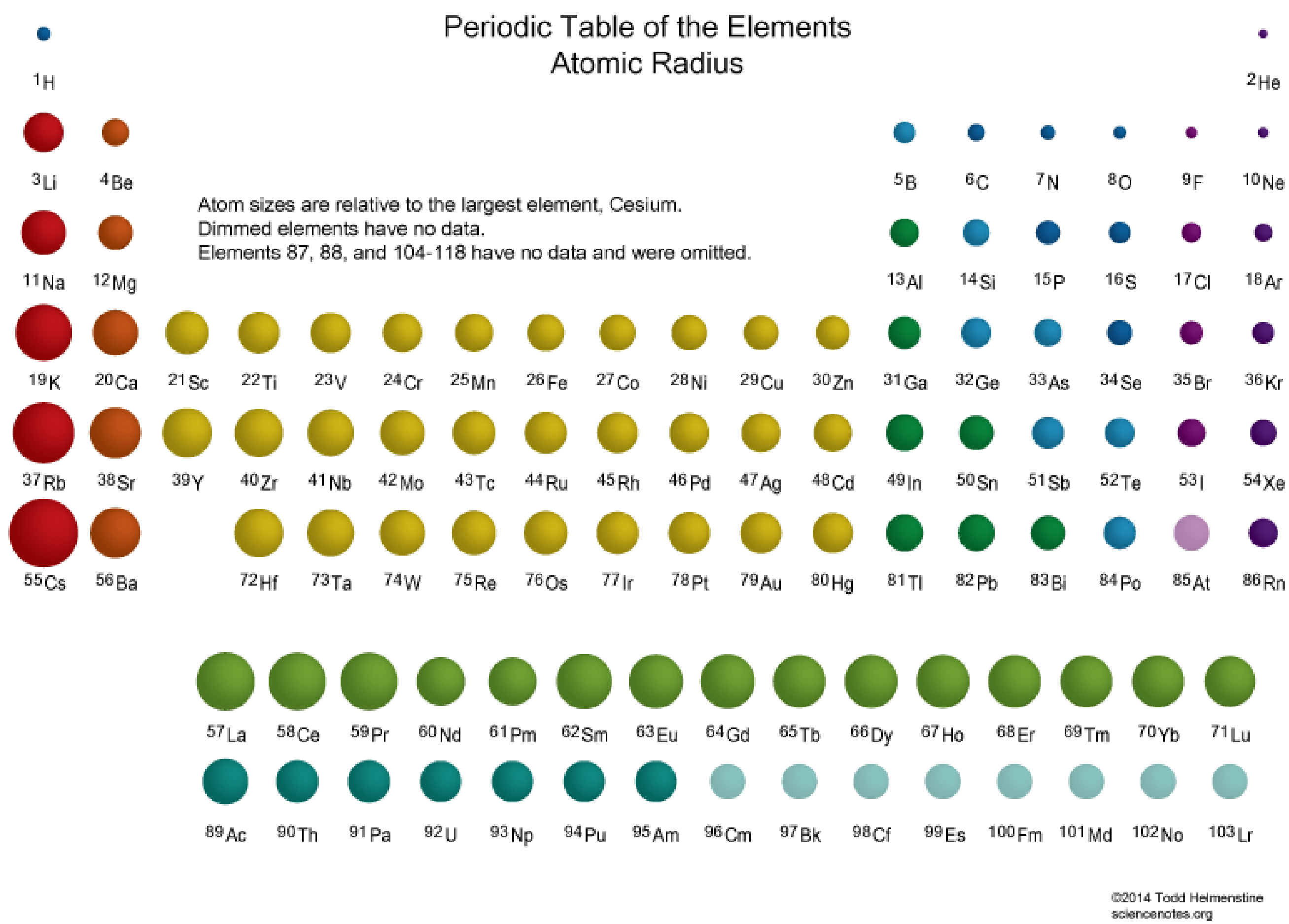
# Size of the Atom

For an arbitrary atom $^{A}X$, the atomic radius $r$ of X can be estimated as

$$\frac{4}{3}\pi r^3 N_A = \frac{A}{\rho}$$

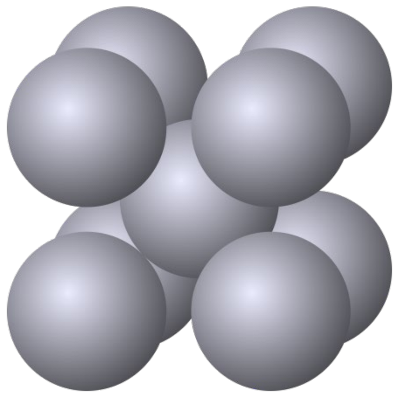
# Size of the Atom

## Atomic size: few angstroms



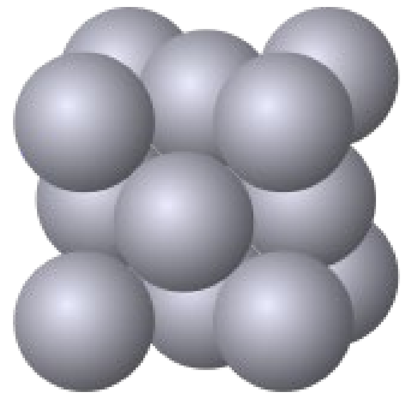
# (Further Reading) Size of the Atom

body centered cubic (BCC)



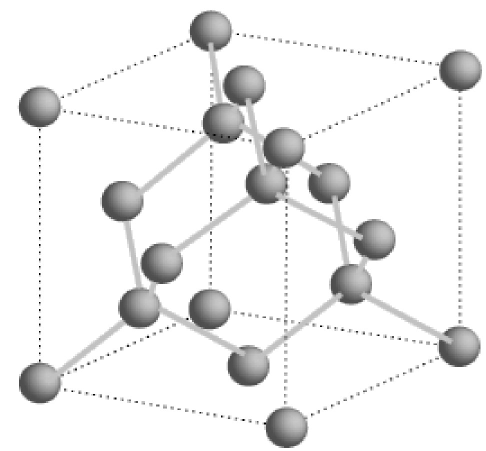
lithium

face centered cubic (FCC)



aluminum, lead, copper

diamond cubic



diamond, silicon

| | atomic packing factor |
|---|---|
| simple cubic | 0.524 |
| bcc | 0.680 |
| fcc | 0.740 |
| diamond cubic | 0.34 |

The **largest** packing factor

$$\frac{\pi}{3\sqrt{2}} \simeq 0.74048.$$