Welcome to 3.091

Lecture 2

September 11, 2009

The Periodic Table

3.091 Introduction to Solid State Chemistry

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

MIT

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poly (oxyethylence methacrylate) -b- poly (laurel methracrylate)

ADMINISTRATOR : HILARY SHELDON

PROFESSOR: DONALD R. SADOWAY

Videostreams and readings for all lectures to date are on 'Lecture Videos' page.

COURSE HIGHLIGHTS

This subject teaches basic principles of chemistry and shows how they apply in describing the behavior of the solid state. The relationship between electronic structure, chemical bonding, and crystal structure is developed. Attention is given to characterization of atomic and molecular arrangements in crystalline and amorphous solids: metals, ceramics, semiconductors and polymers (including proteins). Each lecture ends with a five-minute segment presenting a "real world" application of the subject. Examples are drawn from industrial practice (including the environmental impact of chemical processes), from energy generation and storage, e.g., batteries and fuel cells, and from emerging technologies, e.g., biomaterials.

General Principles of Chemistry covered include: Elements and Compounds, Chemical Formulas and Reactions; Evolution of Atomic Theory and Primary Bonding. Solid Sate Chemistry topics include: Crystal

KEY INFORMATION

Lecture

Professor Donald R. Sadoway

Office Hours: TBA.

With just cause, you may change your recitation section by contacting Hilary at ..

ANNOUNCEMENTS

If you need to make up a quiz, please arrange the time and location with your recitation instructor. Make-ups will be offered ONLY to students who missed the quizzes for valid reasons. Arrange to take your make-up

course information (continued)

- Syllabus
- Text, Tests and Grading
- Office Hours, etc
- Courseware
- Announcements
- Recitations

useful links

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FALL TERM 2009 SCHEDULE

SEPTEMBER

September 9: Lecture 1. Vision Statement, Administrative Details. Introduction. Taxonomy of chemical species. Origins of modern chemistry. Reading : Averill Ch. 1.

September 11: Lecture 2. Classification schemes for the elements. Mendeleyev and the Periodic Table. Atomic structure. Reading : Averill 1.7, p. 302 (Ch. 7), 1.6, 3.0-3.4.
Supplemental Readings

September 14: Lecture 3. Rutherford model of the atom, Bohr model of hydrogen. Reading : Averill 1.5, 6.2-6.3.
Supplemental Readings

September 16: Lecture 4. Atomic spectra of hydrogen, matter/energy interactions involving atomic hydrogen. Reading : Averill 6.4, Cecilia Payne .
Supplemental Readings

September 18: Lecture 5. The Shell Model (Bohr- Sommerfeld Model) and multi-electron atoms. Quantum numbers: n, l, m, s. Reading: Averill 6.5.
Supplemental Readings

September 21: Lecture 6. De Broglie , Heisenberg, and Schrödinger. The Aufbau Principle, Pauli Exclusion Principle, and Hund's Rules. Photoelectron Spectroscopy. Average Valence Electron Energy. Reading : Averill 6.4.
Supplemental Readings

September 23: Lecture 7. Octet stability by electron transfer: ionic bonding. Properties of ionic compounds: crystal lattice energy. Reading: Averill 8.1-8.2, 12.5, 8.3.
Supplemental Readings

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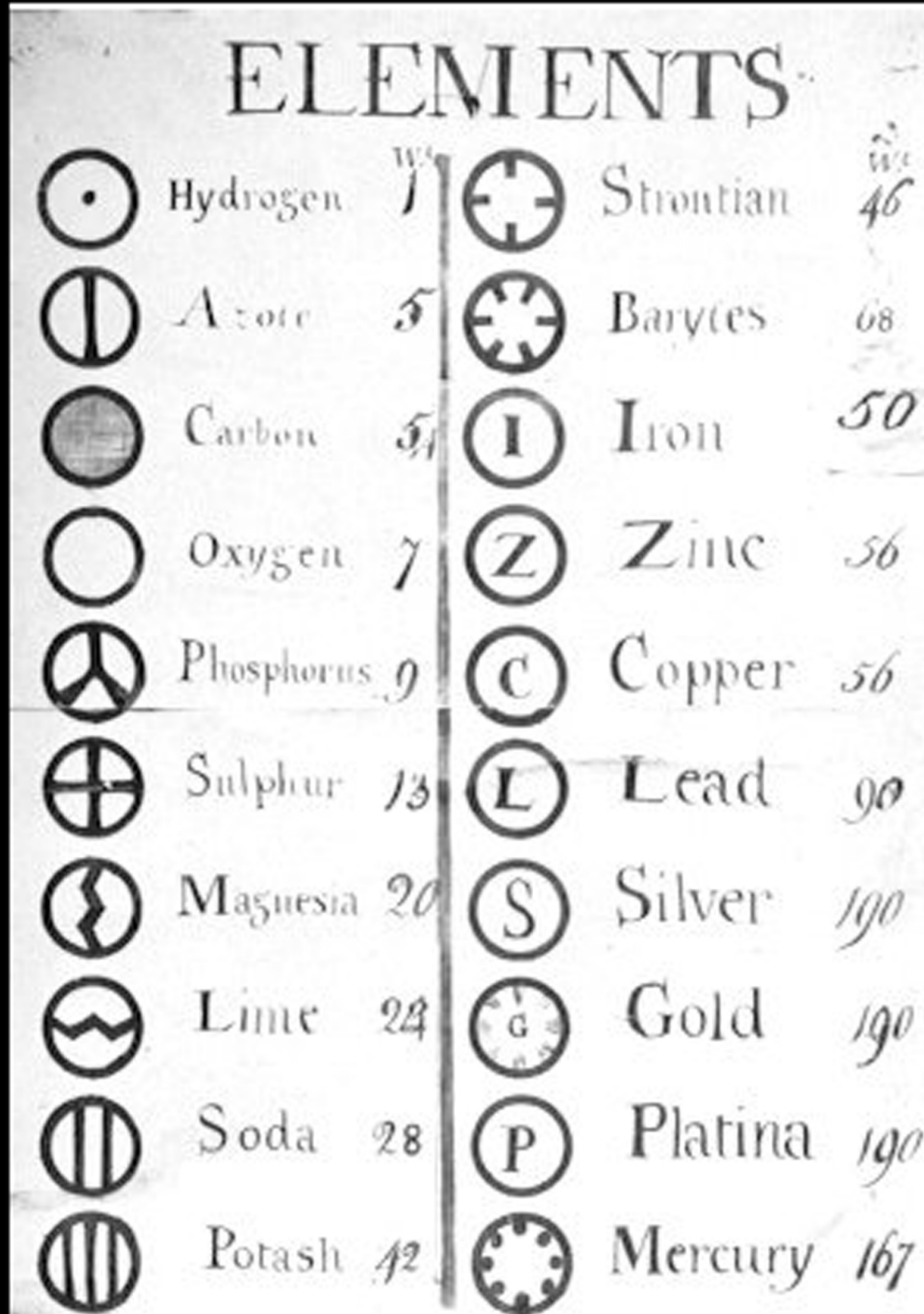
John Dalton 1803



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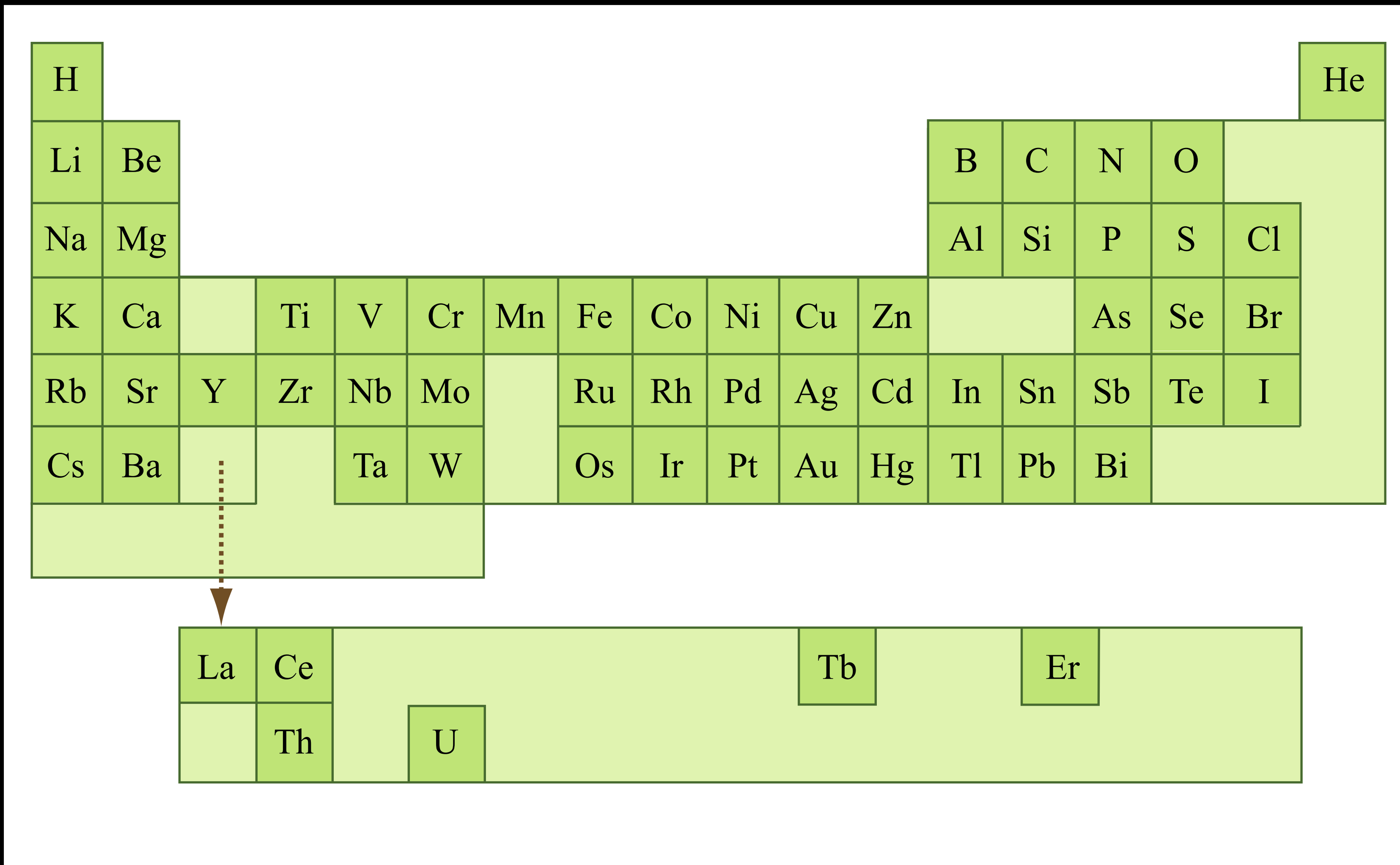
Dalton’s Model of the Atom (1803)

1. Matter is composed of atoms that are **indivisible** and **indestructible**.
2. All atoms of an element are **identical**.
3. Atoms of **different elements** have **different weights** and **different chemical properties**.
4. Atoms of different elements **combine in simple whole number ratios** to form **compounds**.
5. Atoms **cannot be created or destroyed**. When a compound is decomposed, the atoms are recovered unchanged.

1869



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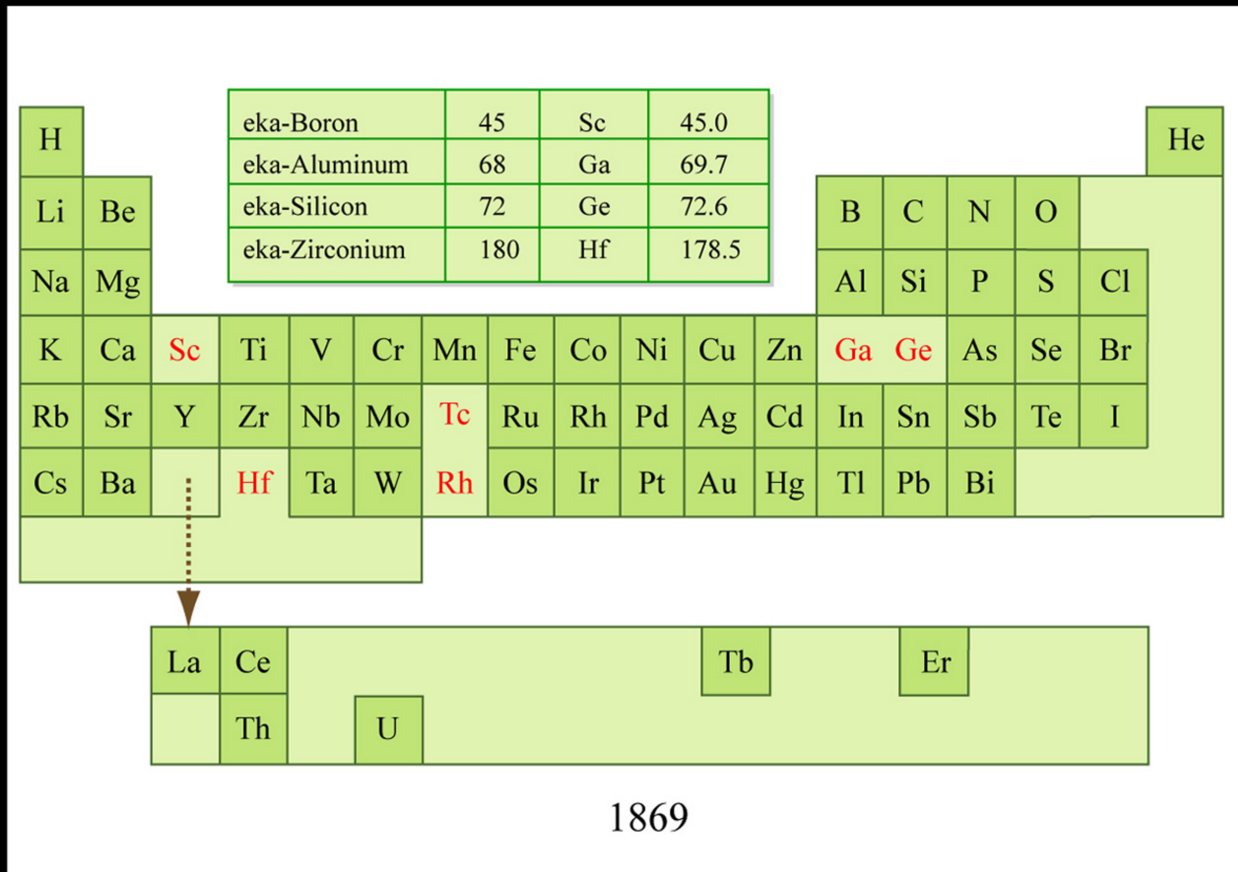
1869


eka-Boron 45 Sc 45.0
eka-Aluminum 68 Ga 69.7
eka-Silicon 72 Ge 72.6
eka-Zirconium 180 Hf 178.5
H He
Li Be B C N O
Na Mg Al Si P S Cl
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I
Cs Ba Hf Ta W Rh Os Ir Pt Au Hg Tl Pb Bi
La Ce Tb Er
Th U
1869

principles of modern chemistry:

* recognize patterns

* develop a quantitative model that
  - explains our observations
  - makes predictions that can be tested by experiment

Comparison of eka-silicon with germanium

eka-silicon	germanium
72 g/mol	72.59 g/mol
5.5 g/cm^3	5.36 g/cm^3
"high" m.p.	m.p. = 958ºC
Es forms EsO_2 which has high m.p. and ρ = 4.7 g/cm^3	Ge forms GeO_2 m.p. = 1100ºC and ρ = 4.70 g/cm^3
$EsCl_4$ volatile liquid with b.p. < 100ºC and ρ = 1.9 g/cm^3	$GeCl_4$ volatile liquid b.p. = 83ºC and ρ = 1.88 g/cm^3

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basics

?! WEB COURSEWARE (Special Thanks to Dr. Craig Counterman)

Archives of Lecture Notes, Idle Mind Solutions, and more

Periodic Table

Fundamental Physical Constants

Units and Constants

Unit Conversions

Atomic and Molecular Orbitals

Crystal Structures

Crystal Structures and Miller Indices

Crystal Structures and Packing

Diffusion Simulation

LECTURES

Monday, Wednesday ar
Friday, 11:00-12:00,

course information (conti

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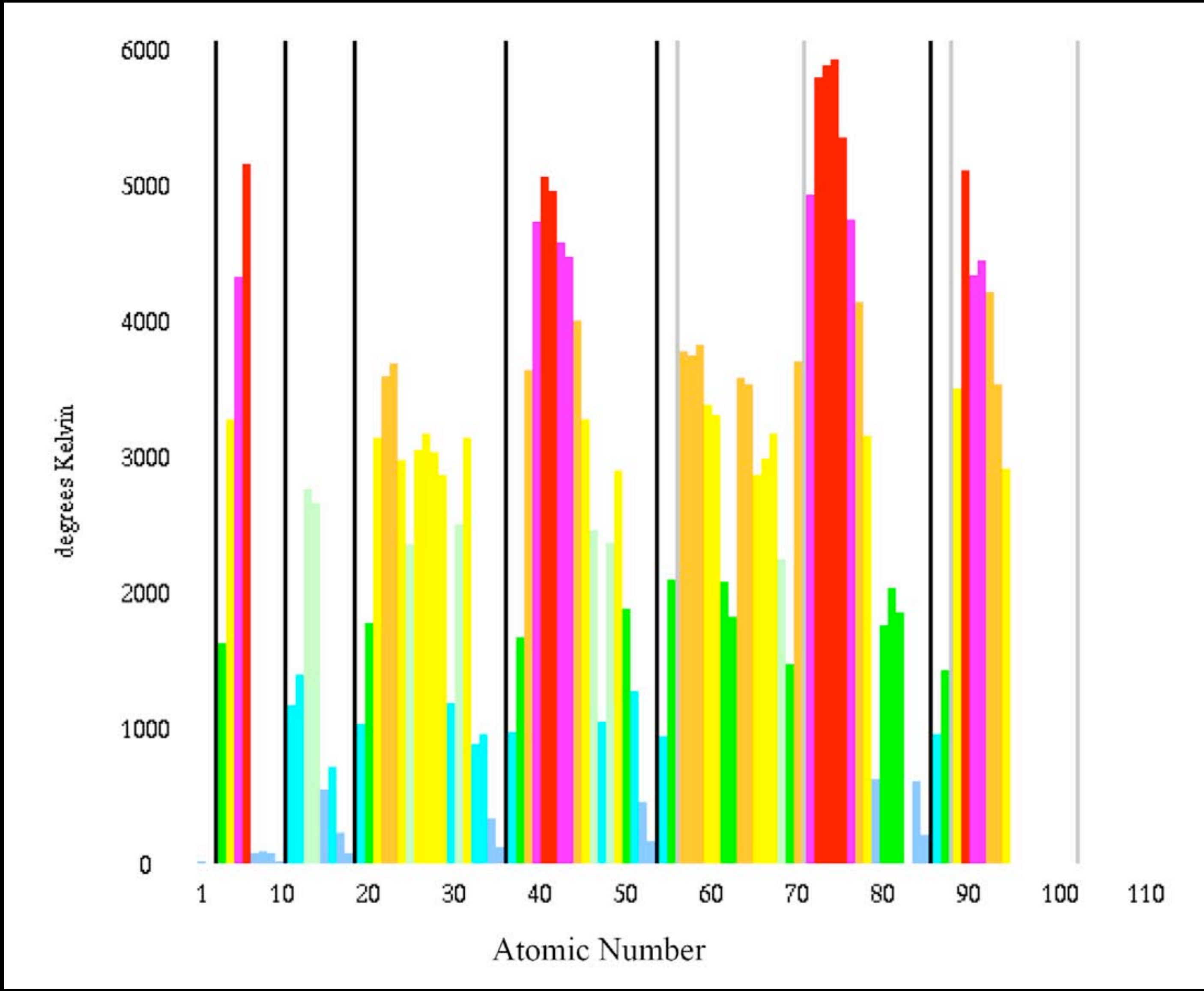
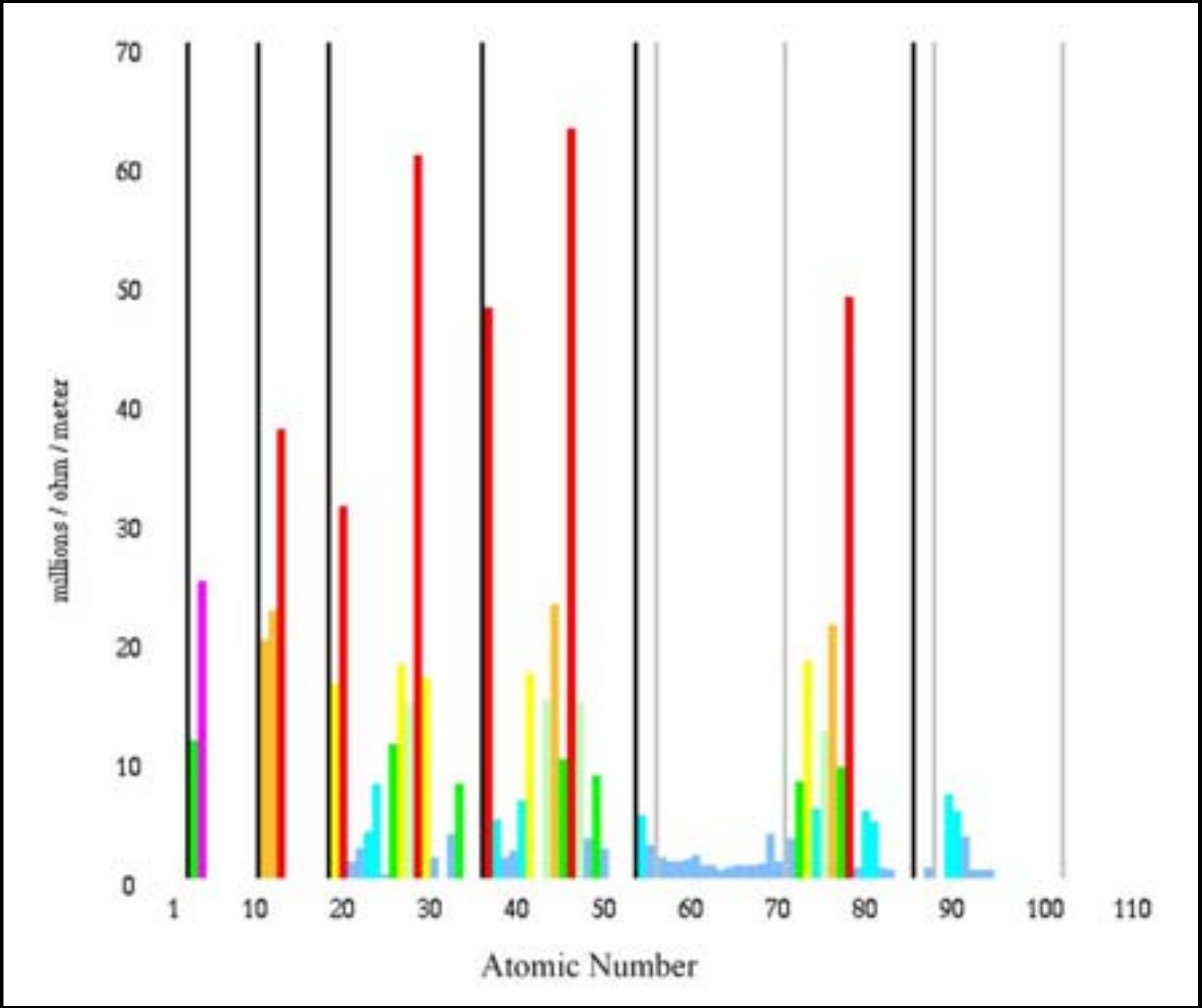
hw, quizzes and tests

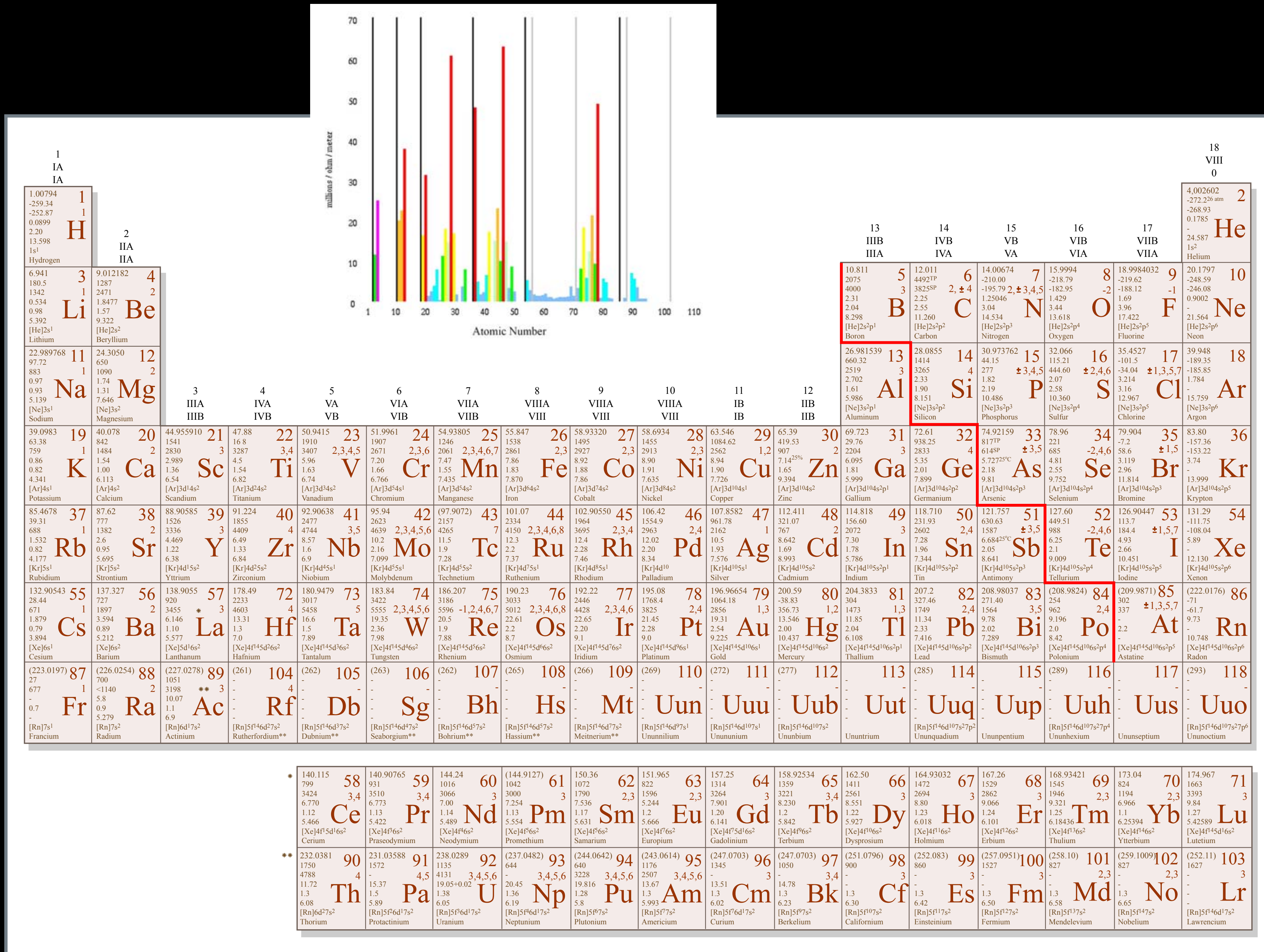
- Handouts
- Weekly Homework Assi
- Weekly Homework Quiz

Boiling point vs proton number



Electrical conductivity vs proton number





millions / ohm / meter
Atomic Number

the superheavies

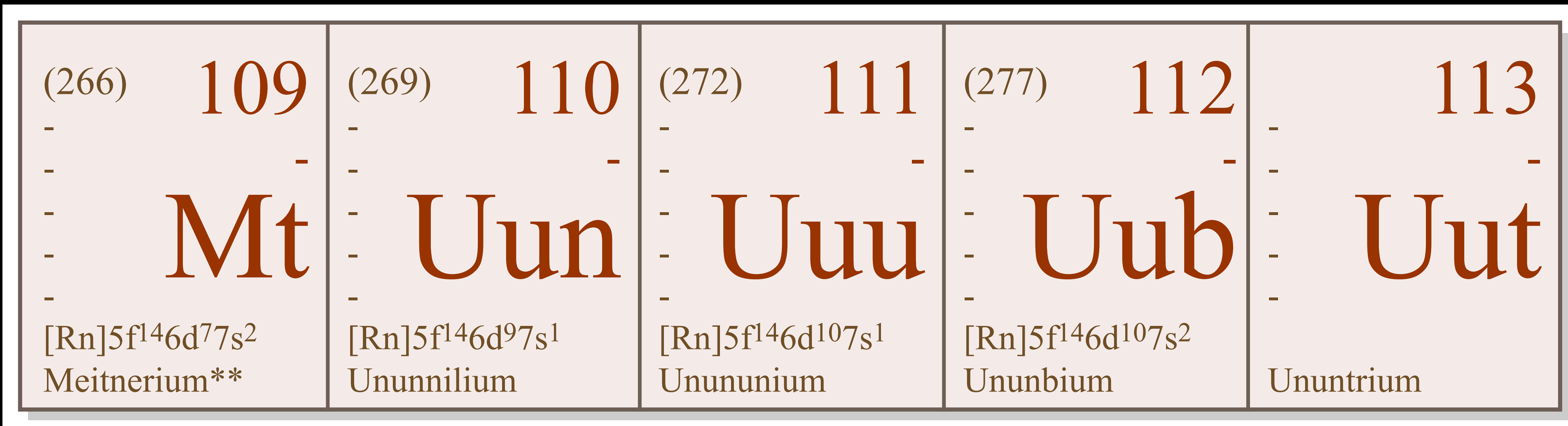
(269) 110	(272) 111	(277) 112	113	(285) 114	115	(289) 116	117	(293) 118
Uun	Uuu	Uub	Uut	Uuq	Uup	Uuh	Uus	Uuo
[Rn]$5f^{14}6d^{9}7s^{1}$	[Rn]$5f^{14}6d^{10}7s^{1}$	[Rn]$5f^{14}6d^{10}7s^{2}$		[Rn]$5f^{14}6d^{10}7s^{2}7p^{2}$		[Rn]$5f^{14}6d^{10}7s^{2}7p^{4}$		[Rn]$5f^{14}6d^{10}7s^{2}7p^{6}$
Ununnilium	Unununium	Ununbium	Ununtrium	Ununquadium	Ununpentium	Ununhexium	Ununseptium	Ununoctium

Image by MIT OpenCourseWare.

Naming the Superheavy Elements

1	un		
2	bi		
3	tri		
4	quad		
5	pent	+	ium
6	hex		
7	sept		
8	oct		
9	enn		
0	nil		

111	**unununium**	**Uuu**
112	**ununbium**	**Uub**
113	**ununtrium**	**Uut**
114	**ununquadium**	**Uuq**
115	**ununpentium**	**Uup**
116	**ununhexium**	**Uuh**
117	**ununseptium**	**Uus**
118	**ununoctium**	**Uuo**
119	**ununenium**	**Uue**
120	**unbinilium**	**Ubn**


(266) 109
Mt
[Rn]5f146d77s2
Meitnerium**
(269) 110
Uun
[Rn]5f146d97s1
Ununnilium
(272) 111
Uuu
[Rn]5f146d107s1
Unununium
(277) 112
Uub
[Rn]5f146d107s2
Ununbium
113
Uut
Ununtrium

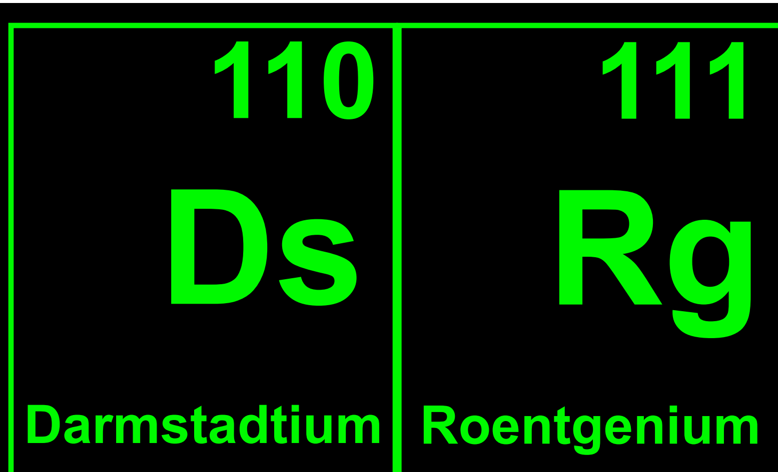
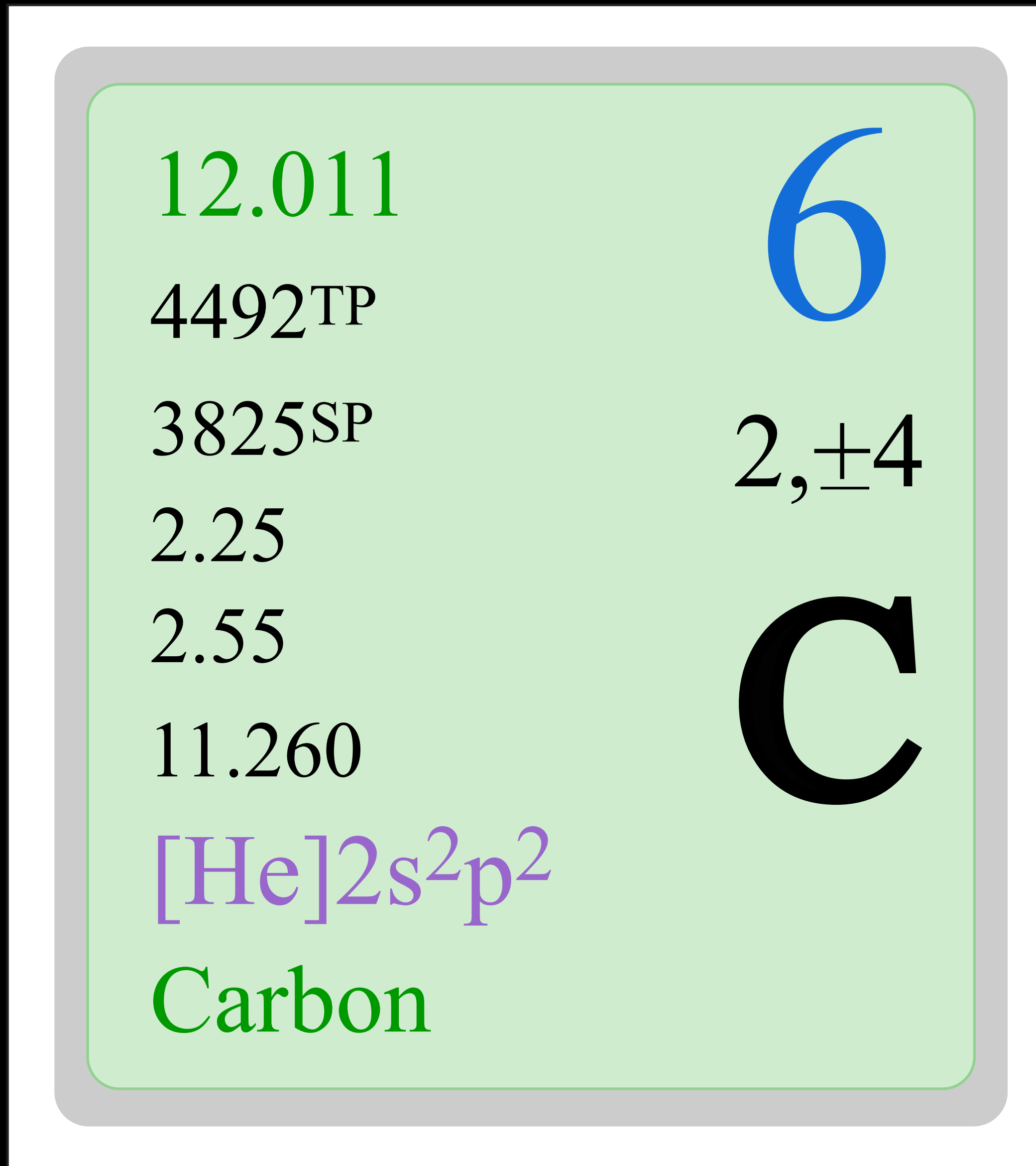

110
Ds
Darmstadtium
111
Rg
Roentgenium

Figure removed due to copyright restrictions.
Strathern, Paul. *Mendeleyev's Dream: The Quest for the Elements*. New York, NY: Thomas Dunne Books, 2001. ISBN: 9780312262044.

Table 1.1 The Structure of the Atom

particle	symbol	charge (C)	mass (kg)
electron	$\boldsymbol{e^-}$	-1.6×10^{-19}	9.11×10^{-31}
proton	$\boldsymbol{p^+}$	$+1.6\times10^{-19}$	1.673×10^{-27}
neutron	$\boldsymbol{n^o}$	0	1.675×10^{-27}



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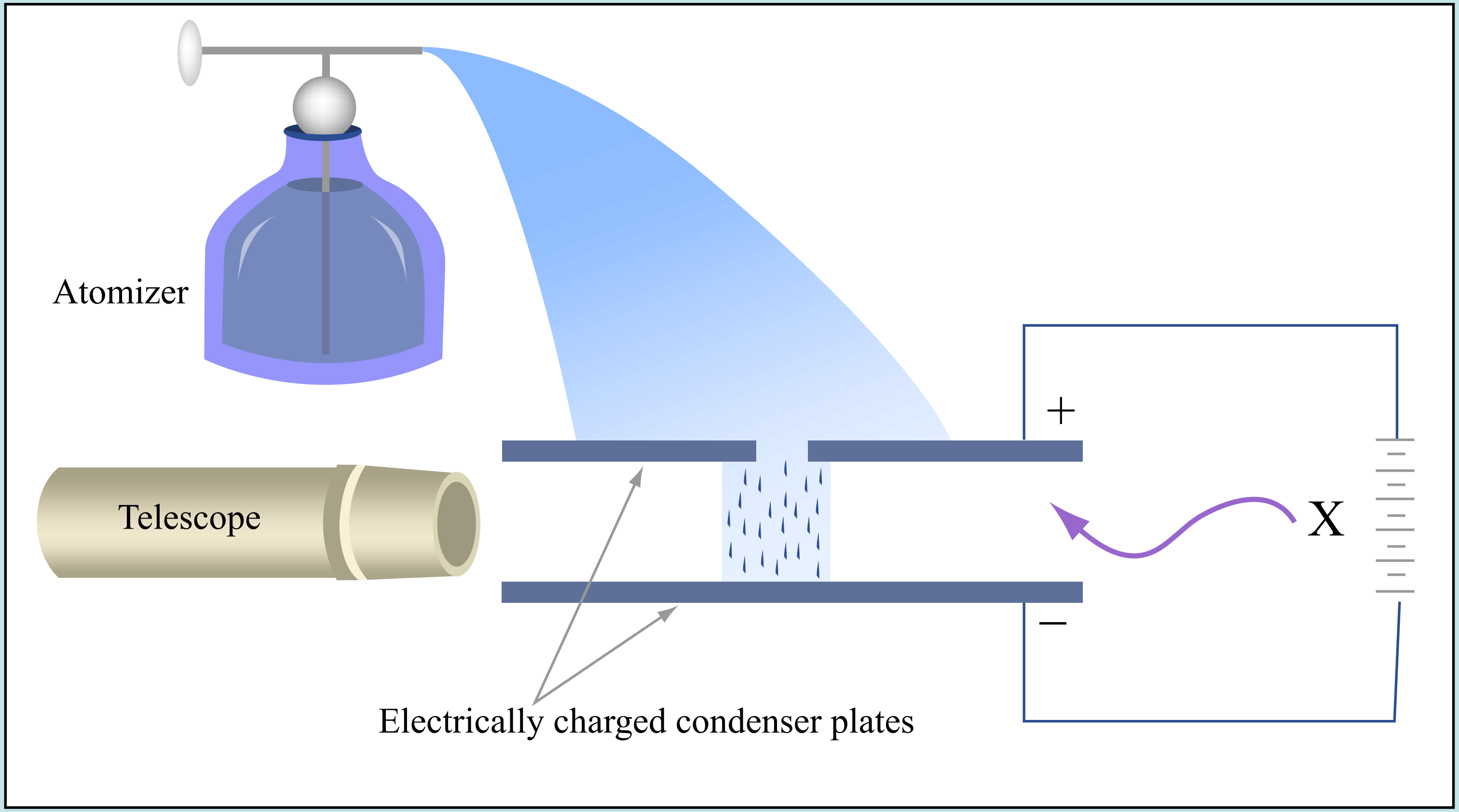

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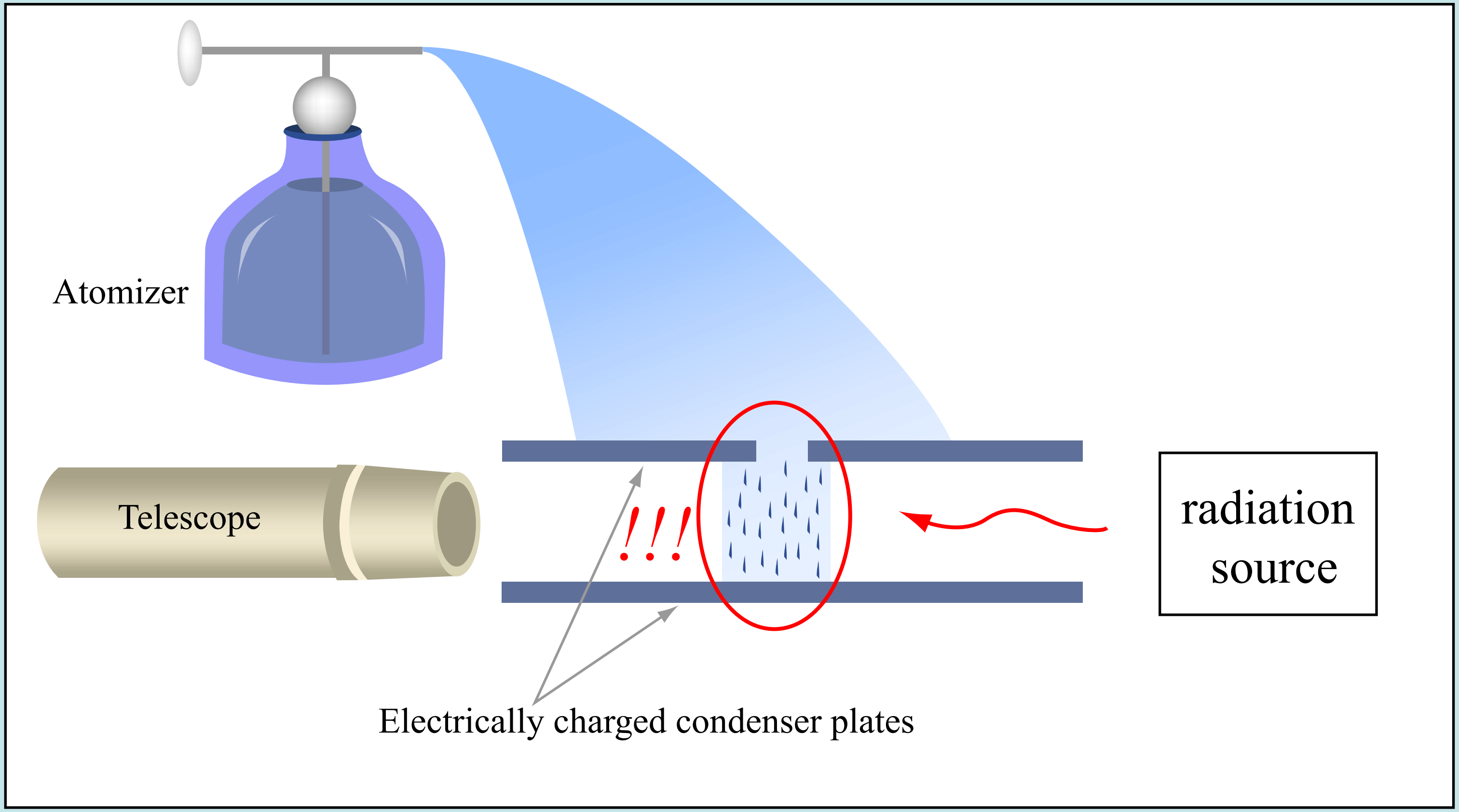
Robert A. Millikan, University of Chicago (1909)
Nobel Prize in Physics 1923



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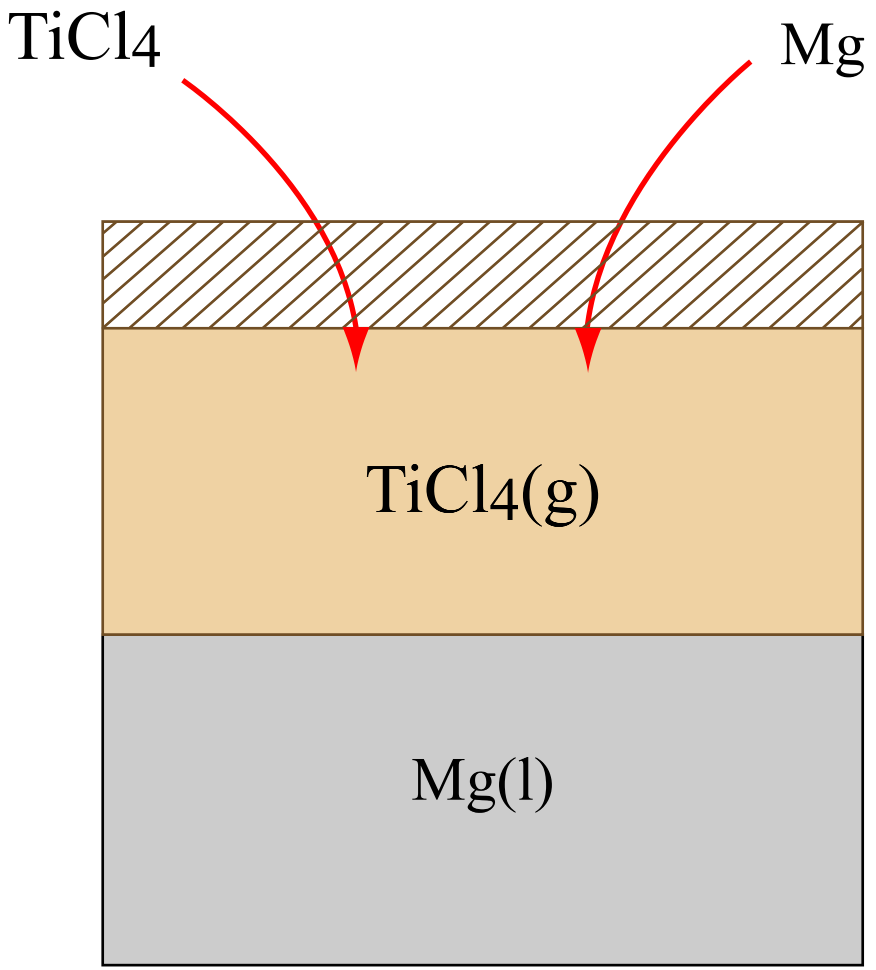
Kroll Reaction



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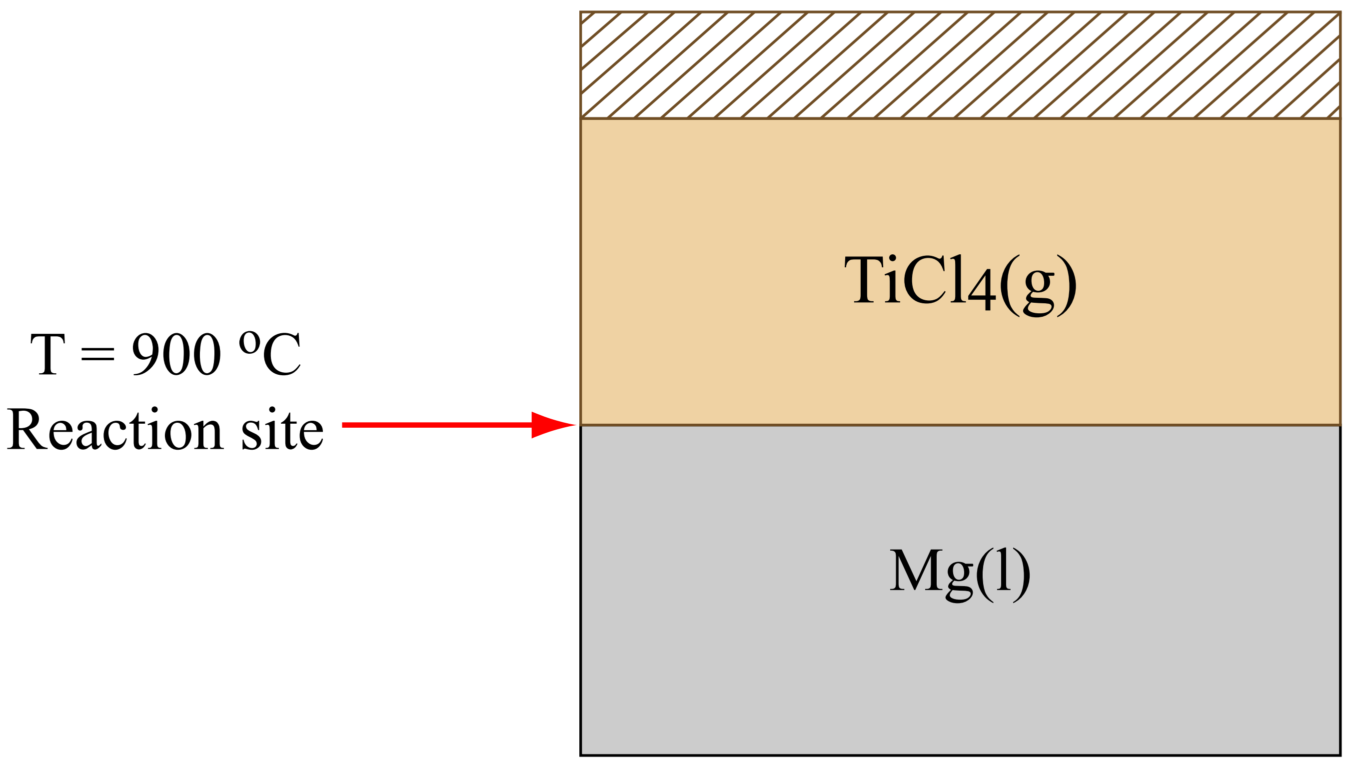
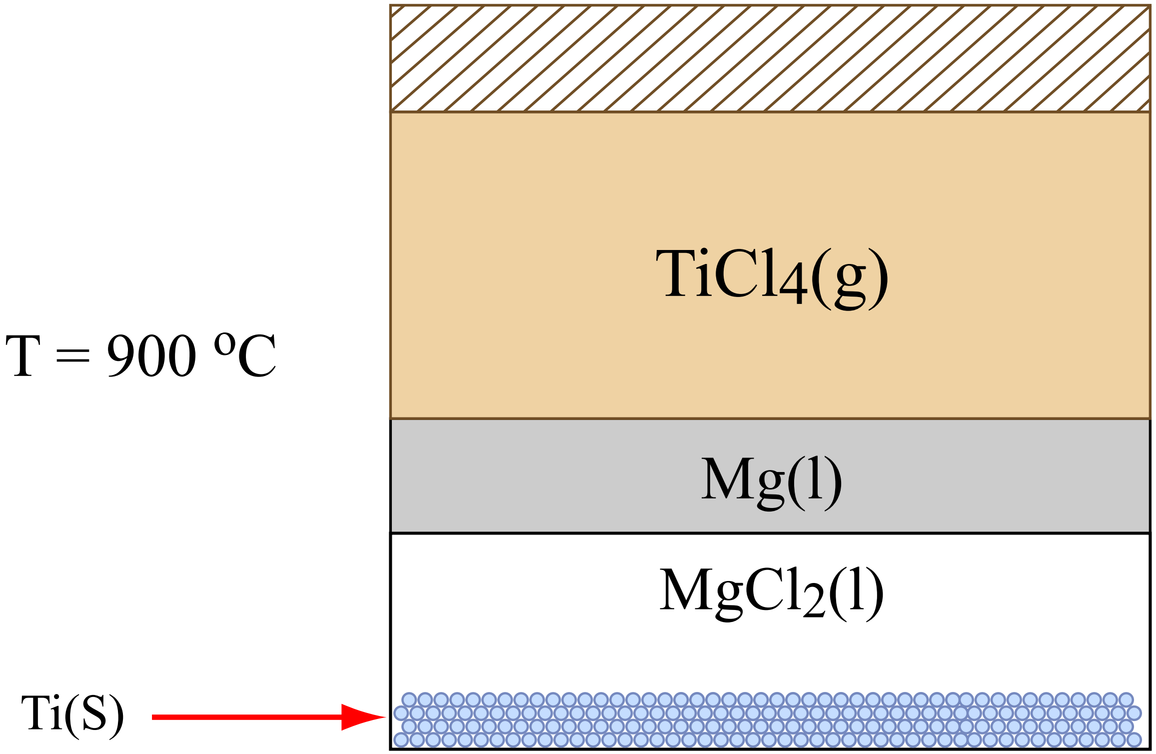
Kroll Reaction



Kroll Reaction



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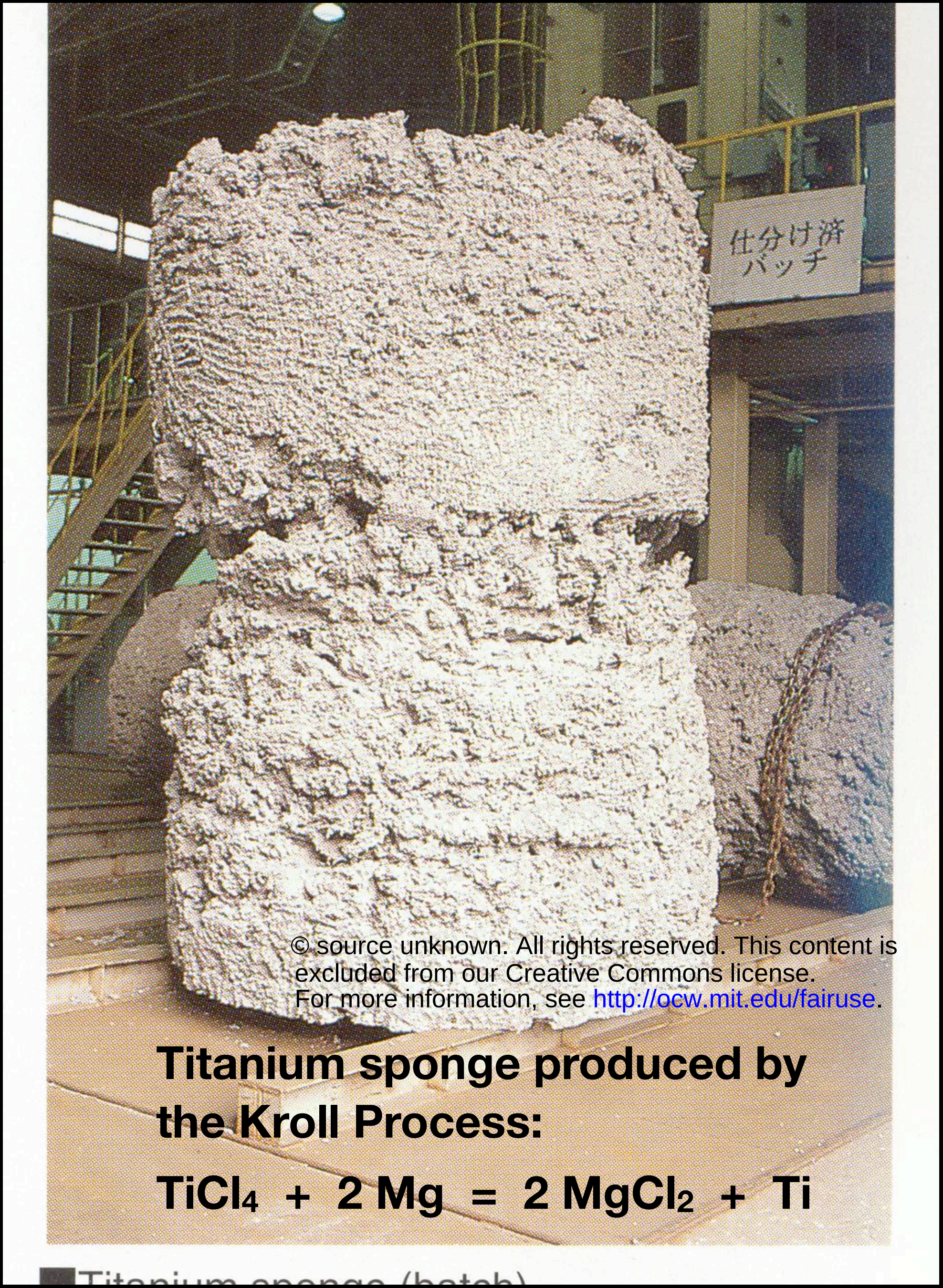
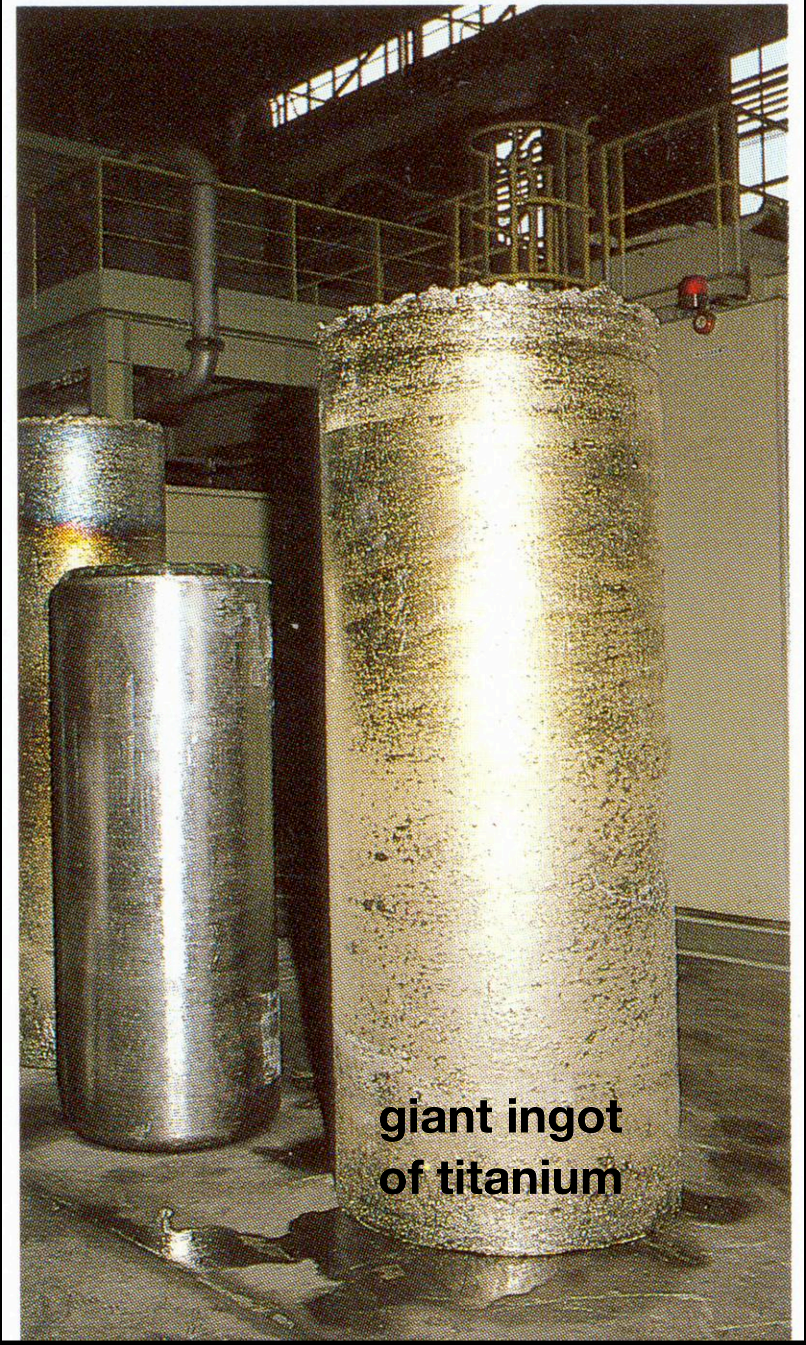


Titanium sponge produced by the Kroll Process:

$$TiCl_4 + 2\,Mg = 2\,MgCl_2 + Ti$$



giant ingot of titanium

Aleksandr P. BORODIN

- composer and member of "The Five":
  Balakirev, Borodin, Cui, Mussorgsky,
  and Rimsky-Korsakov

- professor of chemistry,
  Medico-Surgical Academy, St. Petersburg

- friend of Mendeleyev

***today's selection*:**
Polovtsian Dance No. 17 from *Prince Igor*

D.I. Mendeleyev

(1834 - 1907)

image made during the 60s showing him as he was at the time he enunciated the Table of the Elements

Д. И. Менделеев (60-е годы).