



## **PROGRAM**

of stay of participants of  
"D.I.Mendeleyev and His Contribution  
in the Development of World Science"  
International Scientific Conference  
in Tobolsk, September 15<sup>th</sup> – 19<sup>th</sup>, 2009





Czar Nicholas II and Alexi at Tobolsk, Siberia in 1917 - Beinecke Library, Yale University



David Clark, Stepan Kalmykov, and  
David Hobart in Tobolsk, Siberia



**Dr. David Hobart  
Los Alamos  
National Laboratory**

**Academician Boris Myasoedov  
Secretary General  
Russian Academy of Sciences**

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# ***Historical Perspectives and Far Reaching and Unexpected Applications of Mendeleev's Periodic Table of the Elements***

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**Los Alamos, NM 87545 USA**

***Presented at the***

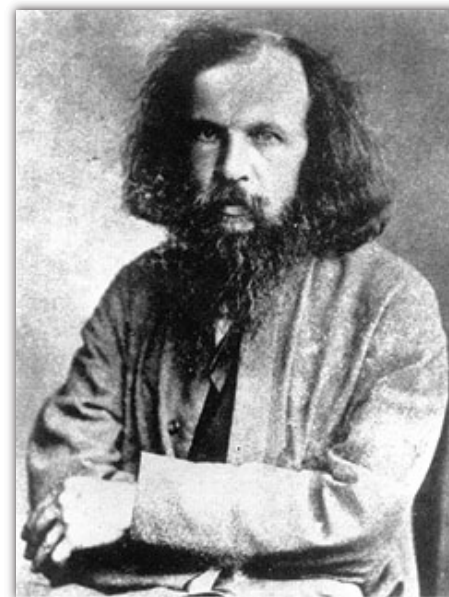
***D. I. Mendeleev and His Contributions to the World Science Conference  
Celebrating the 175<sup>th</sup> Anniversary of the Birth of the Father of the Periodic Table***

***Tobolsk, Siberia, Russia, September 16-19, 2009***

LA-UR-09-05702

# From Modest Beginnings

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**Dmitri Ivanovich Mendeleev** was born on February 8th, 1834 in Verhnie Aremzyani near Tobolsk, Russian Empire

**From modest beginnings in a small village in Siberia an extraordinary Russian chemist conceived of a profound and revolutionary scientific contribution to modern science: the Periodic Table of the Elements.**

# The Greek Periodic Table ~ 400 BC

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As with most profound discoveries a number of important developments and observations were made prior to that discovery



# Definition of an Element



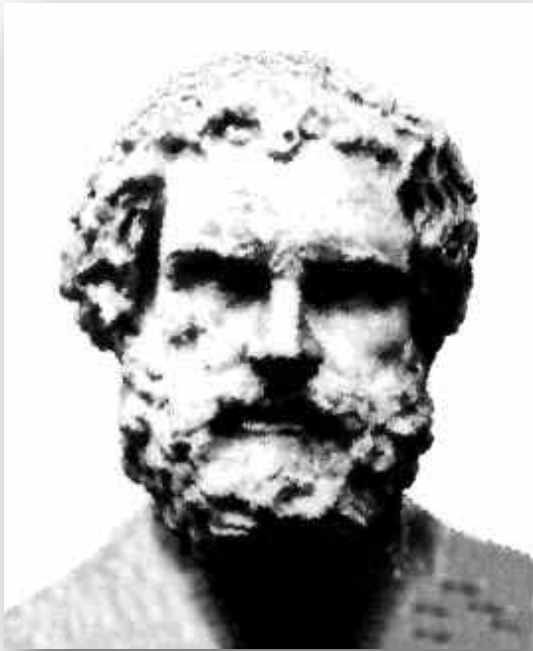
**Robert Boyle**  
**1627-1691**

In 1661 Boyle criticized the experiments of “*alchemists*”

- Chemistry is the science of the composition of substances - not merely an adjunct to the art of alchemy
- Elements are the un-decomposable constituents of material bodies
- Understanding the distinction between mixtures and compounds, he made progress in detecting their ingredients - which he termed *analysis*

# The Atomic Theory

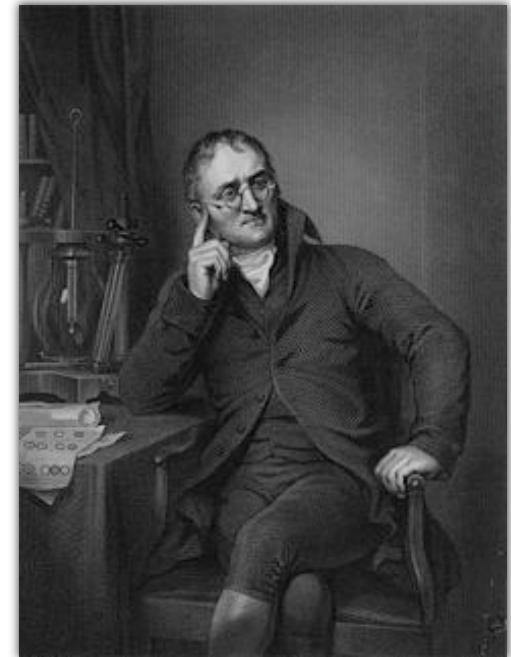
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**Democritus of Abdera**  
460-370 BC

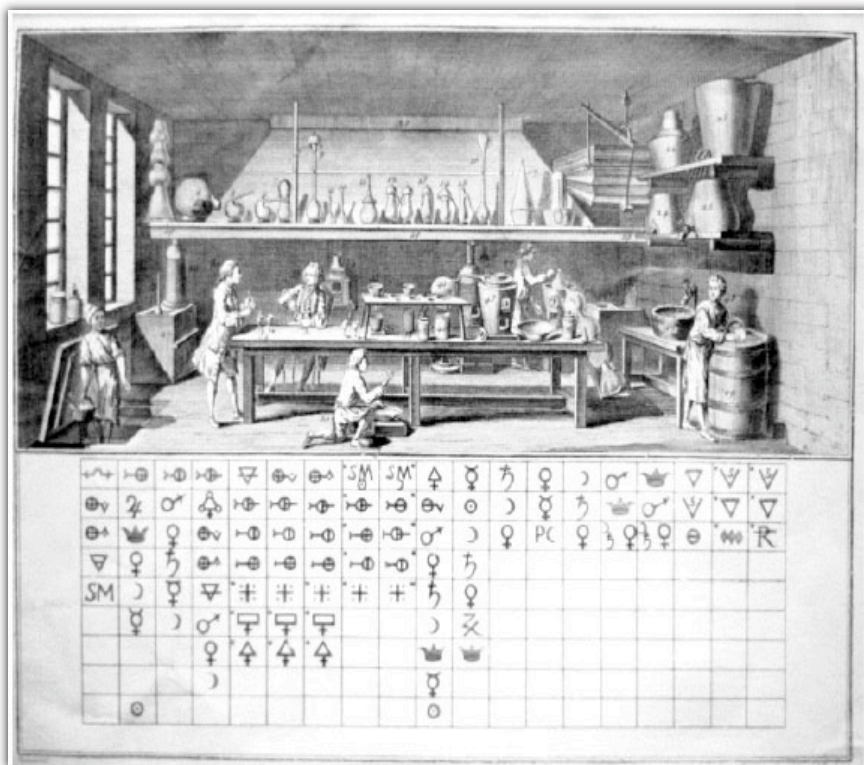
The Greek philosopher Democritus first proposed the atomic theory but centuries later John Dalton established the scientific foundation:

- All atoms of a given element are identical
- The atoms of different elements can be distinguished by their relative weights



**John Dalton**  
1766-1844

# Early Knowledge and Discovery



The elements gold, silver, copper, tin, lead, mercury, and others were known from antiquity.



Searching for the “Philosopher’s Stone” German alchemist Henning Brand discovered **phosphorous** in 1669

# Discovery of New Elements

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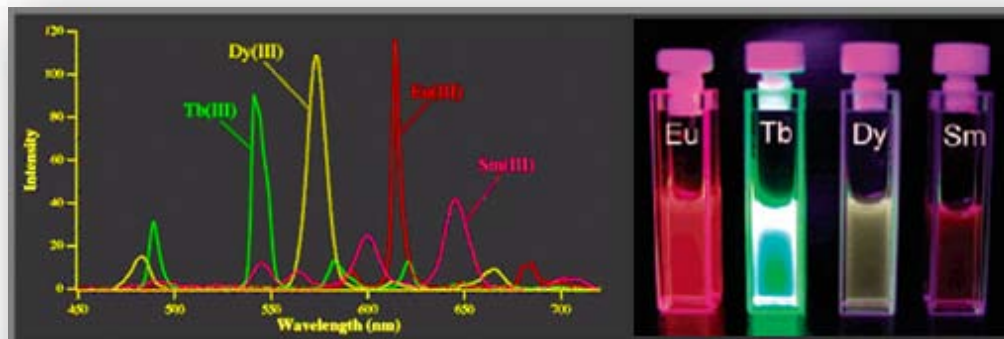


**Martin Klaproth (1743-1817)**  
Ti, Zr, U, Te, Sr, Ce, Cr



**Jöns Berzelius (1779-1848)**  
Si, Se, Ce, Li, V, Th

The lanthanide elements were discovered by many scientists between 1803 and 1907



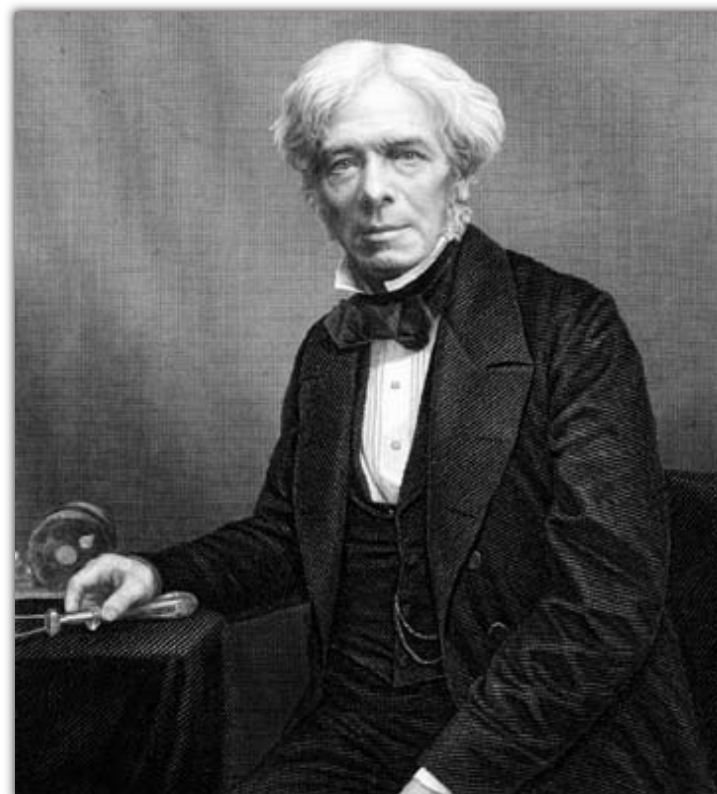
# “Electrifying” Discoveries

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**Sir Humphrey Davy**  
1778-1829

Using electrochemistry he discovered several **alkali** and **alkaline earth metals** and the elemental nature of **carbon**, **chlorine**, and **bromine**.



**Michael Faraday**  
1791-1867

He electrochemically investigated **chlorine**, invented the system of oxidation numbers, and popularized the terms anode, cathode, electrode, and ion.

# More New Elements Discovered

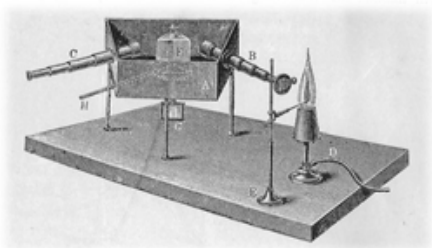
Robert Bunsen and Gustav Kirchhoff contributed to the fundamental understanding of spectroscopy and discovered two alkali metals, **cesium** and **rubidium**, with the aid of the spectroscope they had invented the year before. This inaugurated a new era in the means used to find new elements.



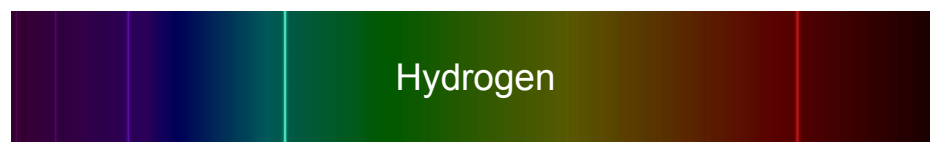
**Robert Bunsen**  
1811-1899



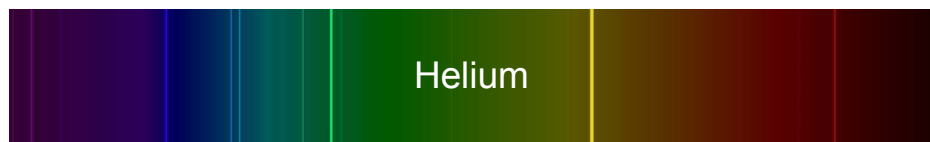
**Gustav Robert Kirchhoff**  
1824-1887



Spectroscope



Hydrogen



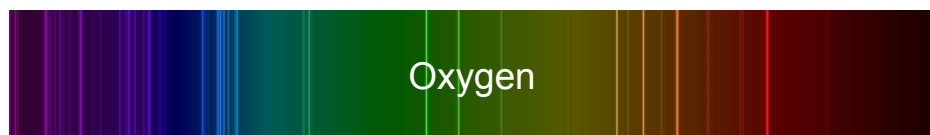
Helium



Carbon



Nitrogen



Oxygen

**GAS DISCHARGE SPECTRA**

# Emerging Patterns Recognized

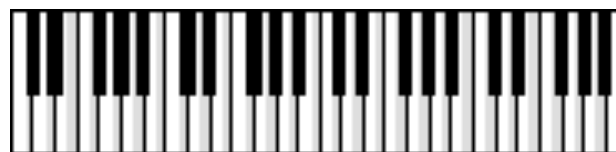
## Dobereiner's Law of Triads (1817)



## Alexandre-Emile Béguyer de Chancourtois' Cylinder (1862)



## Newland's Law of Octaves (1863)



Newlands' Arranged Elements in Octaves:

H	F	Cl	Co/Ni	Br	Pd	I	Pt/Ir
Li	Na	K	Cu	Rb	Ag	Cs	Tl
G	Mg	Ca	Zn	Sr	Cd	Ba/V	Pb
Bo	Al	Cr	Y	Ce/La	U	Ta	Th
C	Si	Ti	In	Zn	Sn	W	Hg
N	P	Mn	As	Di/Mo	Sb	Nb	Bi
O	S	Fe	Se	Ro/Ru	Te	Au	Os



# Mendeleev's Periodic Table (1869)

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=197,4.		
	Fe=56	Rn=104,4	Ir=198.		
	Ni=Co=59	Pi=106,4	O=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?			

Д. Менделѣевъ



His table including 63 known elements that incorporated triads, octaves, and diagonals

Dmitri Ivanovich Mendeleev  
1834-1906





# Meyer's Periodic Table (1870)



**Julius L. Meyer**  
1830-1895

**Julius Lothar Meyer (1830-1895)**  
Table from *Annalen der Chemie, Supplementband 7*, 354 (1870)

Periodic table according to Lothar Meyer, 1870

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	B=11,0	Al=27,3		--		?In=113,4	Tl=202,7	
	C=11,97	Si=28		--	--	Sn=117,8		Pb=206,4
			Ti=48		Zr=89,7			
	N=14,01	P=30,9		As=74,9		Sb=122,1		Bi=207,5
			V=51,2		Nb=93,7		Ta=182,2	
	O=15,96	31,98		Se=78		Te=128,7		--
			Cr=52,4		Mo=95,6		W=183,5	
--	F=19,1	Cl=35,38		Br=79,75		I=126,5		--
			Mn=54,8		Ru=103,5		Cs=198,6 ?	
			Fe=55,9		Rh=104,1		Ir=196,7	
			Co=Ni=58,6		Pd=106,2		Pt=196,7	
Li=7,01	Na=22,99	K=39,04		Rb=85,2		Cs=132,7		--
			Cu=63,3		Ag=107,66		Au=196,2	
?Be=9,3	Mg=23,9	Ca=39,9		Sr=87,0		Ba=136,8		--
			Zn=64,9		Cd=111,6		Hg=199,8	

Julius Meyer was a contemporary and competitor of Mendeleev. He made an abbreviated table with half the known elements in 1864 - the first time that elements had been grouped according to their *valence*.

He later constructed an extended table but unfortunately published it after Mendeleev's table was in print!

# Discovery of Noble Gases

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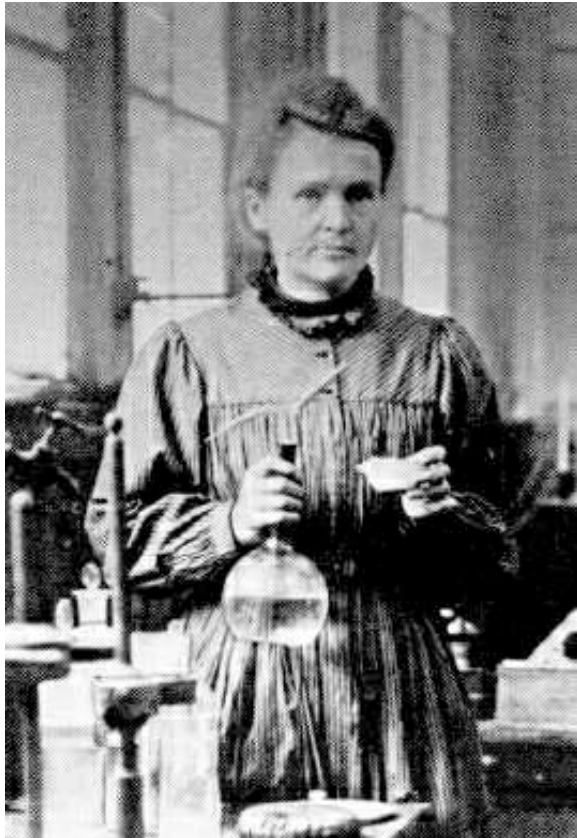
**William Ramsay**  
(1852-1916)



**John William Strutt**  
*Third Baron Rayleigh*  
(1842-1919)

- Lord Rayleigh and William Ramsay discovered the "inert gases."
- In 1895 Rayleigh reported the discovery of **argon** a new gaseous element that was chemically inert that did not fit any of the known periodic groups.
- Ramsey discovered the rest of the inert gases and positioned them on the right side of the periodic table according to their atomic weights.

# Discovery of New Elements



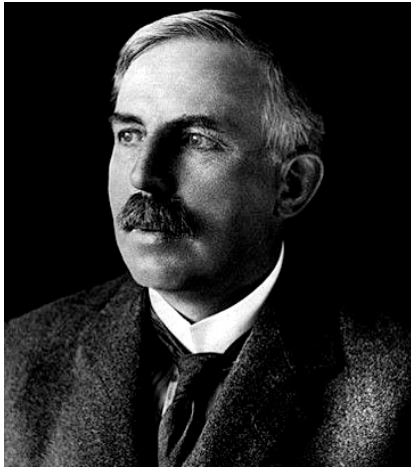
**Marie Curie (1867-1934)**



**Pierre Curie (1859-1906)**

In 1898 Madam Curie and her husband Pierre isolated the new elements **polonium** and **radium** from the uranium ore pitchblende - filling additional holes and adding new elements to Mendeleev's table.

# The Theory of Atomic Structure



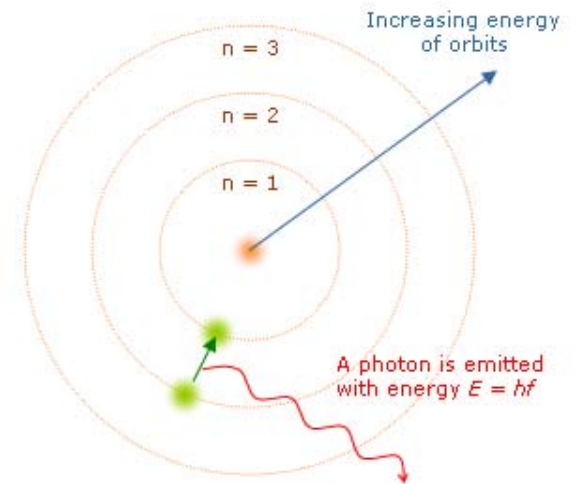
**Ernest Rutherford**  
(1871-1937)



**Niels Bohr**  
(1885-1962)



**Max Planck**  
(1858-1947)

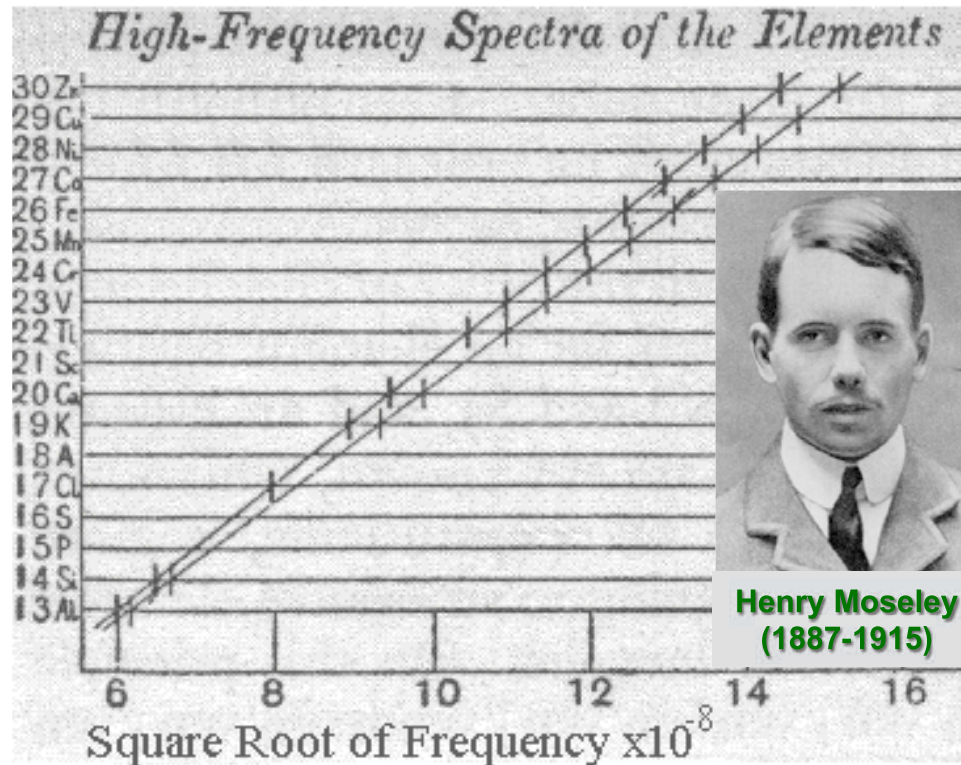


**Bohr Atom**

- Rutherford proposed that all of the mass of the atom was in the nucleus surrounded by nearly empty space.
- Bohr adapted Rutherford's theory to Planck's quantum theory and stated that electrons travel in discrete orbits around the nucleus

# Moseley's X-ray Experiments

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In 1913 Moseley subjected the known elements to x-rays and derived the relationship between x-ray frequency and number of protons.

When the elements were arranged according to increasing **atomic numbers** and not **atomic masses**, the inconsistencies in Mendeleev's table were eliminated!

# Quantum Mechanics



**Niels Bohr**  
(1885-1962)



**Werner Heisenberg**  
(1901-1976)



**Erwin Schrödinger**  
(1887-1961)



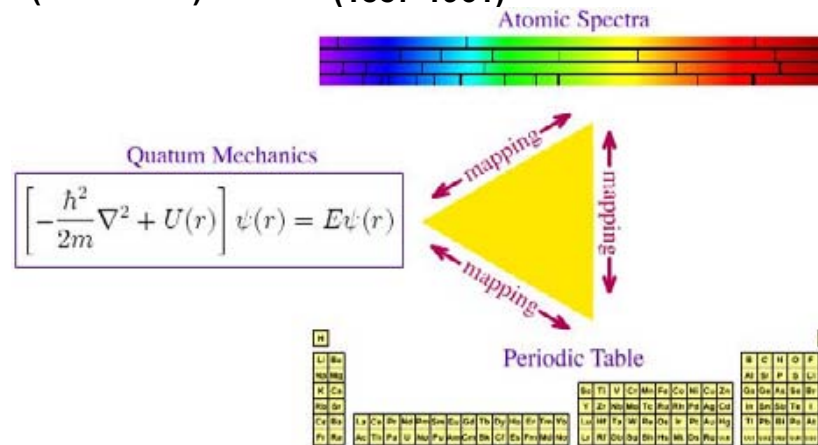
**Wolfgang Pauli**  
(1900-1958)



**Albert Einstein**  
(1879-1955)



**Max Born**  
(1882-1970)



**Paul Dirac**  
(1902-1984)

The uncertainty principle combined with the Bohr atom and the duality of wave and particle properties resulted in the quantum mechanical description of the atom through the collaborative effort of some of the most brilliant minds of the 20<sup>th</sup> Century





# The Periodic Table 1938

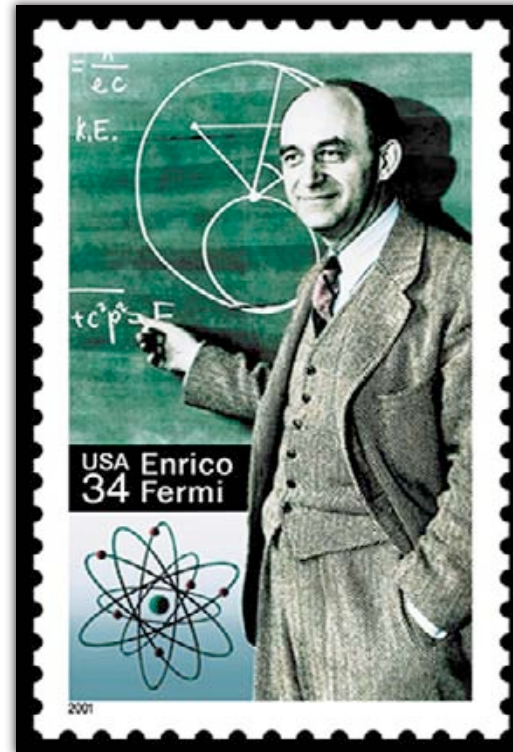
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Th	Pa	U													
		<i>Lanthanides</i>															
		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		

# Modern Alchemy by Transmutation?

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**Leo Szilard  
(1898-1964)**



**Enrico Fermi (1901-1954)**

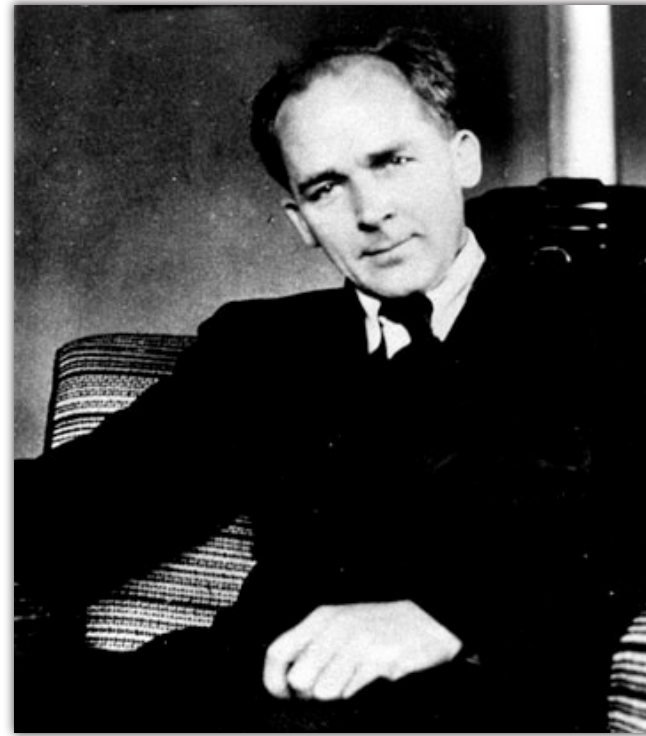
- In 1934 Enrico Fermi and Leo Szilard proposed using neutron bombardment to cause a “chain reaction.”
- They also attempted synthesizing new elements by neutron bombardment of uranium with mysterious and inconclusive results.

# Discovery of Fission

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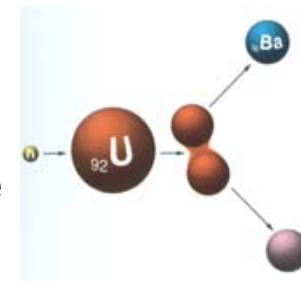


Otto Hahn (1879-1968) Lise Meitner (1878-1968)



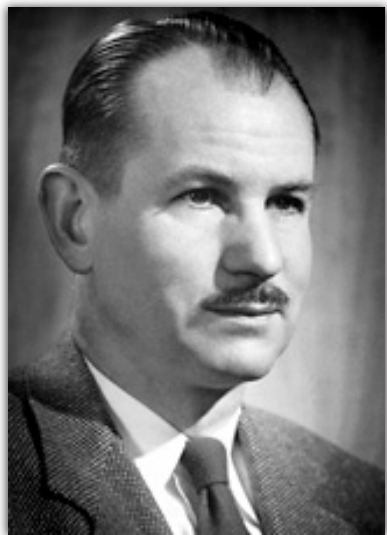
Fritz Strassman (1902-1980)

In the 1930's Hahn, Meitner, and Strassmann bombarded uranium atoms with neutrons and eventually concluded that they had “fissioned” or split the uranium atom into radioactive daughter elements!



# Discovery of Neptunium

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**Edwin  
McMillan  
(1907-1991)**



**Philip Abelson  
(1913-2004)**

With excitement about fission reaching the University of California, Berkeley, McMillan and Abelson bombarded uranium with moderated (slow) neutrons, resulting in “fusion” of the reactants:

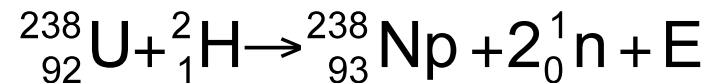


Announced in 1940, the new man-made element was named neptunium (Np) after Neptune, the planet beyond Uranus.

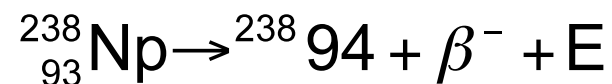
# The Discovery of Plutonium

McMillan was called away to work on the new wartime device called "RADAR."

In 1940-1941 Berkeley professor Glenn Seaborg and graduate student Art Wahl bombarded uranium with deuterons to make neptunium and followed its beta decay:



$$t_{1/2} {}_{93}^{238}\text{Np} = 2.1 \text{ days}$$



$$t_{1/2} {}_{94}^{238} = 87.7 \text{ years}$$

# The Discovery of Plutonium

---

Seaborg named the new element **plutonium** after the next planet, Pluto and assigned it the symbol **Pu**.

The announcement of the discovery was withheld because of security when the unusual nuclear behavior of this element was determined.



Glenn T.  
Seaborg  
1912 – 1999

# The Periodic Table 1945

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Th	Pa	U	Np	Pu											
		<i>Lanthanides</i>															
		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		

# The Discovery of Americium and Curium



In 1944/1945, Seaborg and coworkers synthesized two new elements:

- *Element 95, americium* was named after its continent of discovery
- *Element 96, curium* honors Madame Curie

Seaborg inadvertently announced these discoveries on the “Quiz Kids” radio program!

*The chemistry of americium and curium was very perplexing and these elements were not behaving as was expected!*



# Seaborg's Actinide Hypothesis

In 1945, with the discovery of the elements, *americium* and *curium*, and their *rare-earth-like* behavior, Glenn Seaborg proposed a radical rearrangement of the Periodic Table and proposed a new “actinide” series.

He was told by his major professor, G. N. Lewis, that if he published this theory, he would ruin his reputation.

Seaborg said he didn't have a reputation and published anyway! Seaborg's hypothesis was right on target!



# Quantum Explanation of Periodicity

Quantum numbers  $n$ ,  $l$ ,  $m$ ,  $s$

$l = 0 \rightarrow$  *sharp*  
 $l = 1 \rightarrow$  *principal*  
 $l = 2 \rightarrow$  *diffuse*  
 $l = 3 \rightarrow$  *fundamental*

<b>s</b>												<b>p</b>						
H																		He
Li	Be											B	C	N	O	F	Ne	
Na	Mg											Al	Si	P	S	Cl	Ar	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
Fr	Ra											<b>f</b>						
		Lanthanides	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
		Actinides	Th	Pa	U	Np	Pu	Am	Cm									

# The Discovery of Berkelium and Californium



Street, Thompson, Seaborg, and Ghiorso

In 1949, Seaborg and coworkers at Berkeley synthesized elements 97 and 98 by nuclear bombardment and named them after the city and state of their discovery.

# The Discovery of Einsteinium and Fermium



In 1952, a team led by Seaborg discovered einsteinium and fermium in debris from the first thermonuclear (fusion) explosion (“MIKE” ) detonated on Eniwetok Island in the South Pacific. The elements were named in honor of the famous scientists.

# The Discovery of Mendeleevium

Discovered in 1955 by Ghiorso, Harvey, Choppin, Thompson, and Seaborg at Berkeley by bombardment of Es with He ions.

Seaborg: “It was fitting that the element be named for the Russian chemist Mendeleev who developed the periodic table. In discovering transuranium elements we depended on his table for predicting their chemical properties based on their position in the table.

During the Cold War naming an element for a Russian was a bold gesture that did not sit well with some Americans. However, Md was approved by IUPAC in August 1997



Gregory Choppin, Glenn Seaborg, Bernard Harvey, and Albert Ghiorso at Berkeley Laboratory

31	32	34	35	3
Галлий	Германий	Селен	Бром	Кобальт
38	40	41	43	
Иттрий	Цирконий	Молибден	Технеций	
49	50	52		
Иттрий	Олово	Сурьма	Родий	
56	57	72	73	75
Лантан	Гафний	Тантал	Вольфрам	

101	(258)
<b>Md</b>	
Mendelevium	

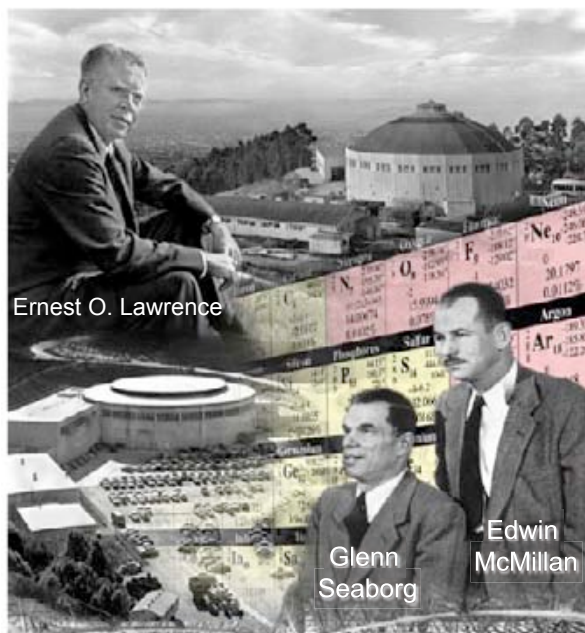


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LAWRENCE BERKELEY NATIONAL LABORATORY



U.S. DEPARTMENT OF  
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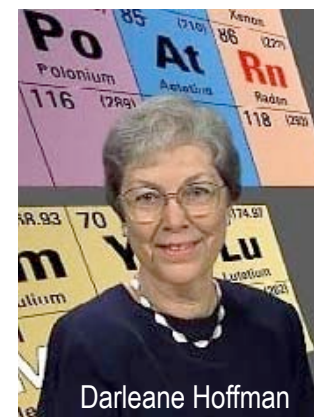


Ernest O. Lawrence

Glenn Seaborg  
Edwin McMillan



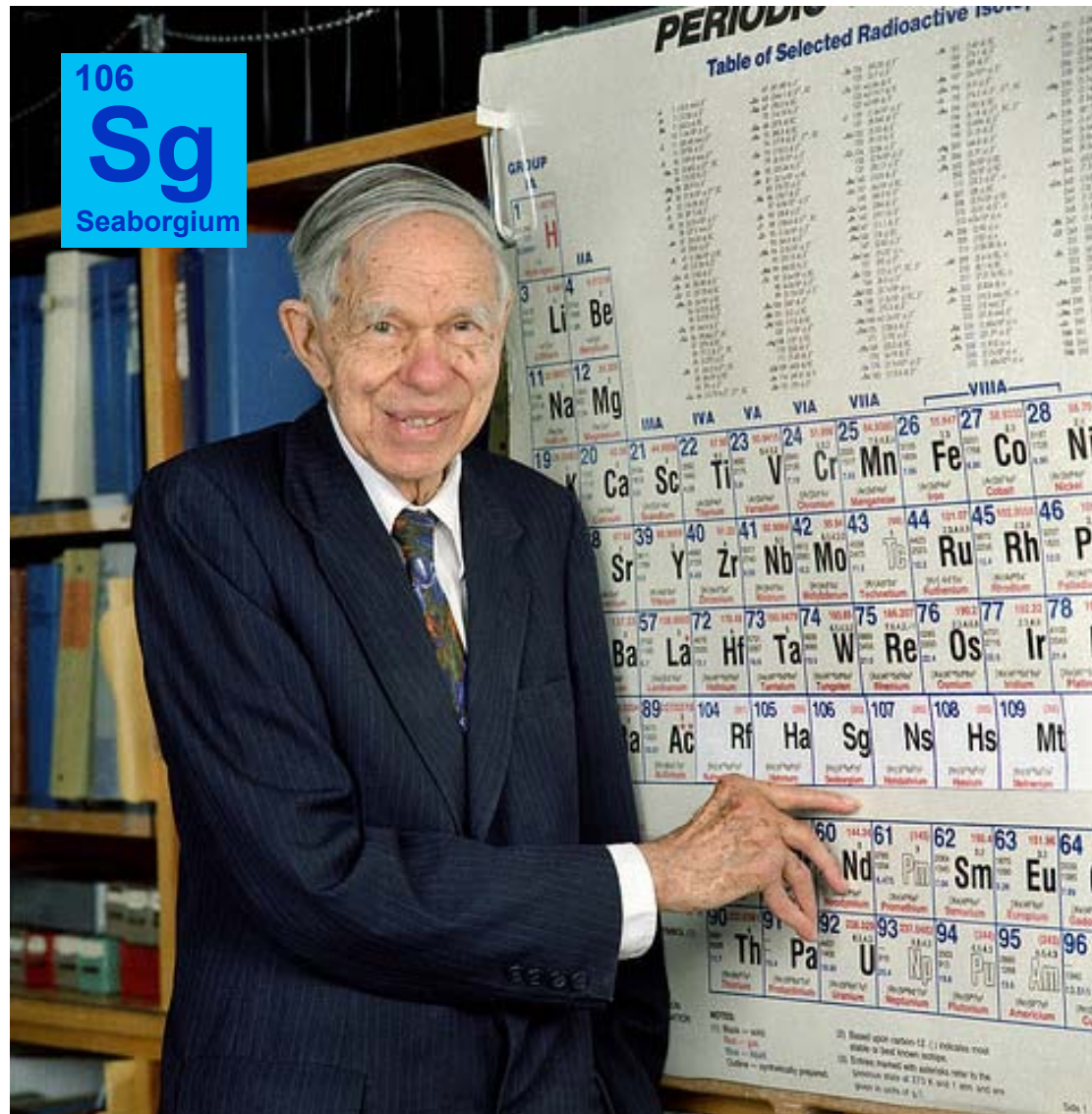
Kenneth Hulet Glenn Seaborg Albert Ghiorso



Darleane Hoffman

1949 -1999 Berkeley scientists synthesized more than a dozen elements beyond curium including berkelium through seaborgium along with many of their isotopes

# Element 106 Named Seaborgium







Photographs showing the colors of the various oxidation states of plutonium in solution presented to Prof. Seaborg at the 50<sup>th</sup> Anniversary of Discovery

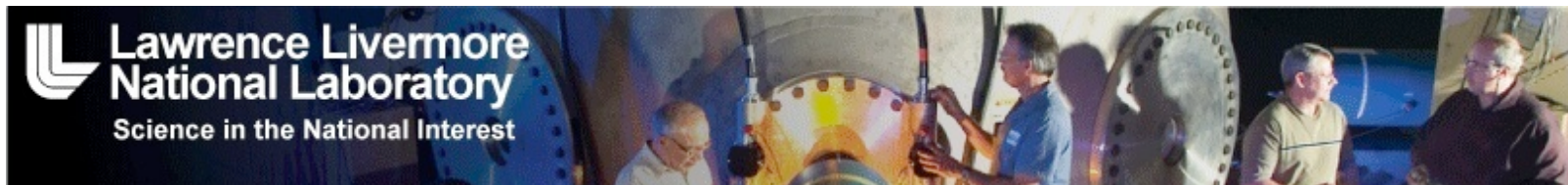


**FLEROV LABORATORY OF NUCLEAR REACTIONS  
JOINT INSTITUTE FOR NUCLEAR RESEARCH  
DUBNA, RUSSIA**



**Periodic Table**  
Периодическая таблица элементов Д.И. Менделеева

периоды период	группы элементов																	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII
1	H 1																	He 2
2	Li 3	Be 4	B 5	C 6	N 7	O 8	F 9	Ne 10										
3	Na 11	Mg 12	Al 13	Si 14	P 15	S 16	Cl 17	Ar 18										
4	K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28								
5	Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46								
6	Cs 55	Ba 56	La 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78								
7	Fr 87	Ra 88	Ac 89	Rf 104	Db 105	Sg 106	Bh 107	Hs 108	Mt 109	Ds 110								
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## LLNL's HEAVY ELEMENT RESEARCH GROUP

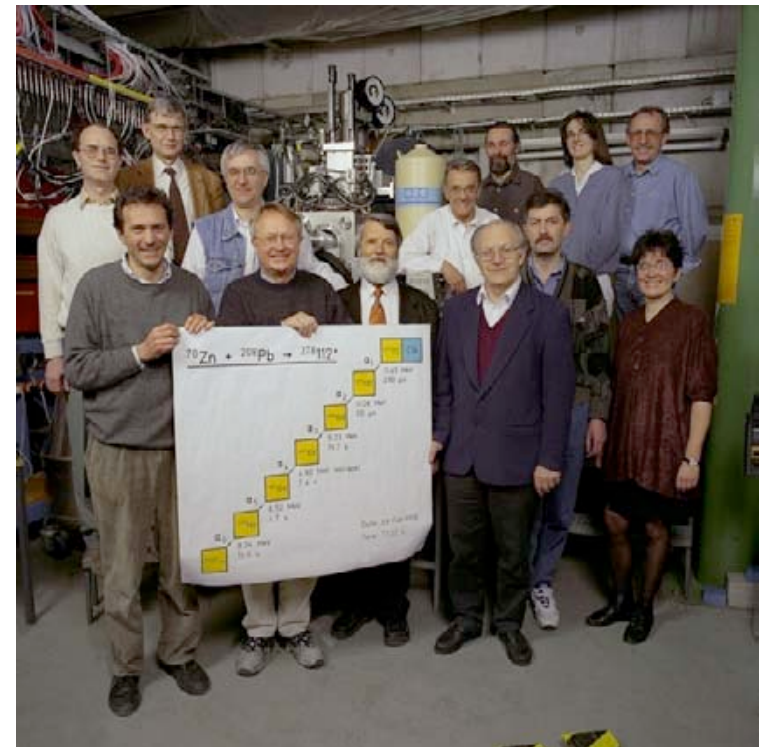
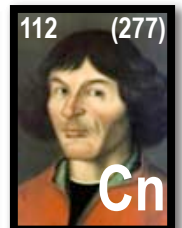
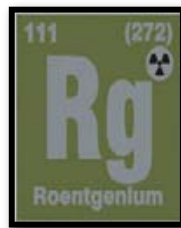
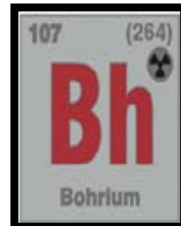
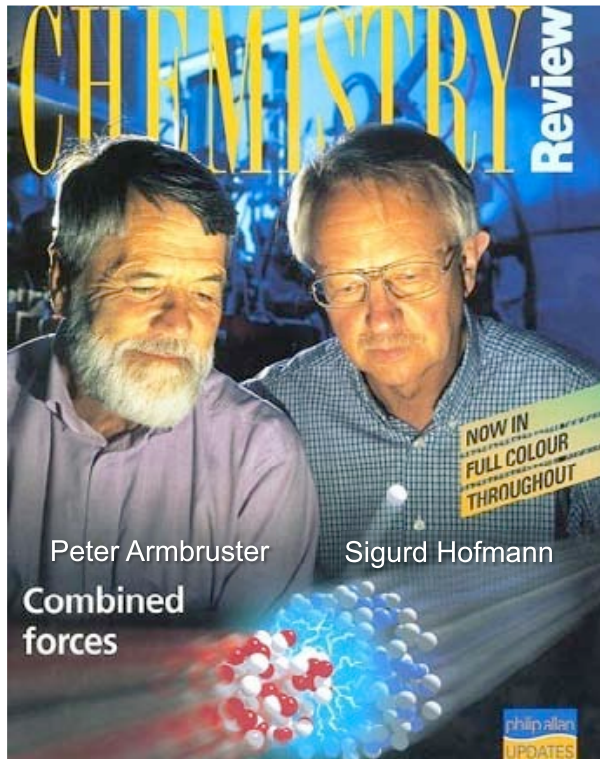


Periodic Table of the Elements

1 H 1.008	2 He 4.003																																		
3 Li 6.941	4 Be 9.012	5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18											11 Na 22.99	12 Mg 24.31	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95										
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 97.91	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)	87 Fr (223)	88 Ra (226)	89 Ac~ (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (271)	111 Uu (272)	112 Uut (277)	113 Uuq (285)	114 Uup (289)	115 Uub (288)	116 Uuq (292)	117 Uuh (294)	118 Uuo (294)
*Lanthanides		58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0																				
~Actinides		90 Th 232.0	91 Pa (231)	92 U (238)	93 Np (241)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)																				

- In 1999 and 2001 LLNL announced the discovery of elements 114 and 116.
- In 2004, LLNL working in collaboration with the Joint Institute for Nuclear Research (JINR) in Dubna, Russia observed the existence of elements 113 and 115.
- In 2005 the Livermore-Dubna team discovered element 118.





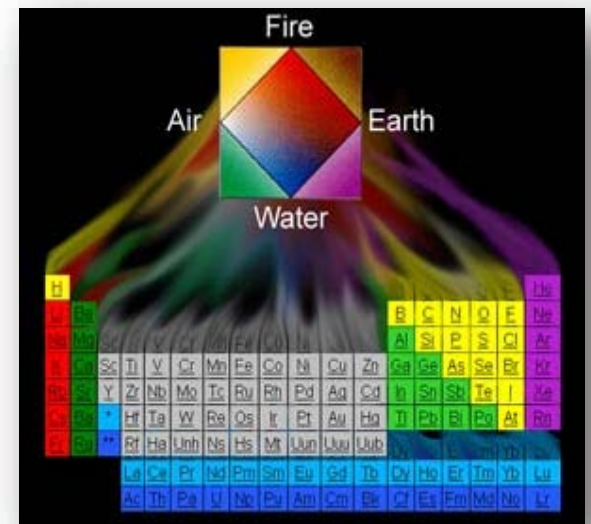
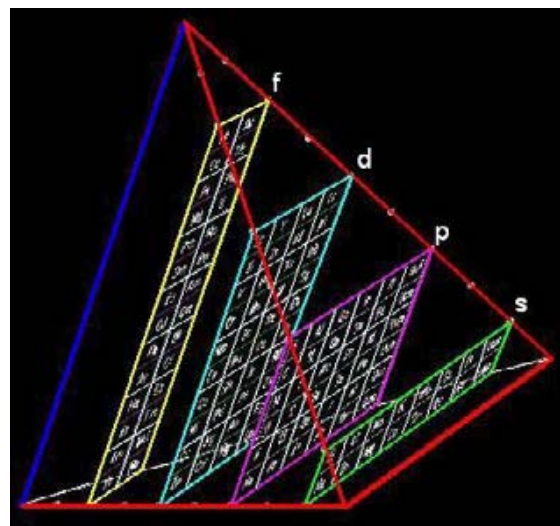
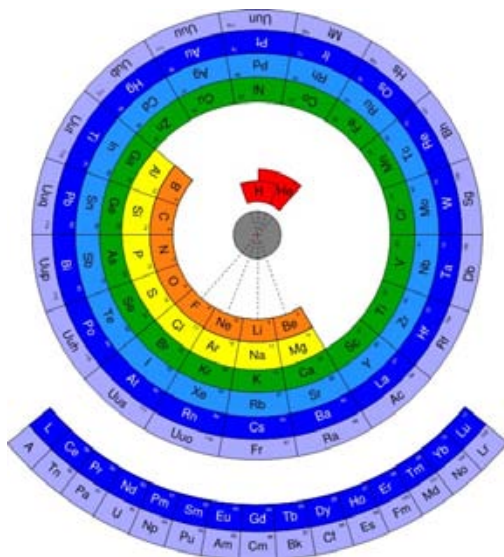
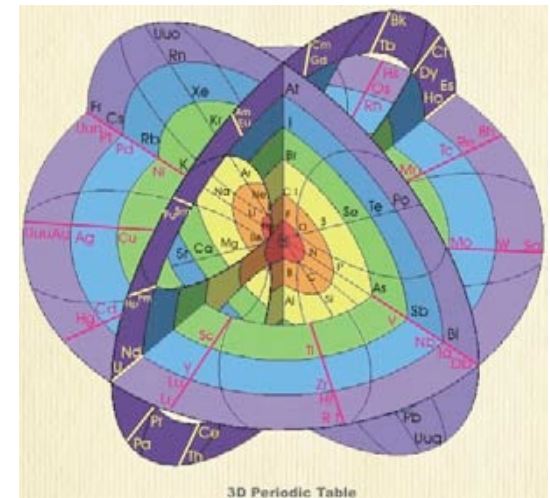
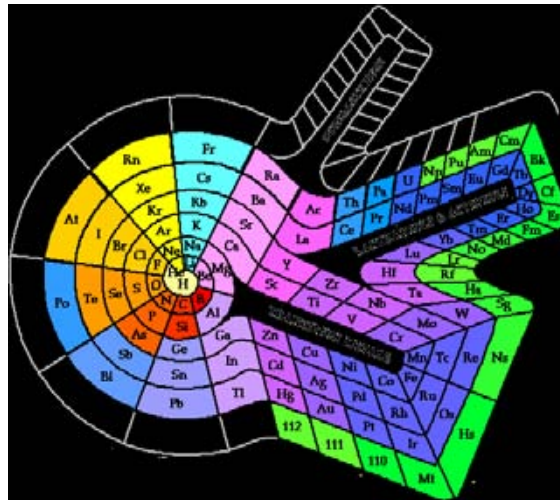
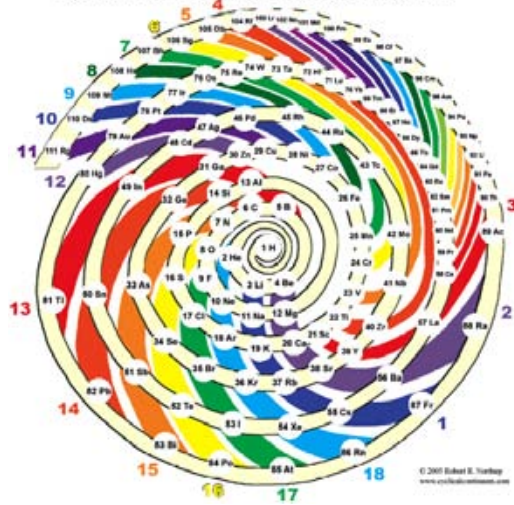
July 2009 - Credited with its discovery, the GSI-Darmstadt group of Sigurd Hofmann proposes the name **COPERNICIUM** for element 112 - IUPAC approved the symbol "Cn".

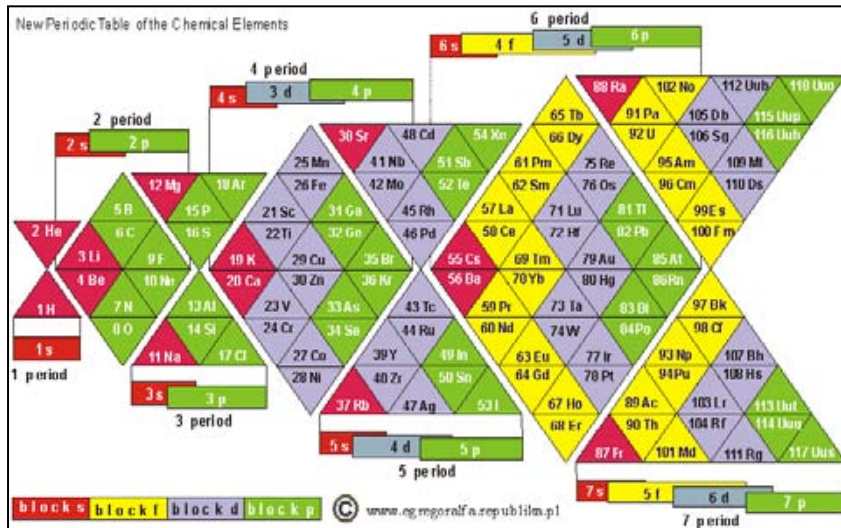


# Periodic Table Variations

<h1>THE ELEMENTS</h1>																		He <sup>2</sup> Helium																																															
Li <sup>3</sup> Lithium		Be <sup>4</sup> Beryllium		B <sup>5</sup> Boron		C <sup>6</sup> Carbon		N <sup>7</sup> Nitrogen		O <sup>8</sup> Oxygen		F <sup>9</sup> Fluorine		Ne <sup>10</sup> Neon																																																			
Na <sup>11</sup> Sodium		Mg <sup>12</sup> Magnesium		Al <sup>13</sup> Aluminum		Si <sup>14</sup> Silicon		P <sup>15</sup> Phosphorus		S <sup>16</sup> Sulfur		Cl <sup>17</sup> Chlorine		Ar <sup>18</sup> Argon																																																			
K <sup>19</sup> Potassium		Ca <sup>20</sup> Calcium		Sc <sup>21</sup> Scandium		Ti <sup>22</sup> Titanium		V <sup>23</sup> Vanadium		Cr <sup>24</sup> Chromium		Mn <sup>25</sup> Manganese		Fe <sup>26</sup> Iron		Co <sup>27</sup> Cobalt		Ni <sup>28</sup> Nickel		Cu <sup>29</sup> Copper		Zn <sup>30</sup> Zinc		Ga <sup>31</sup> Gallium		Ge <sup>32</sup> Germanium		As <sup>33</sup> Arsenic		Se <sup>34</sup> Selenium		Br <sup>35</sup> Bromine		Kr <sup>36</sup> Krypton																															
Rb <sup>37</sup> Rubidium		Sr <sup>38</sup> Strontium		Y <sup>39</sup> Yttrium		Zr <sup>40</sup> Zirconium		Nb <sup>41</sup> Niobium		Mo <sup>42</sup> Molybdenum		Tc <sup>43</sup> Technetium		Ru <sup>44</sup> Ruthenium		Rh <sup>45</sup> Rhodium		Pd <sup>46</sup> Palladium		Ag <sup>47</sup> Silver		Cd <sup>48</sup> Cadmium		In <sup>49</sup> Indium		Sn <sup>50</sup> Tin		Sb <sup>51</sup> Antimony		Te <sup>52</sup> Tellurium		I <sup>53</sup> Iodine		Xe <sup>54</sup> Xenon																															
Cs <sup>55</sup> Cesium		Ba <sup>56</sup> Barium		La <sup>57</sup> Lanthanum		Ce <sup>58</sup> Cerium		Pr <sup>59</sup> Praseodymium		Nd <sup>60</sup> Neodymium		Pm <sup>61</sup> Promethium		Sm <sup>62</sup> Samarium		Eu <sup>63</sup> Europium		Gd <sup>64</sup> Gadolinium		Tb <sup>65</sup> Terbium		Dy <sup>66</sup> Dysprosium		Ho <sup>67</sup> Holmium		Er <sup>68</sup> Erbium		Tm <sup>69</sup> Thulium		Yb <sup>70</sup> Ytterbium		Lu <sup>71</sup> Lutetium		Hf <sup>72</sup> Hafnium		Ta <sup>73</sup> Tantalum		W <sup>74</sup> Tungsten		Re <sup>75</sup> Rhenium		Os <sup>76</sup> Osmium		Ir <sup>77</sup> Iridium		Pt <sup>78</sup> Platinum		Au <sup>79</sup> Gold		Hg <sup>80</sup> Mercury		Tl <sup>81</sup> Thallium		Pb <sup>82</sup> Lead		Bi <sup>83</sup> Bismuth		Po <sup>84</sup> Polonium		At <sup>85</sup> Astatine		Rn <sup>86</sup> Radon			
Fr <sup>87</sup> Francium		Ra <sup>88</sup> Radium		Rf <sup>104</sup> Rutherfordium		Db <sup>105</sup> Dubnium		Sg <sup>106</sup> Seaborgium		Bh <sup>107</sup> Bohrium		Hs <sup>108</sup> Hassium		Mt <sup>109</sup> Meitnerium		Ds <sup>110</sup> Darmstadtium		Rg <sup>111</sup> Roentgenium		Uub <sup>112</sup> Ununbium		Uut <sup>113</sup> Ununtrium		Uuq <sup>114</sup> Ununquadium		Uup <sup>115</sup> Ununpentium		Uuh <sup>116</sup> Ununhexium		Uus <sup>117</sup> Ununseptium		Uuo <sup>118</sup> Ununoctium		Ac <sup>89</sup> Actinium		Th <sup>90</sup> Thorium		Pa <sup>91</sup> Protactinium		U <sup>92</sup> Uranium		Np <sup>93</sup> Neptunium		Pu <sup>94</sup> Plutonium		Am <sup>95</sup> Americium		Cm <sup>96</sup> Curium		Bk <sup>97</sup> Berkelium		Cf <sup>98</sup> Californium		Es <sup>99</sup> Einsteinium		Fm <sup>100</sup> Fermium		Md <sup>101</sup> Mendelevium		No <sup>102</sup> Nobelium		Lr <sup>103</sup> Lawrencium			
<p>Radioactive elements</p> <p>Many of the elements shown here are highly unstable and decay rapidly. The half-lives of many of these elements are so short that they have never been observed in nature. However, some of these elements are produced in the laboratory and have been observed in the form of a solid or liquid. The half-lives of these elements range from a few seconds to a few years. The half-lives of these elements are listed in the table below.</p> <p>More information on these elements can be found at <a href="http://www.chemeddl.org">www.chemeddl.org</a></p>				La <sup>57</sup> Lanthanum		Ce <sup>58</sup> Cerium		Pr <sup>59</sup> Praseodymium		Nd <sup>60</sup> Neodymium		Pm <sup>61</sup> Promethium		Sm <sup>62</sup> Samarium		Eu <sup>63</sup> Europium		Gd <sup>64</sup> Gadolinium		Tb <sup>65</sup> Terbium		Dy <sup>66</sup> Dysprosium		Ho <sup>67</sup> Holmium		Er <sup>68</sup> Erbium		Tm <sup>69</sup> Thulium		Yb <sup>70</sup> Ytterbium		Lu <sup>71</sup> Lutetium		Ac <sup>89</sup> Actinium		Th <sup>90</sup> Thorium		Pa <sup>91</sup> Protactinium		U <sup>92</sup> Uranium		Np <sup>93</sup> Neptunium		Pu <sup>94</sup> Plutonium		Am <sup>95</sup> Americium		Cm <sup>96</sup> Curium		Bk <sup>97</sup> Berkelium		Cf <sup>98</sup> Californium		Es <sup>99</sup> Einsteinium		Fm <sup>100</sup> Fermium		Md <sup>101</sup> Mendelevium		No <sup>102</sup> Nobelium		Lr <sup>103</sup> Lawrencium		<p>On the other side of the page you will find a version with smaller pictures but with detailed technical data on each of the elements, plus more pics.</p> <p>More images and complete technical data can be found at <a href="http://www.periodictable.com">www.periodictable.com</a></p>	

Cyclical Continuum of Elemental Properties



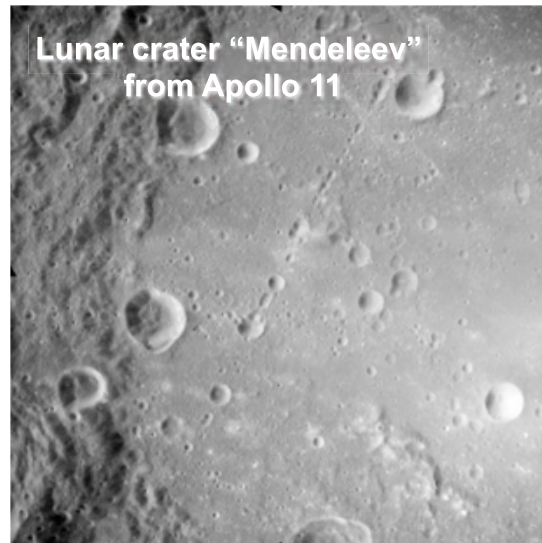
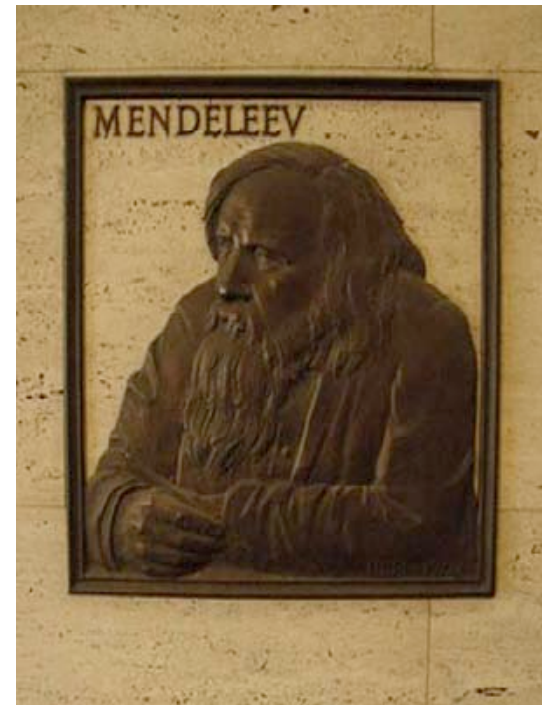
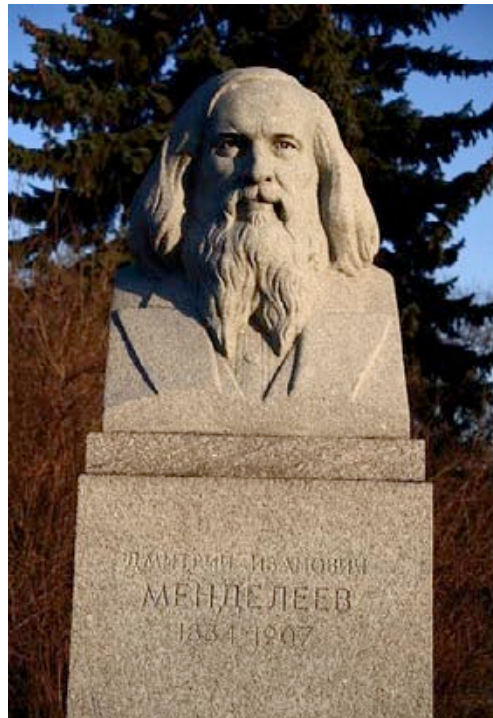




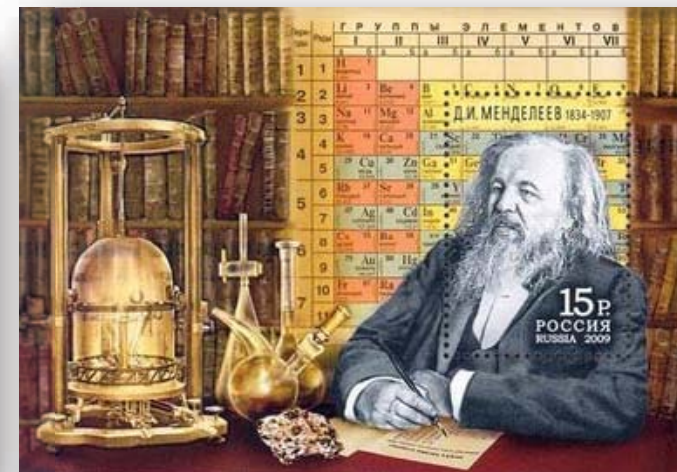
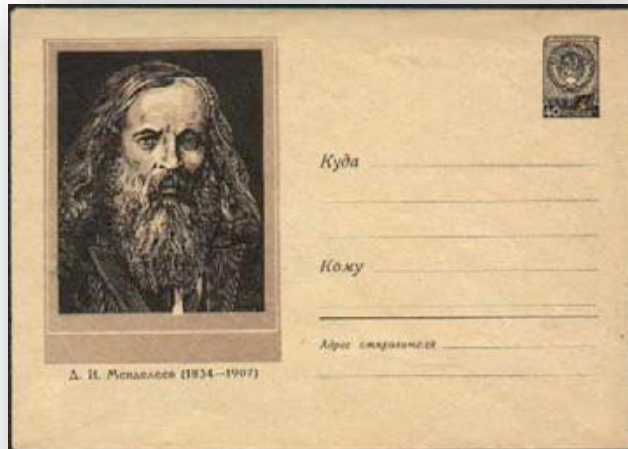
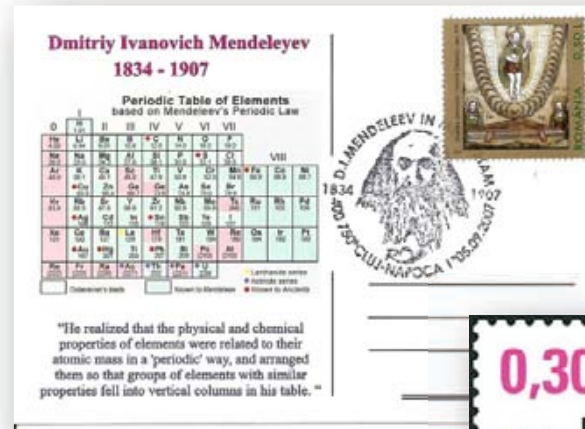
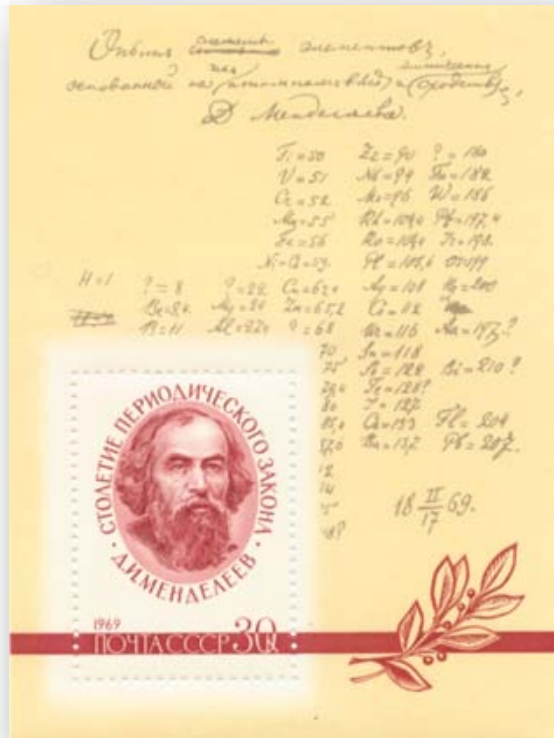
# Mendeleev Memorials and Monuments



Slovak University of Technology  
Bratislava, Slovakia



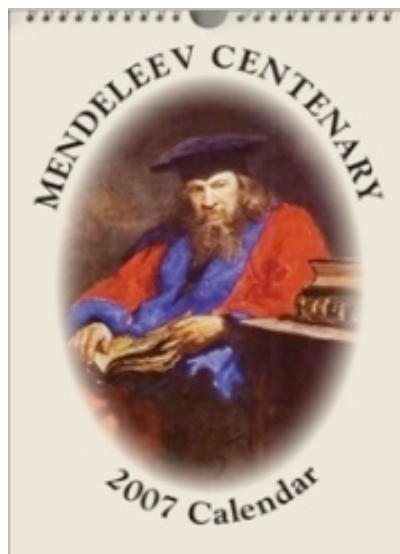
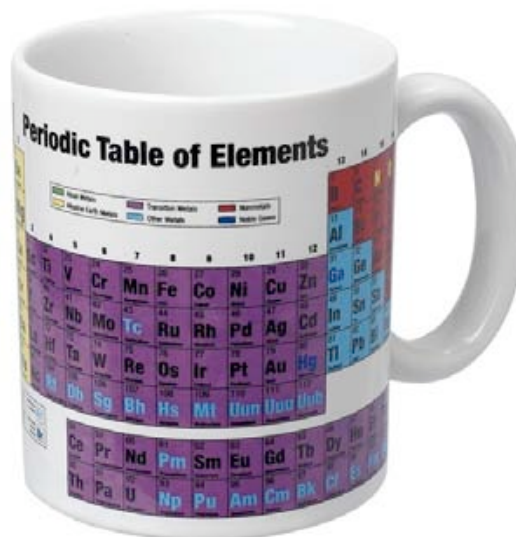
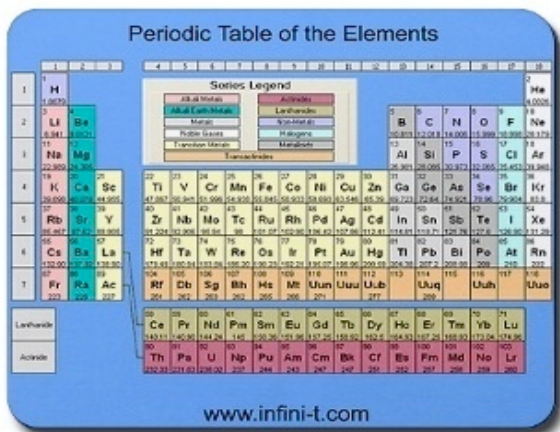
# Commemorative Stamps and First Day Covers



# Coins and Medallions



# Periodic Paraphernalia



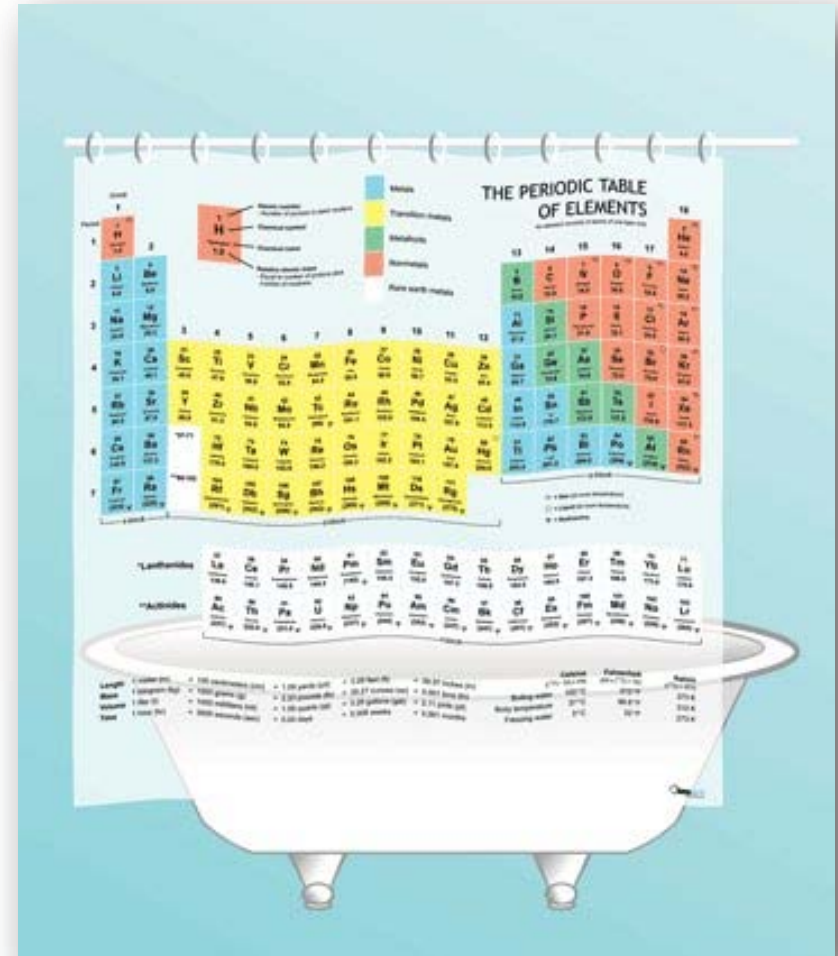
# WebElements Shop



# Rather Unusual Uses for the Periodic Table



Action hero Chuck Norris destroys the Periodic Table because he only recognizes the “Element of Surprise”!



Periodic Table shower curtain

# Periodic Table Humor

A moment in the life of the Mendeleev family ...



Translation: "One day, maybe we'll understand why Dimitri always arranges his blocks the same way".

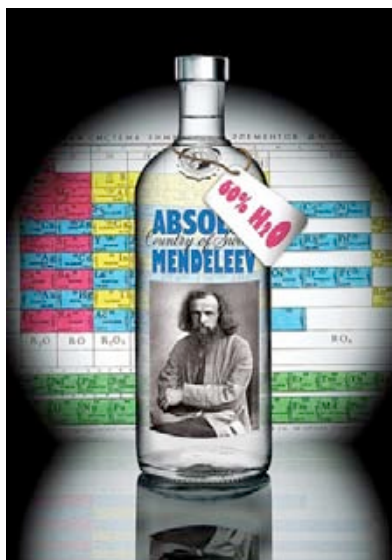
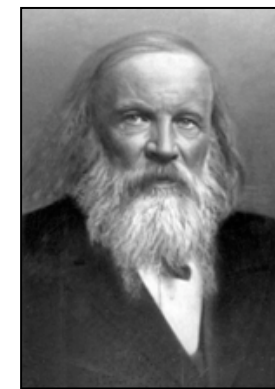




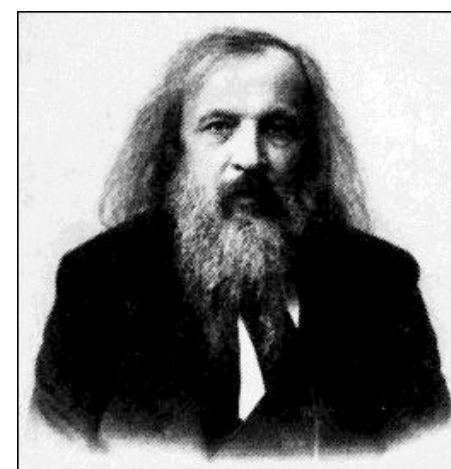
31	32a	34	35	3
33	41	43	44	
49	50	52	53	54
56	57	72	73	74
75	76	77	78	79

# Dmitri Mendeleev “Renaissance Man”

Mendeleev was a great chemist but he was interested in many other fields of science. He promoted development of Russia’s precious natural resources such as coal, petroleum, salt, metals, cheese, beer, and vodka!

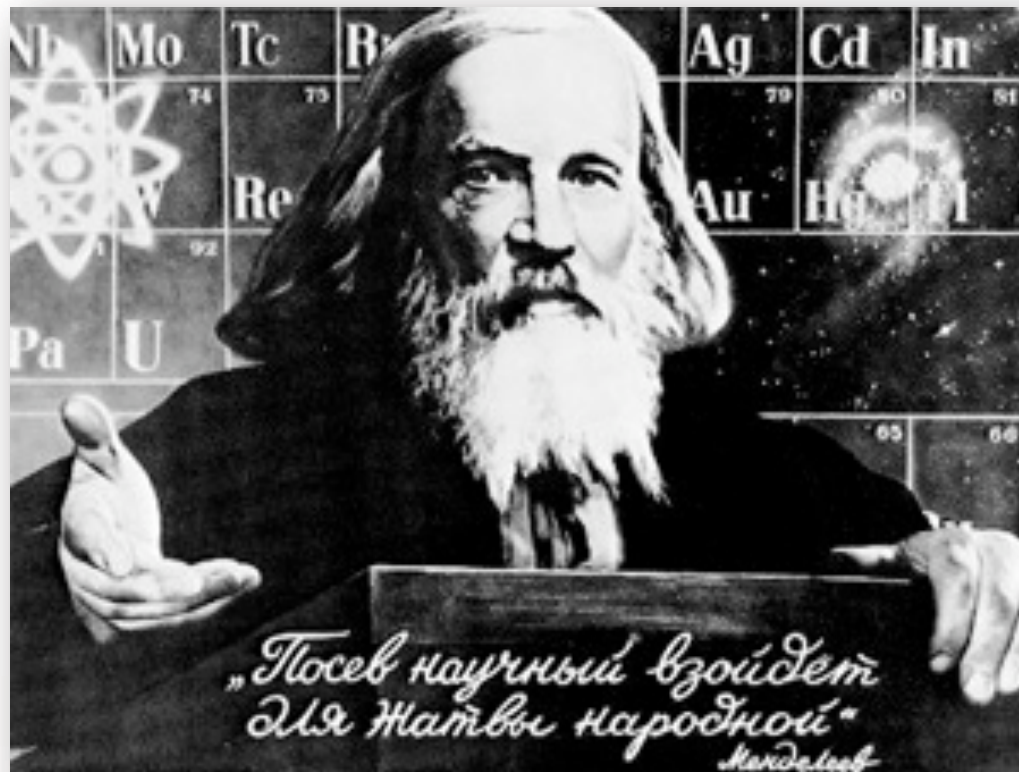


He was an author, educator, government economist, inventor, adventurer, and..... In 1887 he ascended high above the clouds in a hot air balloon to observe a solar eclipse.



# Mendeleev's Legacy

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If some universal catastrophe was to engulf the world and humankind could retain only one scientific concept to rebuild civilization, what would it be? The chemist's answer is almost invariably *the Periodic Table of the Elements*. (Richard P. Feynman )

“The Periodic Table encapsulates the concept of elements, organizes physical and chemical trends of substances, and compares the structure of the different atoms – an enormous amount of information in a small space.” (James L. Marshall)

# Acknowledgements

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Extensive use of:

- The Internet for photographs, biographies, and periodic table collectables and souvenirs
- "*Dmitriy Mendeleev: A Short CV, and a Story of Life*" by Eugene V. Babaev, Chemistry Department, Moscow State University

Financial support from the U.S. Department of Energy and the Russian Academy of Sciences is greatly appreciated.

***Happy Birthday  
Dmitri Ivanovich Mendeleev***

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