Welcome to 3.091

Lecture 1

September 9, 2009

Introduction to Solid State Chemistry

Donald R. Sadoway

John F. Elliott Professor of Materials Chemistry
Dept. of Materials Science & Engineering (Course III)

born Toronto, Ontario, CANADA

attended University of Toronto

1972 B.A.Sc. (Engineering Science)
1973 M.A.Sc. (Chemical Metallurgy)
1977 Ph.D. (Chemical Metallurgy)

1977 NATO Postdoctoral Fellow, MIT
1978 joined MIT faculty

basic research:

electrochemistry in nonaqueous media

☞ molten salts, ionic liquids, & polymers

applied research:

environmentally sound technologies for extraction, refining, and recycling of metals: Ti, Fe

mobile power: solid polymer batteries;
stationary power: colossal batteries for high amperage storage

production of O_2, structural metals, and photovoltaic Si from lunar & Martian "soils"

workmanship

⇓

performance = *f* (design, construction)

⇑

choice of materials

⇑

composition

+

atomic arrangement

} ⇒ properties

the thesis of 3.091:
electronic structure of the elements holds the key to understanding

☞ syllabus

3.091 Syllabus

- 1. General Principles of Chemistry
- 2. Solid State Chemistry:
  Basic Concepts and Applications

3.091 Introduction to Solid State Chemistry
Fall Term 2009

Lecturer Professor Donald R. Sadoway

Subject Administrator Hilary Sheldon

Text Two-volume set consisting of (1) a custom edition of *Chemistry: Principles, Patterns, and Applications, 1st Edition*, by Bruce Averill and Patricia Eldredge, Pearson, San Francisco, 2007, (ISBN 10: 0-558-34563-8), 2009 and (2) selected readings from other Pearson and Prentice Hall texts compiled under the title *Introduction to Solid-State Chemistry* published by Pearson Custom Publishing (ISBN 10: 0-558-36407-1), 2009. texts.

Lectures Monday, Wednesday, and Friday, 11:00-12:00,

Recitations Sections meet on Tuesdays and Thursdays each week.

Homework Weekly. Posted along with model solutions at the website. One week later, in recitation, students will take a 10-minute quiz based on the subject matter of the homework. The scores on these weekly quizzes will count as the "homework" portion of the cumulative grade in the subject. All scores count -- no dropping of lowest score(s) from the average.

3.091 Homework No. 1

- assigned today, September 9
- tested next Tuesday, September 15

celebration of learning

- posted at website along with model solutions

3.091 Fall Term 2009

Homework #1

September 9 (to be tested September 15)

from Averill:

Chapter 1

Topic	Problems
Elements VS Compounds	14, 15
Periodic Table, Reading Information of the	32, 36, 38, 39, 42, 44
Periodic Table, Patterns in the	47, 48
Isotopes	73, 76
Ions and Oxidization States	34, 82
Concept of Mole	25
Molecular Mass	65, 80

Chapter 3

Topic	Problems
Molecular Mass	33
Unit Conversions (mass to moles to molecules and vice versa)	35, 43, 44
Balancing Chemical Reactions	72
Agents in a Chemical Reaction (Limiting, in excess, etc)	90, 103

Tests #1 Wednesday, October 7, 11:05-11:55.

#2 Wednesday, October 28, 11:05-11:55.

#3 Monday, November 23, 11:05-11:55.

permissible aids: periodic table, table of constants, calculator, and an aid sheet

FINAL EXAM: 3 hours. Time and location to be set by the Registrar and published by October 1.

Final Exam Period is December 14 – 18.

Do not plan to leave town until after your last final.

Grading Freshmen -- Pass/No Record
(Institute requirement for Pass is performance at C-level or better)

Upperclassmen -- A, B, C, D, F

Final grade composition:

- 16.75% homework
- 16.75% each for three tests
- 33% final exam

Passing grade (C-level) $\geq$ 50% absolute (no grading on a curve)

Academic Honesty

It is expected that students in 3.091 will maintain the highest standards of academic honesty. In particular, it is expected that while taking a test or examination, students will not (1) accept information of any kind from others; (2) represent as their own the work of anyone else; or (3) use aids to memory other than those expressly permitted by the examiner. Following a test or examination, students will not try to deceive the teaching staff by misrepresenting or altering their previous work in order to improve their score. Please consult http://web.mit.edu/academicintegrity/.

Departures from the above standards are contrary to fundamental principles of MIT and of the scientific community at large. Such departures are considered serious offenses for which disciplinary penalties, including suspension and expulsion, can be imposed by the Institute.

Classroom Behavior

To maintain a fertile learning environment in a lecture theater seating in excess of 400 people, it is necessary for the instructor to expect adherence to certain rules of conduct. During lecture, students may not

❶ hold conversations;

❷ consume food or drink;

❸ engage in disruptive behavior.

Wireless communications devices must be silenced.

3.091 Introduction to Solid-State Chemistry

Prereq: None
Units: 5-0-7
URL: http://web.mit.edu/3.091/www/

Lecture: *MWF11* (10-250) **7 Recitation Times: (Scheduled REG Day)** ***+final***

Basic principles of chemistry and their application to engineering systems. The relationship between electronic structure, chemical bonding, and atomic order. Characterization of atomic arrangements in crystalline and amorphous solids: metals, ceramics, semiconductors, and polymers (including proteins). Topical coverage of organic chemistry, solution chemistry, acid-base equilibria, electrochemistry, biochemistry, chemical kinetics, diffusion, and phase diagrams. Examples 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. photonic and biomedical devices).
Fall: *D. R. Sadoway*
Spring: *D. Paul*

3.091 Introduction to Solid-State Ch

Prereq: --

Units: 5-0-7

URL: http://web.mit.edu/3.091/www/

Lecture: *MWF11* (10-250) **10 Reci**

recipe for success:
venues for learning

DRS	lecture
staff	recitation
you	reading
you	homework
you	weekly quizzes
you	monthly tests
you	final exam

☞☞☞ partnership!!!

today's lecture

taxonomy

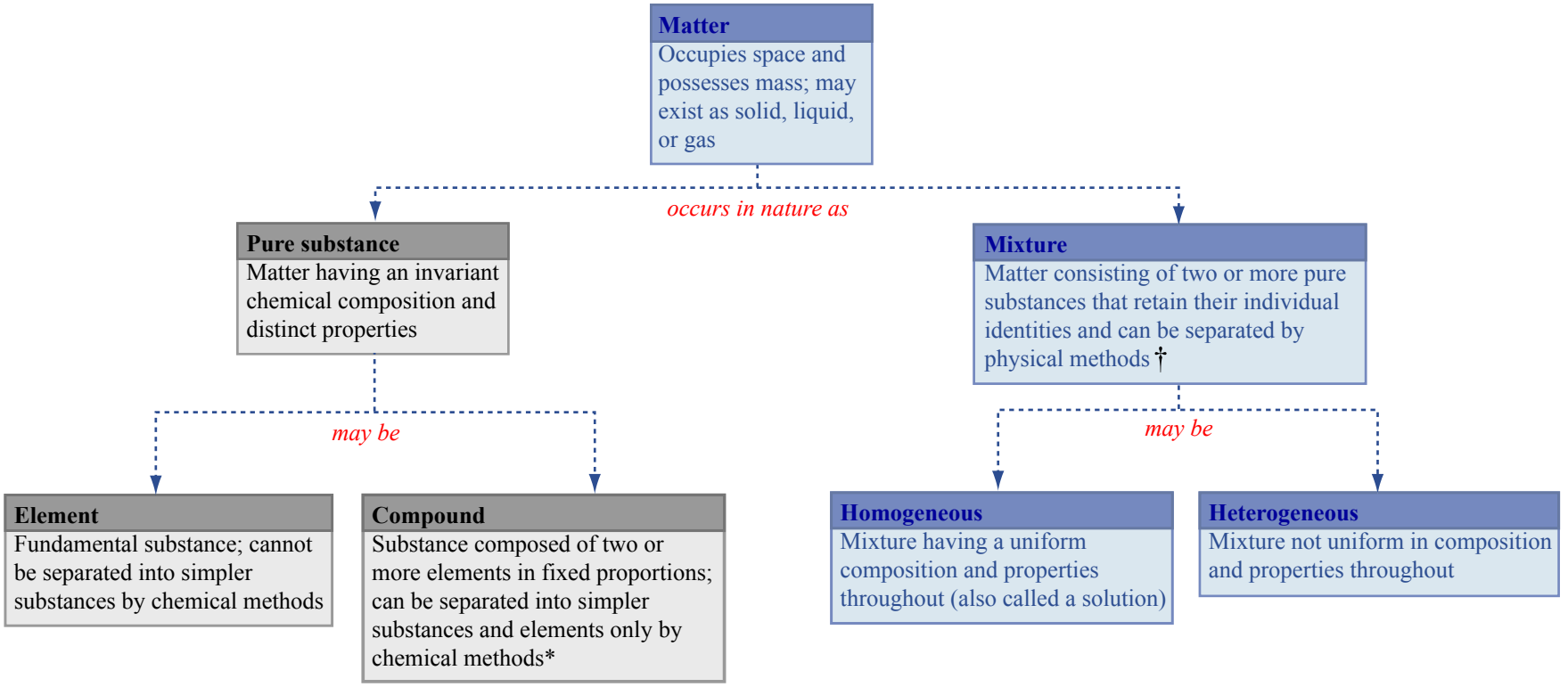
classification

nomenclature

☞ *William Shakespeare*

*** Chemical methods of separation include electrolysis.**

† Physical methods of separation include filtration, distillation, and crystallization.



origins of chemistry

* ancient Egyptian hieroglyphs refer to ***khemeia:*** chemical processes for embalming the dead

origins of chemistry

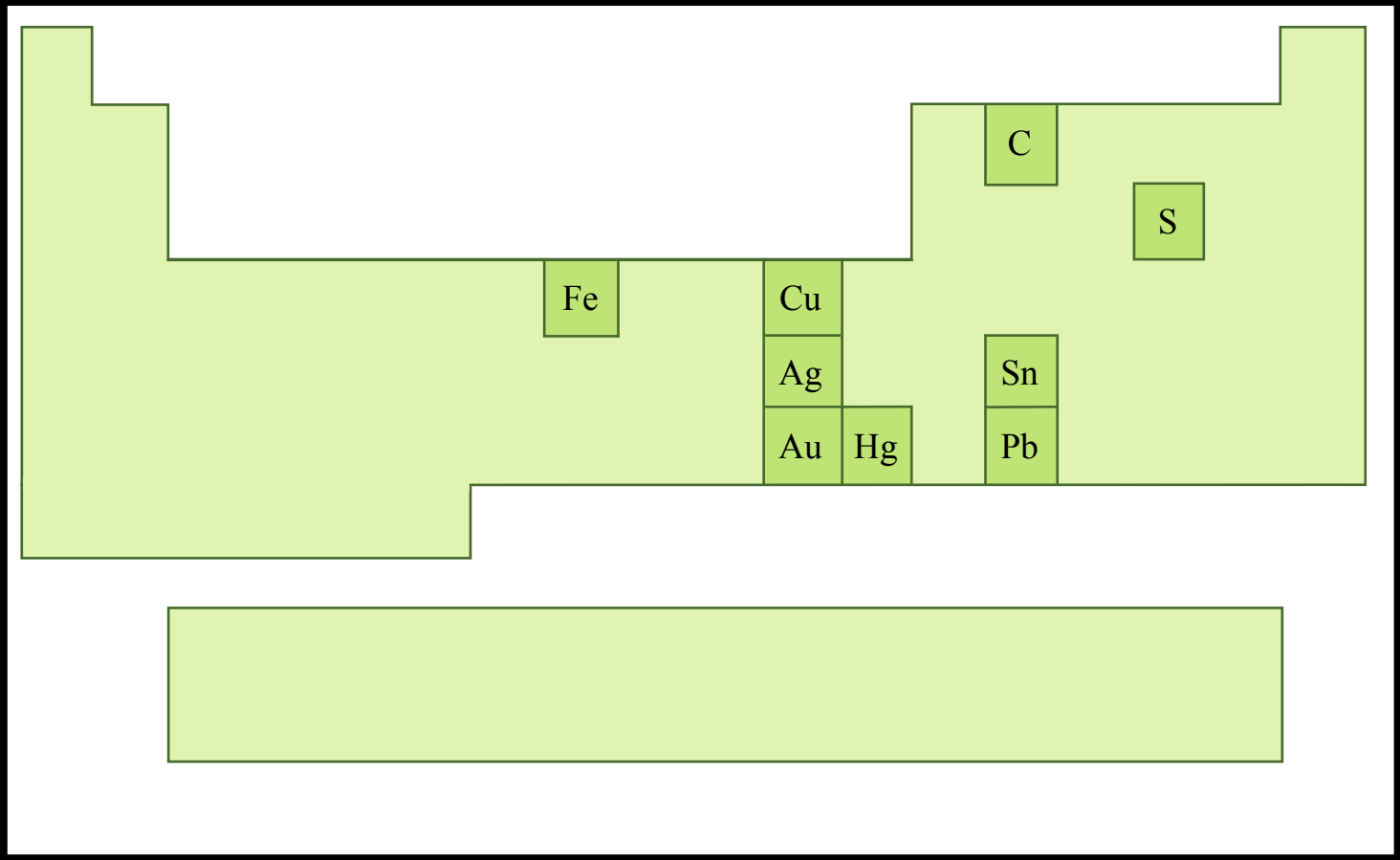
* ancient Egyptian hieroglyphs refer to ***khemeia:*** chemical processes for embalming the dead

* khemeia expanded to other chemical processes, especially, metals extraction

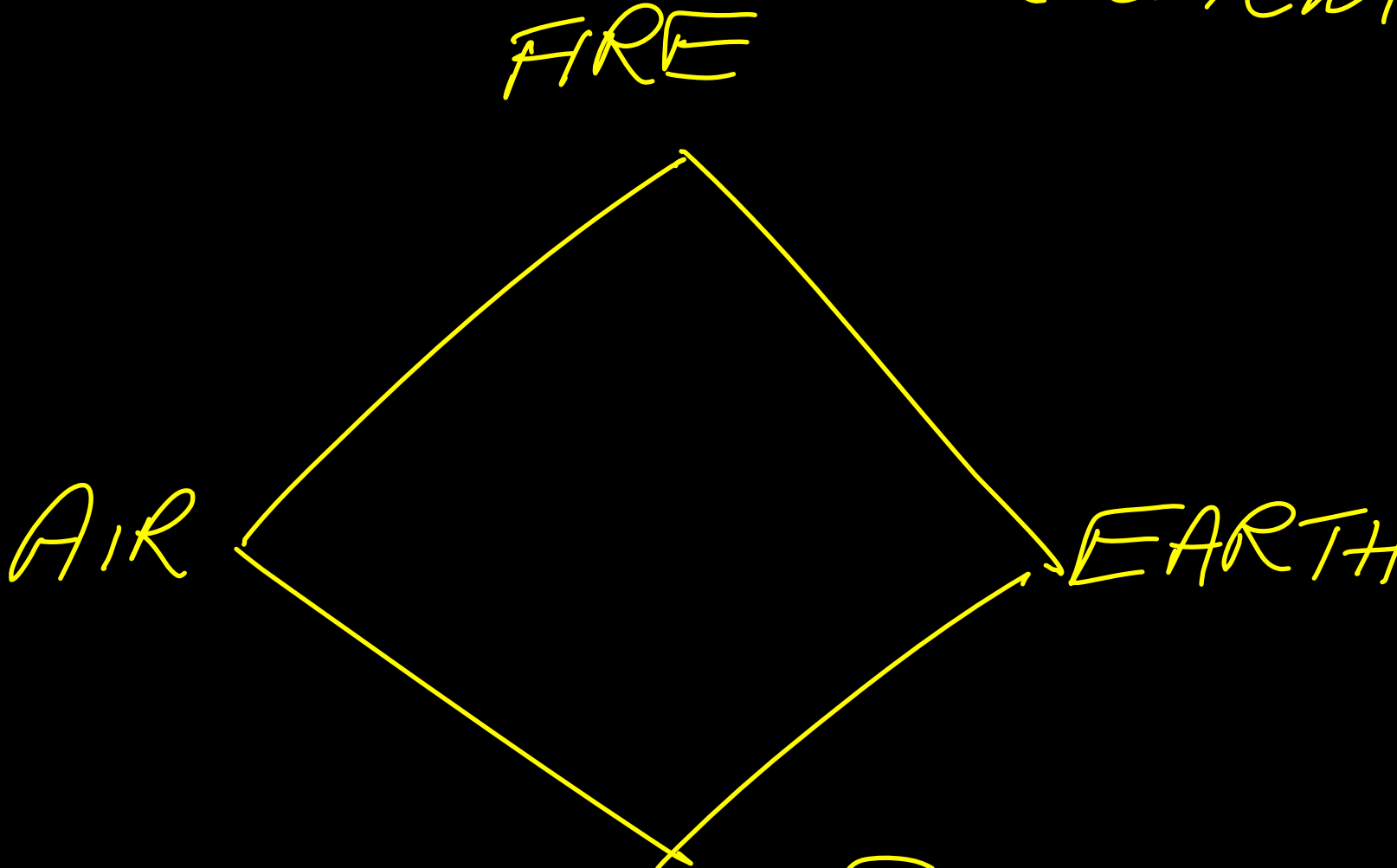
origins of chemistry

chemistry	astronomy
gold	the Sun
silver	the moon
copper	Venus
iron	Mars
tin	Jupiter
lead	Saturn
mercury	Mercury

~ 2400 years ago

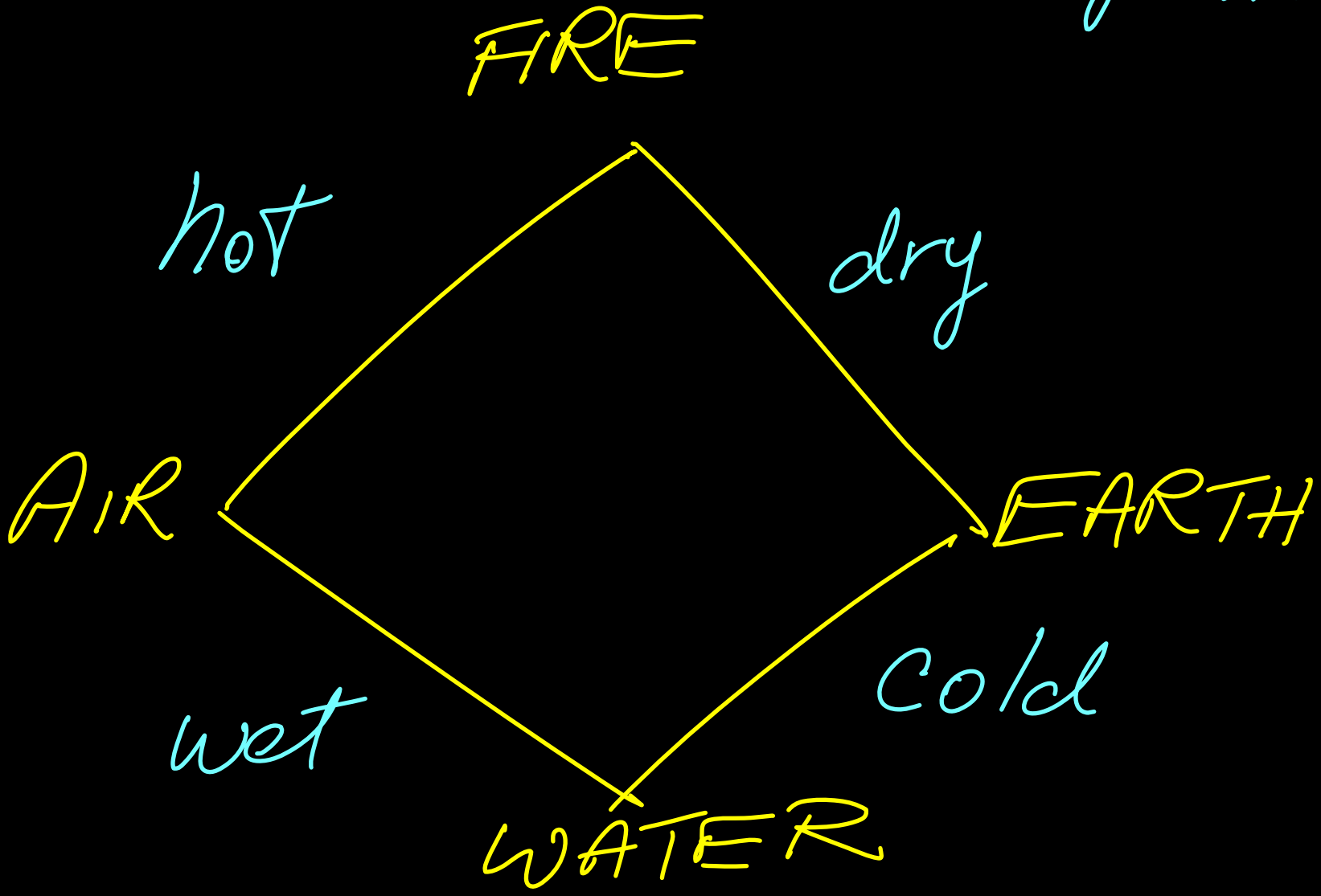


"elements"

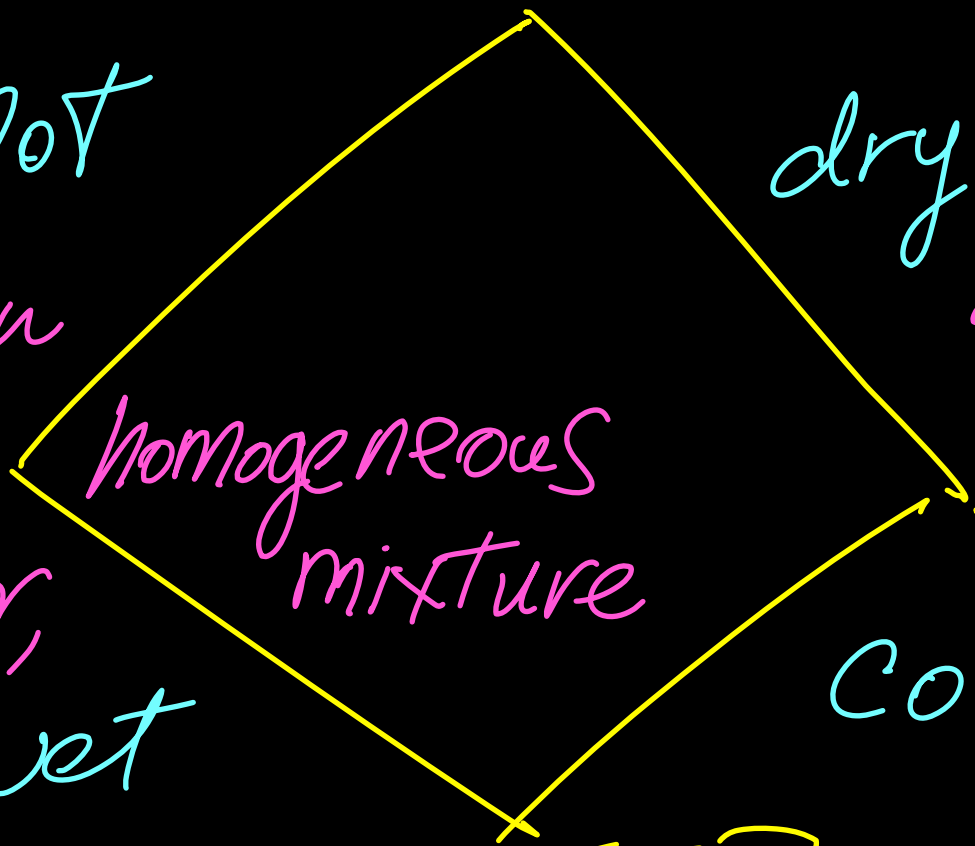


Aristotelean Essences

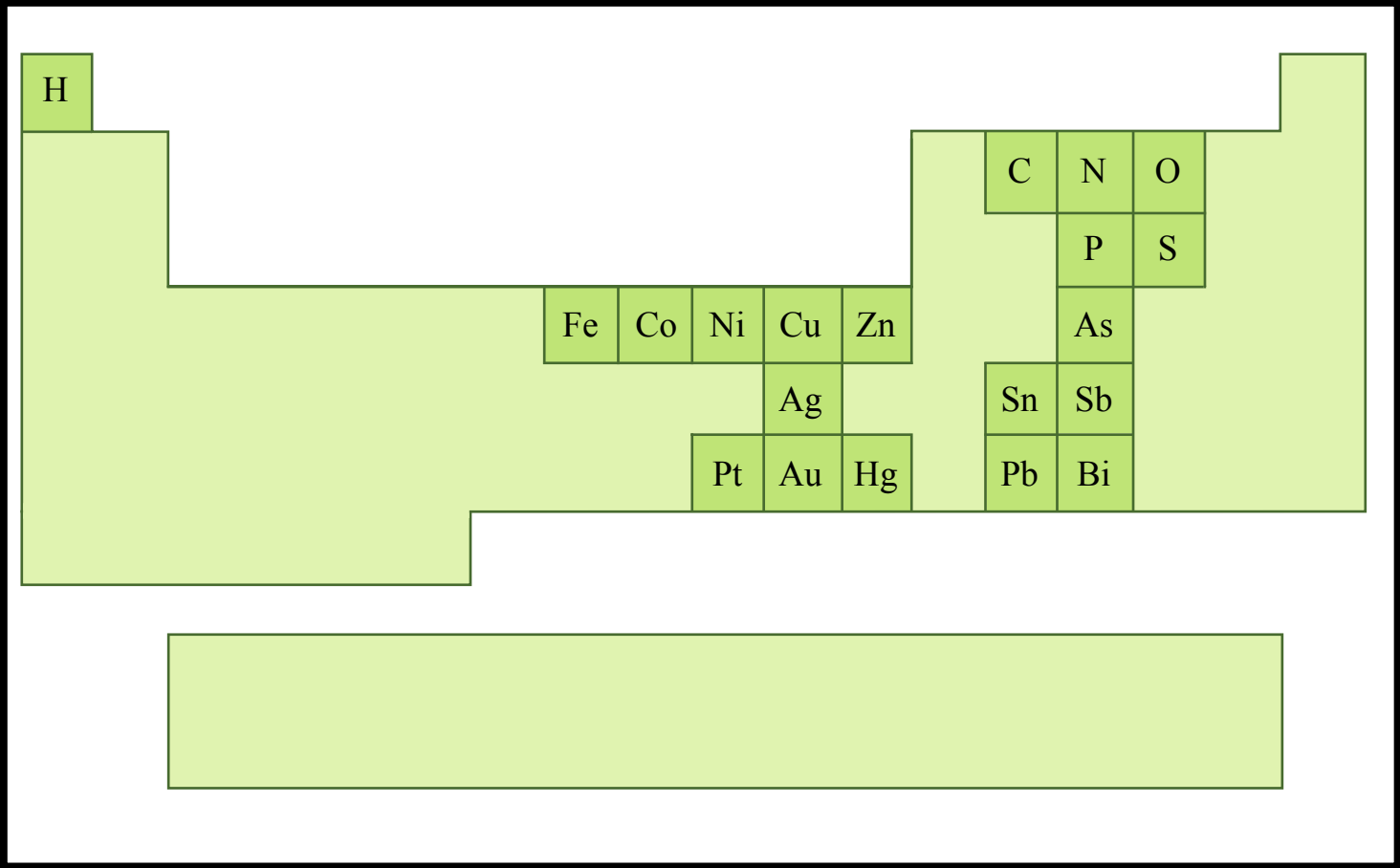
"Compounds"



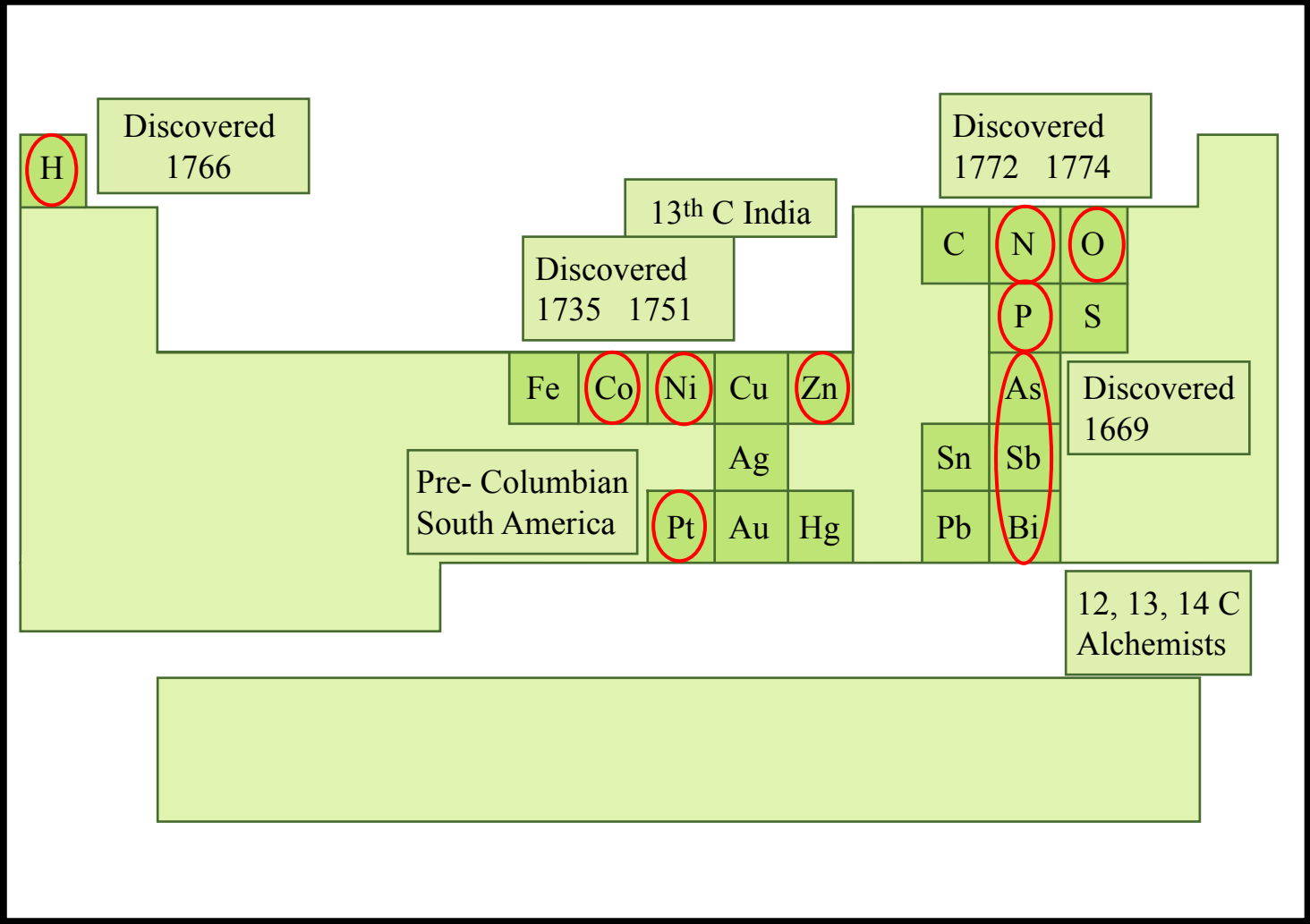
"Compounds"


FIRE
hot
dry
Solution
AIR
$N_2, O_2, Ar,$
CO_2, wet
$SO_2, \ldots$
homogeneous
mixture
aggregate
EARTH
Cold
WATER
Compounds (H_2O)

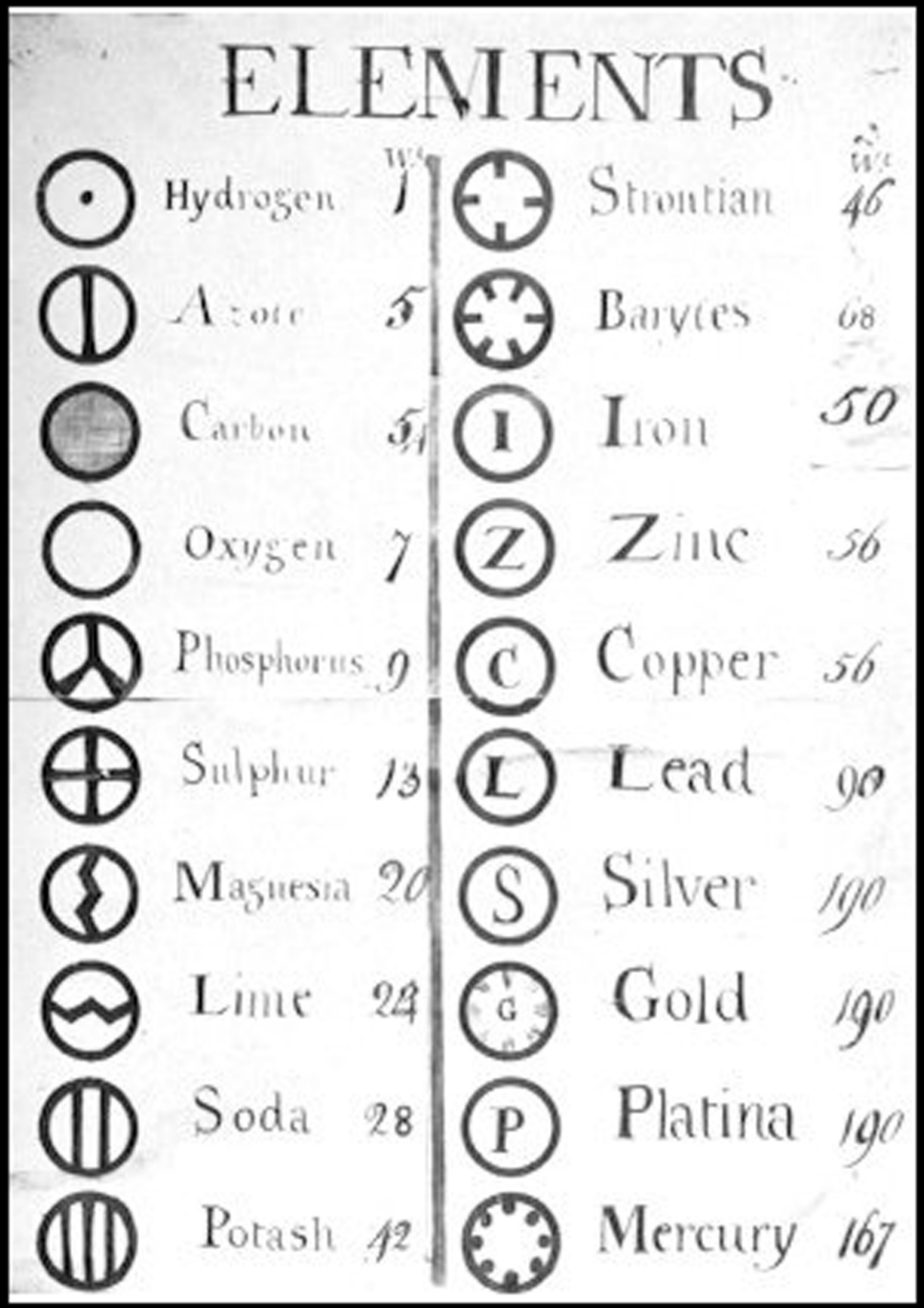
1776



1776

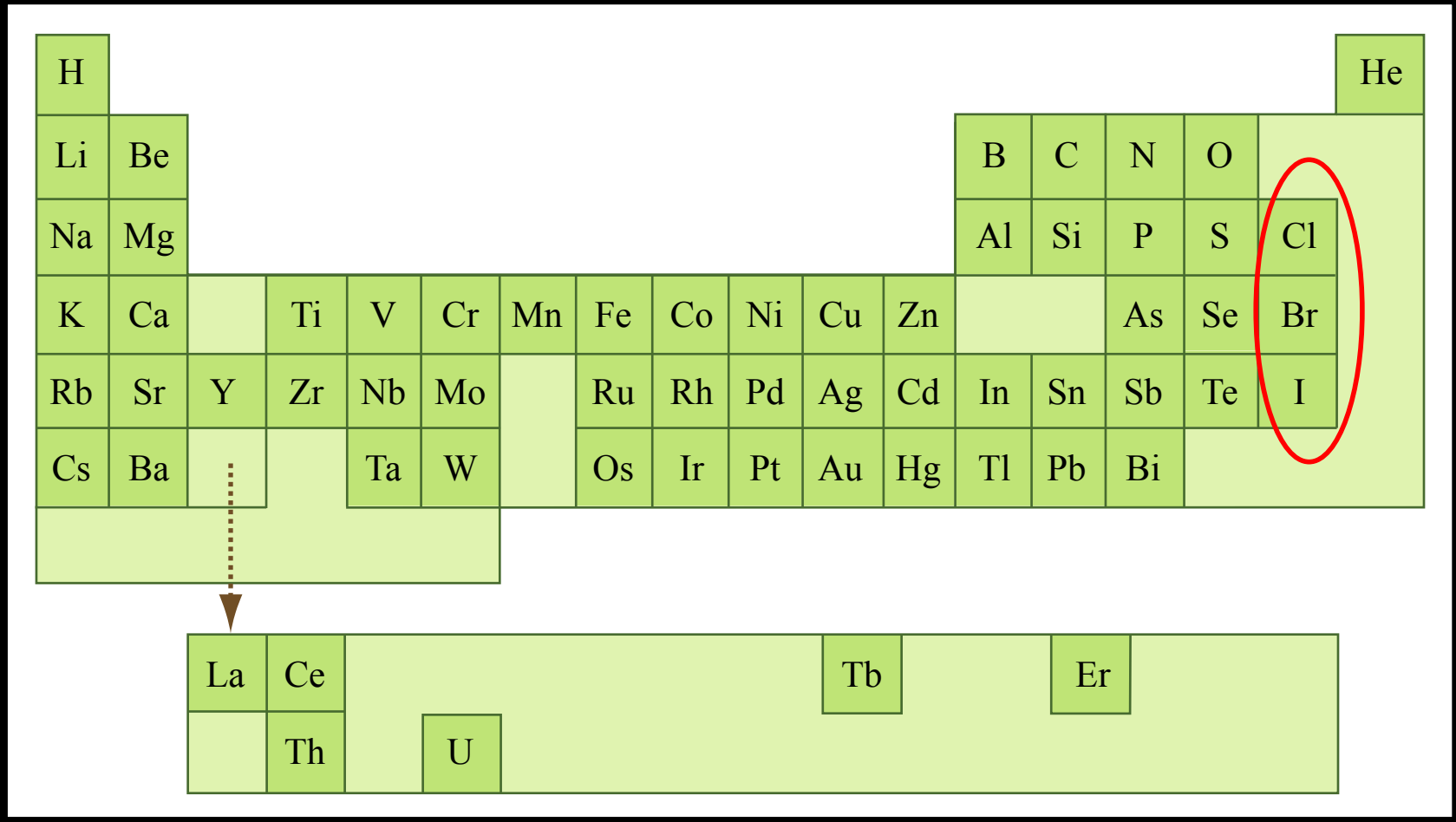


John Dalton 1803



other classifications:

* “triads” 1829, Döbereiner (Jena)



other classifications:

* “triads” 1829, Döbereiner (Jena)

* “octaves” 1864, Newlands (London)

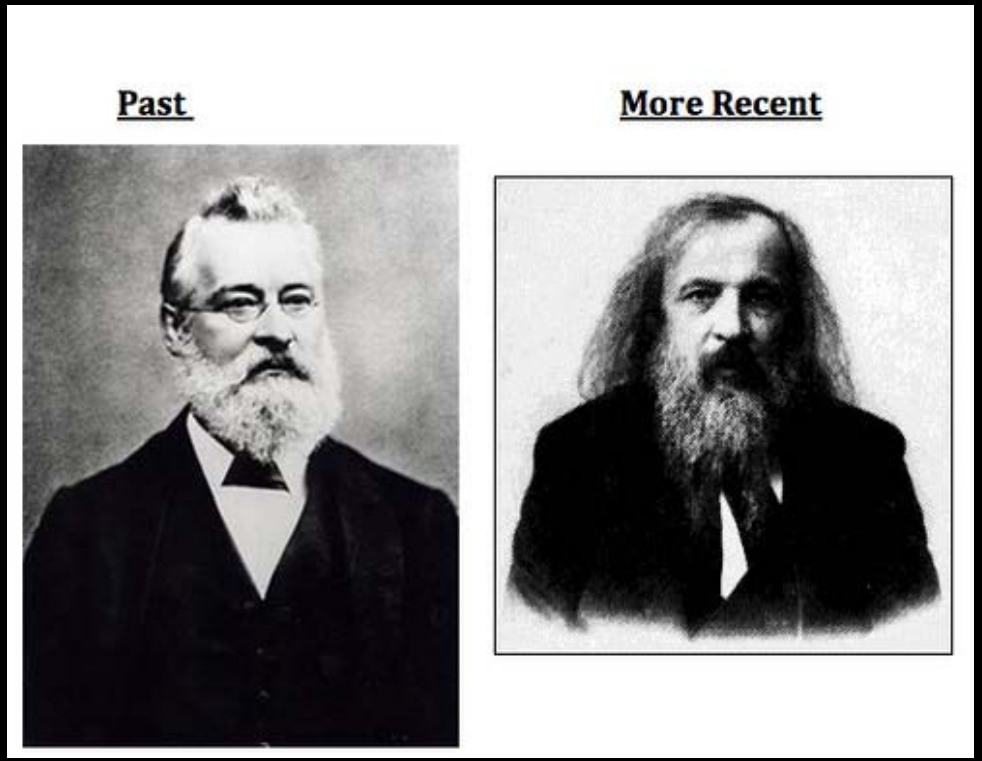


Photo courtesy of scienceheath on Flickr.

No.	No.	No.	No.	No.	No.	No.	No.
H 1	F 8	Cl 15	Co & Ni 22	Br 29	Pd 36	I 42	Pt & Ir 50
Li 2	Na 9	K 16	Cu 23	Rb 30	Ag 37	Cs 44	Tl 51
G 3	Mg 10	Ca 17	Zn 25	Sr 31	Bd [sic-Cd] 38	Ba & V 45	Pb 54
Bo 4	Al 11	Cr 19	Y 24	Ce & La 33	U 40	Ta 46	Th 56
C 5	Si 12	Ti 18	In 26	Zr 32	Sn 39	W 47	Hg 52
N 6	P 13	Mn 20	As 27	Di & Mo 34	Sb 41	Nb 48	Bi 55
O 7	S 14	Fe 21	Se 28	Ro & Ru 35	Te 43	Au 49	Os 51

Note. -- Where two elements happen to have the same equivalent, both are designated by the same number.

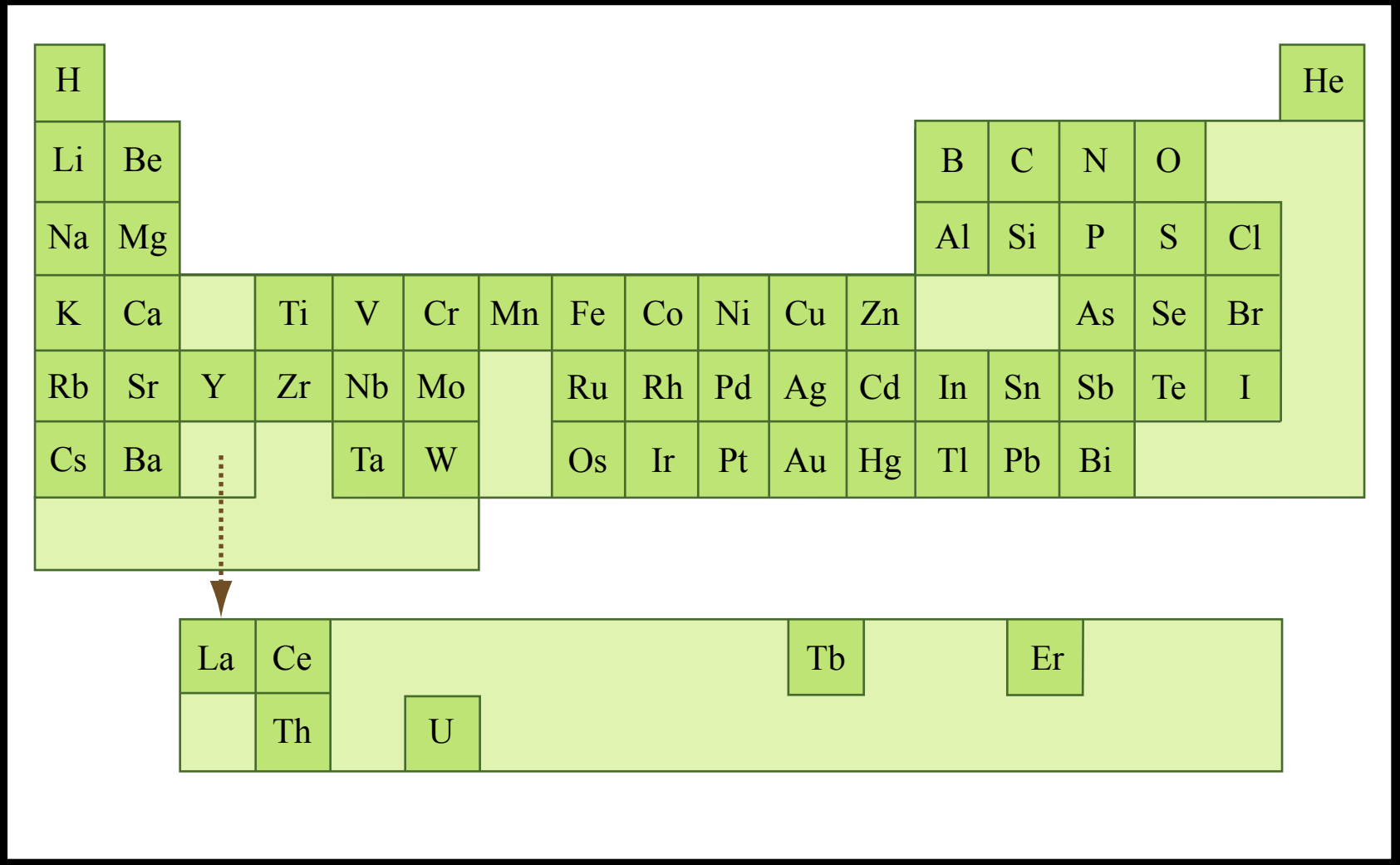
other classifications:

* “triads” 1829, Döbereiner (Jena)

* “octaves” 1864, Newlands (London)

* “periodic table”
  1869, Mendeléef (St. Petersburg)
  1870, Meyer (Tübingen)

1869



но въ ней, мнѣ кажется, уже ясно выражается примѣнимость выставляемаго мною начала ко всей совокупности элементовъ, пай которыхъ извѣстенъ съ достовѣрностію. На этотъ разъ я и желалъ преимущественно найдти общую систему элементовъ. Вотъ этотъ опытъ:

			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?			

а потому приходится въ разныхъ рядахъ имѣть различное измѣненіе разностей, чего нѣтъ въ главныхъ числахъ предлагаемой таблицы. Или же придется предполагать при составленіи системы очень много недостающихъ членовъ. То и другое мало выгодно. Мнѣ кажется притомъ, наиболѣе естественнымъ составить кубическую систему (предлагаемая есть плоскостная), но и попытки для ея образованія не повели къ надлежащимъ результатамъ. Слѣдующія двѣ попытки могутъ показать то разнообразіе сопоставленій, какое возможно при допущеніи основнаго начала, высказаннаго въ этой статьѣ

Li	Na	K	Cu	Rb	Ag	Cs	—	Tl
7	23	39	63,4	85,4	108	133		204
Be	Mg	Ca	Zn	Sr	Cd	Ba	—	Pb
B	Al	—	—	—	Ur	—	—	Bi?
C	Si	Ti	—	Zr	Sn	—	—	—
N	P	V	As	Nb	Sb	—	Ta	—
O	S	—	Se	—	Te	—	W	—
F	Cl	—	Br	—	J	—	—	—
19	35,5	58	80	190	127	160	190	220.

	N=14	P=31	As=75	Sb=122	Bi=210
	O=16	S=32	Se=79,4	Te=128?	
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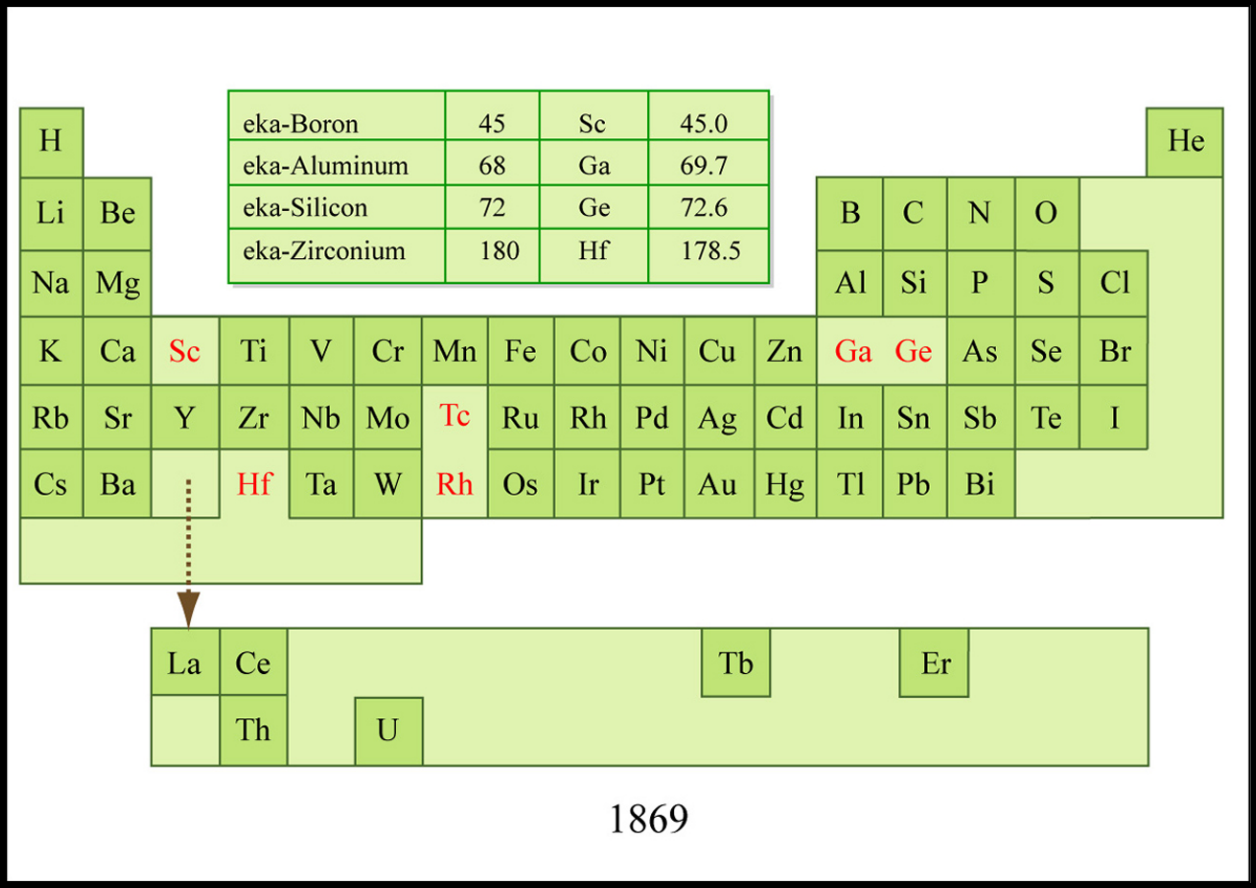
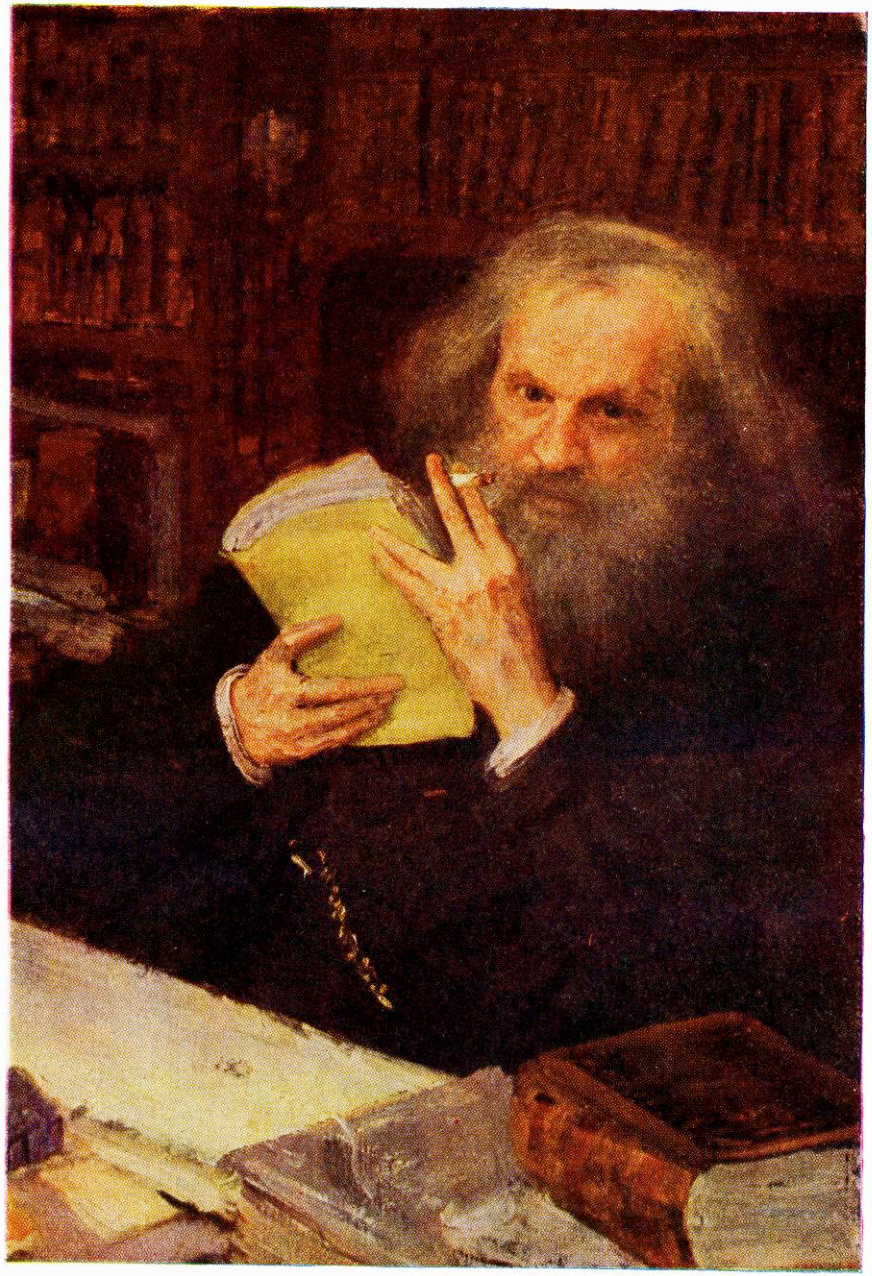
Li	Na	K	Cu	Rb	Ag	Cs	—	Tl
7	23	39	63,4	85,4	108	133		204

1869





Д. И. Менделеев.
Портрет работы И. Е. Репина.

portrait by
I.E. Repin

(1834 – 1907)

Д. И. Менделеев (60-е годы).

3.091SC Introduction to Solid State Chemistry

Fall 2009