

*Welcome to 3.091*

# 3.091 Introduction to Solid State Chemistry

## Fall Term 2004

**Lecturer** Professor Donald R. Sadoway

**Text** *Chemistry: Structure and Dynamics*, 2nd Edition, J.N. Spencer, G.M. Bodner, and L.H. Rickard, Wiley, New York, 2003 (3 volumes)

**Lectures** Monday, Wednesday, and Friday, 11:00-12:00, (L01)  
Monday, Wednesday, and Friday, 1:00-2:00, (L02)

## **3.091 Homework No. 1**

- assigned September 8
- tested September 14

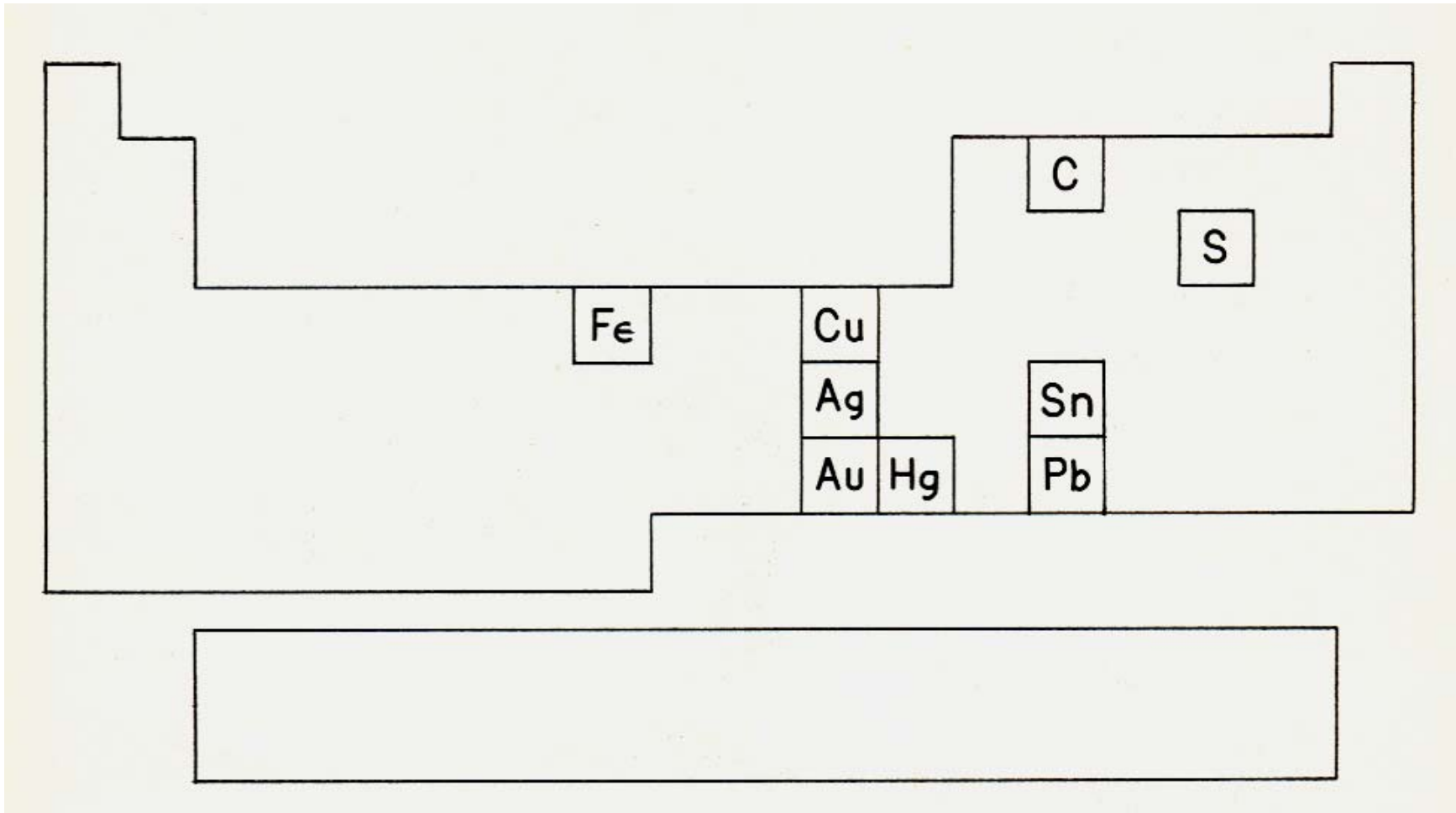
from SBR Core Text:

**Ch. 1 # 9, 39, 47-51, 62, 88**

**Ch. 2 # 83, 102, 123, 129, 173**

- issued along with model solutions

~ 2400 years ago



































John Dalton  
1803

# ELEMENTS

	Hydrogen	<i>1</i>		Strontian	<i>46</i>
	Azote	<i>5</i>		Barytes	<i>68</i>
	Carbon	<i>5</i>		Iron	<i>56</i>
	Oxygen	<i>7</i>		Zinc	<i>56</i>
	Phosphorus	<i>9</i>		Copper	<i>56</i>
	Sulphur	<i>13</i>		Lead	<i>90</i>
	Magnesia	<i>20</i>		Silver	<i>190</i>
	Lime	<i>24</i>		Gold	<i>190</i>
	Soda	<i>28</i>		Platina	<i>190</i>
	Potash	<i>42</i>		Mercury	<i>167</i>

# 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.

# **other classifications:**

\* “triads” 1829, Döbereiner (Jena)

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

# **other classifications:**

- \* “triads” 1829, Döbereiner (Jena)
- \* “octaves” 1864, Newlands (London)

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

# other classifications:

- \* “triads” 1829, Döbereiner (Jena)
- \* “octaves” 1864, Newlands (London)
- \* “periodic table”
  - 1869, Mendeléef (St. Petersburg)
  - 1870, Meyer (Tübingen)





Д. И. Менделеев (60-е годы).

но въ ней, мнѣ кажется, уже ясно выражается приближность въ ставляемаго мною начала ко всей совокупности элементовъ, цѣль которыхъ извѣстель съ достовѣрностію. На этотъ разъ я и желаю преимущественно найти 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	Bh=101,4	Pt=197,4	
			Fe=56	Ru=104,4	Ir=198.	
			Ni=Co=59	Pd=106,4	Os=199.	
H=1			Cu=63,4	Ag=108	Hg=200.	
	Be=9,4	Mg=24	Zn=65,4	Cd=112		
	B=11	Al=27,4	?	Cr=116	Au=197,7	
	C=12	Si=28	?	Su=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=77,6	Ba=137	Pb=207.	
		?	Ce=92			
		?Er=56	La=94			
		?Yt=60	Di=95			
		?In=75,6	Th=118?			

в этомъ приходится въ разныхъ мѣстахъ имѣть различныя измѣненія разностей, чего нѣтъ въ главныхъ числахъ периодической таблицы. Или же придется предположить при составленіи системы очень много недостающихъ членовъ. То и другое мало выгодно. Мнѣ кажется впрочемъ, наиболее естественнымъ составить кубическую систему (предлагая ось изокостваля), но и попытки для ея образованія не повели къ извѣстнымъ результатамъ. Случайныя дѣйствія могутъ показать то разнообразіе сопоставленій, какое возможно при допущеніи основнаго началъ, 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	—	—	—	Cr	—	—	Bi?
C	Si	Ti	—	Zr	Sn	—	—	—
N	P	V	As	Nb	Sb	—	Ta	—
O	S	—	Se	—	Te	—	W	—
F	Cl	—	Br	—	I	—	—	—
19	35,5	58	80	100	127	160	190	220.

1869

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

# 1869

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															

eka-boron      45  
 eka-aluminum   68  
 eka-silicon    72  
 eka-zirconium   180

Sc      45.0  
 Ga      69.7  
 Ge      72.6  
 Hf      178.5

# Comparison of eka-silicon with germanium

## eka-silicon

72 g/mol

5.5 g/cm<sup>3</sup>

“high” m.p.

Es forms EsO<sub>2</sub>  
which has high m.p.  
and  $\rho = 4.7 \text{ g/cm}^3$

EsCl<sub>4</sub> volatile liquid  
with b.p.  $< 100^\circ\text{C}$   
and  $\rho = 1.9 \text{ g/cm}^3$

## germanium

72.59 g/mol

5.36 g/cm<sup>3</sup>

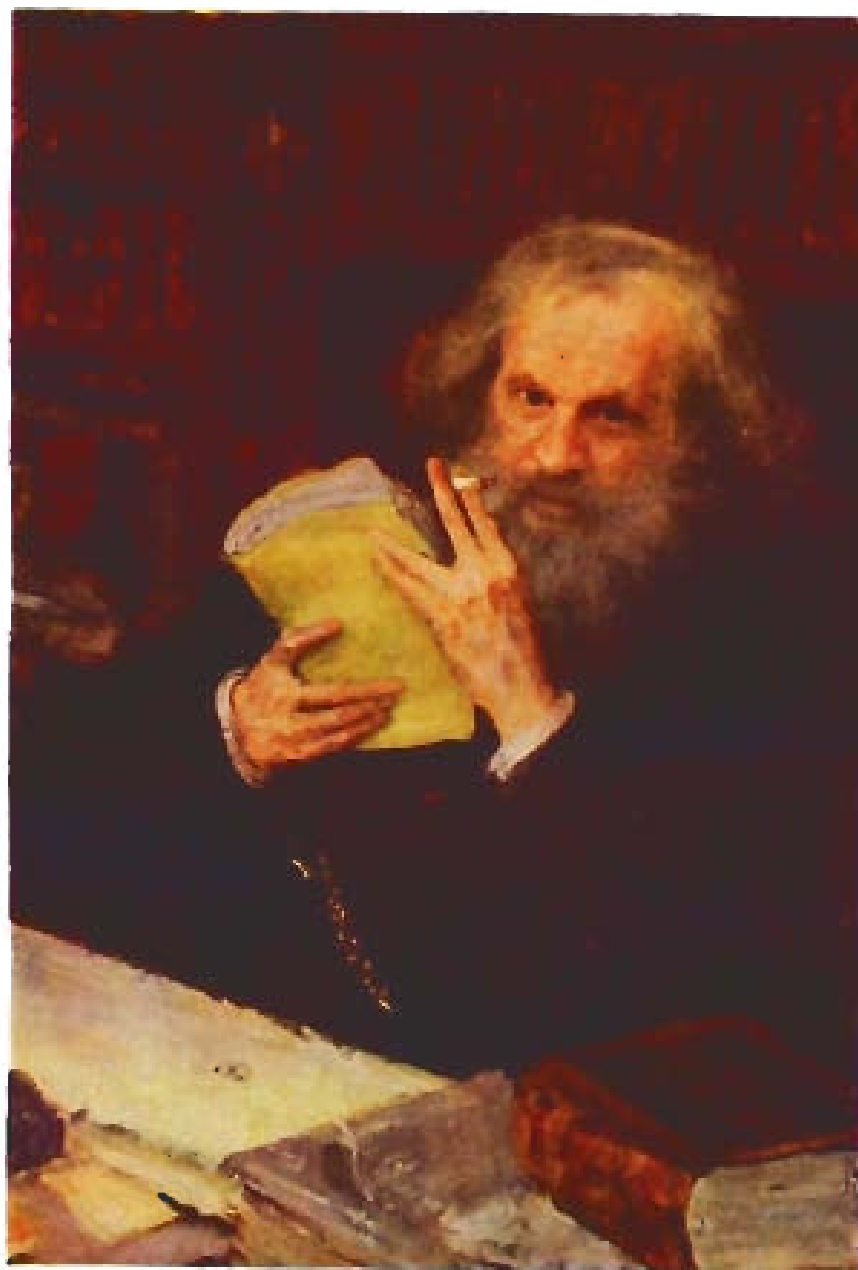
m.p. =  $958^\circ\text{C}$

Ge forms GeO<sub>2</sub>  
m.p. =  $1100^\circ\text{C}$   
and  $\rho = 4.70 \text{ g/cm}^3$

GeCl<sub>4</sub> volatile liquid  
b.p. =  $83^\circ\text{C}$   
and  $\rho = 1.88 \text{ g/cm}^3$

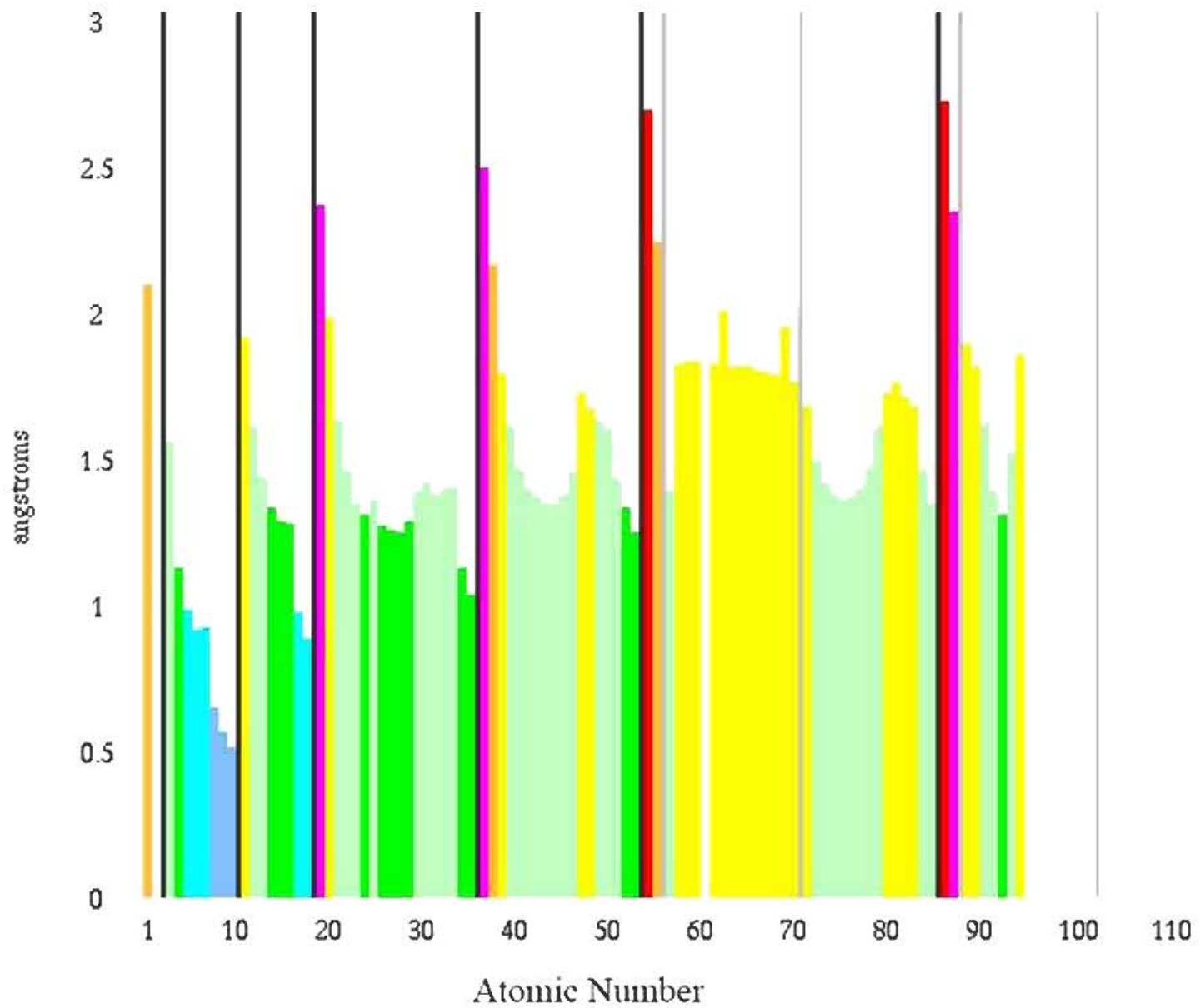
# **principles of modern chemistry:**

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



Д. И. Менделеев.  
Портрет работы П. Е. Рощина.

# Graph: Atomic Radius vs. Atomic Number







1 IA IA																		18 VIII 0																																			
1.00794 -259.34 -252.87 0.0899 2.20 13.598 1s <sup>1</sup> Hydrogen																		4.002602 -272.226 atm -268.93 0.1785 -24.587 1s <sup>2</sup> Helium																																			
6.941 180.5 1342 0.534 0.98 5.392 [He]2s <sup>1</sup> Lithium		9.012182 1287 2471 1.8477 1.57 9.322 [He]2s <sup>2</sup> Beryllium																		20.1797 -248.59 -246.08 0.9002 21.564 [He]2s <sup>2</sup> p <sup>6</sup> Neon																																	
22.989768 97.72 883 0.97 0.93 5.139 [Ne]3s <sup>1</sup> Sodium		24.3050 650 1090 1.74 1.31 7.646 [Ne]3s <sup>2</sup> Magnesium																		35.4527 -189.35 -185.85 1.784 3.16 12.967 [Ne]3s <sup>2</sup> p <sup>5</sup> Chlorine		39.948 -189.35 -185.85 1.784 3.16 12.967 [Ne]3s <sup>2</sup> p <sup>6</sup> Argon																															
39.0983 63.38 759 0.86 0.82 4.341 [Ar]4s <sup>1</sup> Potassium			40.078 842 1484 1.54 1.00 6.113 [Ar]3d <sup>1</sup> 4s <sup>2</sup> Calcium			44.95910 1541 2830 2.989 1.36 6.54 [Ar]3d <sup>1</sup> 4s <sup>2</sup> Scandium			47.88 1541 2830 3.287 4.5 1.54 6.82 [Ar]3d <sup>2</sup> 4s <sup>2</sup> Titanium			50.9415 1910 2830 2.989 1.36 6.54 [Ar]3d <sup>3</sup> 4s <sup>2</sup> Vanadium			51.9961 1907 2671 2.671 7.20 1.55 6.766 [Ar]3d <sup>4</sup> 4s <sup>1</sup> Chromium			54.93805 1538 2861 7.86 8.92 1.83 1.91 7.86 7.86 7.870 [Ar]3d <sup>5</sup> 4s <sup>2</sup> Manganese			55.847 1538 2861 7.86 8.92 1.83 1.91 7.86 7.86 7.870 [Ar]3d <sup>6</sup> 4s <sup>2</sup> Iron			58.93320 1455 2913 8.90 1.91 7.635 [Ar]3d <sup>7</sup> 4s <sup>2</sup> Cobalt			58.6934 1455 2913 8.90 1.91 7.635 [Ar]3d <sup>8</sup> 4s <sup>2</sup> Nickel			63.546 1084.62 907 8.94 1.65 9.394 [Ar]3d <sup>10</sup> 4s <sup>1</sup> Copper			65.39 419.53 2204 6.095 1.81 5.999 [Ar]3d <sup>10</sup> 4s <sup>2</sup> Zinc			69.723 2976 2833 6.48 4.81 2.18 9.81 [Ar]3d <sup>10</sup> 4s <sup>2</sup> p <sup>1</sup> Gallium			72.61 938.25 2833 5.35 2.01 7.899 [Ar]3d <sup>10</sup> 4s <sup>2</sup> p <sup>2</sup> Germanium			74.92159 817P 6148P 5.72725°C 2.18 9.81 9.81 [Ar]3d <sup>10</sup> 4s <sup>2</sup> p <sup>3</sup> Arsenic			78.96 289.72 681 4.81 2.55 9.752 [Ar]3d <sup>10</sup> 4s <sup>2</sup> p <sup>4</sup> Selenium			79.904 -7.2 58.6 3.119 2.96 11.814 [Ar]3d <sup>10</sup> 4s <sup>2</sup> p <sup>5</sup> Bromine			83.80 -157.36 -153.22 3.74 13.999 [Ar]3d <sup>10</sup> 4s <sup>2</sup> p <sup>6</sup> Krypton		
85.4678 39.31 688 1.532 0.82 4.177 [Kr]5s <sup>1</sup> Rubidium		87.62 777 1382 2.6 0.95 5.695 [Kr]4d <sup>5</sup> 5s <sup>2</sup> Strontium		88.90585 1526 3336 4.469 1.22 6.38 [Kr]4d <sup>5</sup> 5s <sup>2</sup> Yttrium		91.224 1855 4409 4.474 1.33 6.84 [Kr]4d <sup>4</sup> 5s <sup>2</sup> Zirconium		92.90638 2477 4744 8.57 1.6 6.9 [Kr]4d <sup>4</sup> 5s <sup>1</sup> Niobium		95.94 2623 4639 10.2 2.16 7.099 [Kr]4d <sup>4</sup> 5s <sup>1</sup> Molybdenum		(97.9072) 2157 4265 11.5 1.9 7.28 [Kr]4d <sup>5</sup> 5s <sup>1</sup> Technetium		101.07 2334 4150 12.3 2.2 7.37 [Kr]4d <sup>5</sup> 5s <sup>1</sup> Ruthenium		102.90550 1964 2963 12.02 2.20 7.46 [Kr]4d <sup>6</sup> 5s <sup>1</sup> Rhodium		106.42 1554.9 2963 12.02 2.20 7.46 [Kr]4d <sup>8</sup> 5s <sup>1</sup> Palladium		107.8582 961.78 105 1.69 8.993 [Kr]4d <sup>10</sup> 5s <sup>1</sup> Silver		112.411 321.07 767 2.072 7.30 1.78 8.993 [Kr]4d <sup>10</sup> 5s <sup>2</sup> Cadmium		114.818 156.60 2602 7.28 1.96 7.344 [Kr]4d <sup>10</sup> 5s <sup>2</sup> p <sup>1</sup> Indium		118.710 231.93 2602 7.28 1.96 7.344 [Kr]4d <sup>10</sup> 5s <sup>2</sup> p <sup>2</sup> Tin		121.757 630.63 1587 6.68425°C 2.05 8.641 9.09 [Kr]4d <sup>10</sup> 5s <sup>2</sup> p <sup>3</sup> Antimony		127.60 449.51 988 6.25 2.1 10.451 [Kr]4d <sup>10</sup> 5s <sup>2</sup> p <sup>4</sup> Tellurium		126.90447 113.7 184.4 4.93 2.66 10.451 [Kr]4d <sup>10</sup> 5s <sup>2</sup> p <sup>5</sup> Iodine		131.29 -111.75 -108.04 5.89 12.130 [Kr]4d <sup>10</sup> 5s <sup>2</sup> p <sup>6</sup> Xenon																			
132.90543 28.44 671 1.879 0.79 3.894 [Xe]6s <sup>1</sup> Cesium		137.327 727 1897 3.594 0.89 5.212 [Xe]6s <sup>2</sup> Barium		138.9055 920 3455 4.616 1.10 5.577 [Xe]5d <sup>1</sup> 6s <sup>2</sup> Lanthanum		178.49 2233 4603 16.6 1.3 7.0 [Xe]4f <sup>1</sup> 5d <sup>1</sup> 6s <sup>2</sup> Cerium		180.9479 3422 4744 16.6 1.3 7.89 [Xe]4f <sup>1</sup> 5d <sup>1</sup> 6s <sup>2</sup> Praseodymium		183.84 3422 5555 19.35 2.36 7.98 [Xe]4f <sup>2</sup> 5d <sup>1</sup> 6s <sup>2</sup> Neodymium		186.207 3186 5596 20.5 1.9 7.88 [Xe]4f <sup>3</sup> 5d <sup>1</sup> 6s <sup>2</sup> Promethium		190.23 3033 5012 22.61 2.2 8.7 [Xe]4f <sup>4</sup> 5d <sup>1</sup> 6s <sup>2</sup> Samarium		192.22 3033 4428 22.65 2.20 9.0 [Xe]4f <sup>5</sup> 5d <sup>1</sup> 6s <sup>2</sup> Europium		195.08 1768.4 3825 21.45 2.28 9.0 [Xe]4f <sup>6</sup> 5d <sup>1</sup> 6s <sup>2</sup> Gadolinium		196.96654 961.78 2856 13.546 2.54 9.225 [Xe]4f <sup>7</sup> 5d <sup>1</sup> 6s <sup>2</sup> Terbium		200.59 1064.18 2856 11.85 2.00 10.437 [Xe]4f <sup>8</sup> 5d <sup>1</sup> 6s <sup>2</sup> Dysprosium		204.3833 304 1473 11.85 2.04 6.108 [Xe]4f <sup>9</sup> 5d <sup>1</sup> 6s <sup>2</sup> p <sup>1</sup> Holmium		207.2 327.46 1749 11.34 2.33 7.416 [Xe]4f <sup>10</sup> 5d <sup>1</sup> 6s <sup>2</sup> p <sup>2</sup> Erbium		208.98037 271.40 1564 9.78 2.02 7.289 [Xe]4f <sup>11</sup> 5d <sup>1</sup> 6s <sup>2</sup> p <sup>3</sup> Bismuth		208.9824 254 962 9.196 2.0 8.2 [Xe]4f <sup>12</sup> 5d <sup>1</sup> 6s <sup>2</sup> p <sup>4</sup> Polonium		(209.9871) 302 337 ±1.3,5,7 -72 -61.7 9.73 [Xe]4f <sup>14</sup> 5d <sup>1</sup> 6s <sup>2</sup> p <sup>5</sup> Astatine		(221.0176) -72 -61.7 9.73 10.748 [Xe]4f <sup>14</sup> 5d <sup>1</sup> 6s <sup>2</sup> p <sup>6</sup> Radon																			
(223.0197) 27 677 5.8 0.7 - [Rn]7s <sup>1</sup> Francium		(226.0254) 700 - - - - [Rn]7s <sup>2</sup> Radium		(227.0278) 1051 3198 10.07 6.1 - [Rn]6d <sup>1</sup> 7s <sup>2</sup> Actinium		(261) - - - - - [Rn]5f <sup>1</sup> 6d <sup>2</sup> 7s <sup>2</sup> Rutherfordium**		(262) - - - - - [Rn]5f <sup>1</sup> 6d <sup>3</sup> 7s <sup>2</sup> Dubnium**		(263) - - - - - [Rn]5f <sup>1</sup> 6d <sup>4</sup> 7s <sup>2</sup> Seaborgium**		(262) - - - - - [Rn]5f <sup>1</sup> 6d <sup>5</sup> 7s <sup>2</sup> Bohrium**		(265) - - - - - [Rn]5f <sup>1</sup> 6d <sup>6</sup> 7s <sup>2</sup> Hassium**		(266) - - - - - [Rn]5f <sup>1</sup> 6d <sup>7</sup> 7s <sup>2</sup> Meitnerium**		(269) - - - - - [Rn]5f <sup>1</sup> 6d <sup>9</sup> 7s <sup>1</sup> Ununnilium		(272) - - - - - [Rn]5f <sup>1</sup> 6d <sup>10</sup> 7s <sup>1</sup> Ununium		(277) - - - - - [Rn]5f <sup>1</sup> 6d <sup>10</sup> 7s <sup>2</sup> Ununbium		(285) - - - - - [Rn]5f <sup>1</sup> 6d <sup>10</sup> 7s <sup>2</sup> p <sup>1</sup> Ununquadium		(289) - - - - - [Rn]5f <sup>1</sup> 6d <sup>10</sup> 7s <sup>2</sup> p <sup>2</sup> Ununhexium		(293) - - - - - [Rn]5f <sup>1</sup> 6d <sup>10</sup> 7s <sup>2</sup> p <sup>6</sup> Ununseptium																									

* 140.115 799 3424 6.770 1.12 5.466 [Xe]4f <sup>1</sup> 5d <sup>1</sup> 6s <sup>2</sup> Cerium		140.90765 931 3510 6.773 5.422 [Xe]4f <sup>6</sup> 6s <sup>2</sup> Praseodymium		144.24 1016 3066 1.14 5.489 [Xe]4f <sup>6</sup> 6s <sup>2</sup> Neodymium		(144.9127) 1042 3000 7.254 1.17 5.631 [Xe]4f <sup>6</sup> 6s <sup>2</sup> Promethium		150.36 1072 1790 7.536 1.17 5.666 [Xe]4f <sup>6</sup> 6s <sup>2</sup> Samarium		151.965 822 1596 5.244 1.2 6.141 [Xe]4f <sup>7</sup> 6s <sup>2</sup> Europium		157.25 1314 3221 8.230 1.20 6.141 [Xe]4f <sup>7</sup> 5d <sup>1</sup> 6s <sup>2</sup> Gadolinium		158.92534 1359 3221 8.230 1.22 6.141 [Xe]4f <sup>9</sup> 6s <sup>2</sup> Terbium		162.50 1411 2694 8.551 1.23 6.101 [Xe]4f <sup>10</sup> 6s <sup>2</sup> Dysprosium		164.93032 1472 2862 8.80 1.23 6.101 [Xe]4f <sup>11</sup> 6s <sup>2</sup> Holmium		167.26 1529 2862 9.066 1.24 6.101 [Xe]4f <sup>12</sup> 6s <sup>2</sup> Erbium		168.93421 1545 1946 9.321 1.25 6.101 [Xe]4f <sup>13</sup> 6s <sup>2</sup> Thulium		173.04 824 1194 9.366 1.1 6.25394 [Xe]4f <sup>14</sup> 6s <sup>2</sup> Ytterbium		174.967 1663 3393 9.84 1.27 5.42589 [Xe]4f <sup>14</sup> 5d <sup>1</sup> 6s <sup>2</sup> Lutetium	
** 232.0381 1750 4788 11.72 1.3 6.08 [Rn]6d <sup>2</sup> 7s <sup>2</sup> Thorium		231.03588 1572 4131 15.37 1.5 5.89 [Rn]5f <sup>6</sup> 6d <sup>1</sup> 7s <sup>2</sup> Protactinium		238.0289 1135 4131 19.05±0.02 1.36 6.05 [Rn]5f <sup>6</sup> 6d <sup>1</sup> 7s <sup>2</sup> Uranium		(237.0482) 644 4131 20.45 1.28 6.19 [Rn]5f <sup>6</sup> 6d <sup>1</sup> 7s <sup>2</sup> Neptunium		(244.0642) 640 19816 13.67 1.3 5.993 [Rn]5f <sup>7</sup> 7s <sup>2</sup> Plutonium		(243.0614) 1176 2507 13.51 1.3 6.02 [Rn]5f <sup>7</sup> 7s <sup>2</sup> Americium		(247.0703) 1345 2507 14.78 1.3 6.23 [Rn]5f <sup>7</sup> 6d <sup>1</sup> 7s <sup>2</sup> Curium		(247.0703) 1050 1478 14.78 1.3 6.23 [Rn]5f <sup>9</sup> 7s <sup>2</sup> Berkelium		(251.0796) 900 1345 1.3 6.30 [Rn]5f <sup>10</sup> 7s <sup>2</sup> Californium		(252.083) 860 1345 1.3 6.42 [Rn]5f <sup>11</sup> 7s <sup>2</sup> Einsteinium		(257.0951) 1527 860 1.3 6.50 [Rn]5f <sup>12</sup> 7s <sup>2</sup> Fermium		(258.10) 827 1345 1.3 6.58 [Rn]5f <sup>13</sup> 7s <sup>2</sup> Mendelevium		(259.1009) 827 1345 1.3 6.65 [Rn]5f <sup>14</sup> 7s <sup>2</sup> Nobelium		(252.11) 1627 1345 - - [Rn]5f <sup>14</sup> 6d <sup>1</sup> 7s <sup>2</sup> Lawrencium	

Figure by MIT OCW.

# Naming the Superheavy Elements

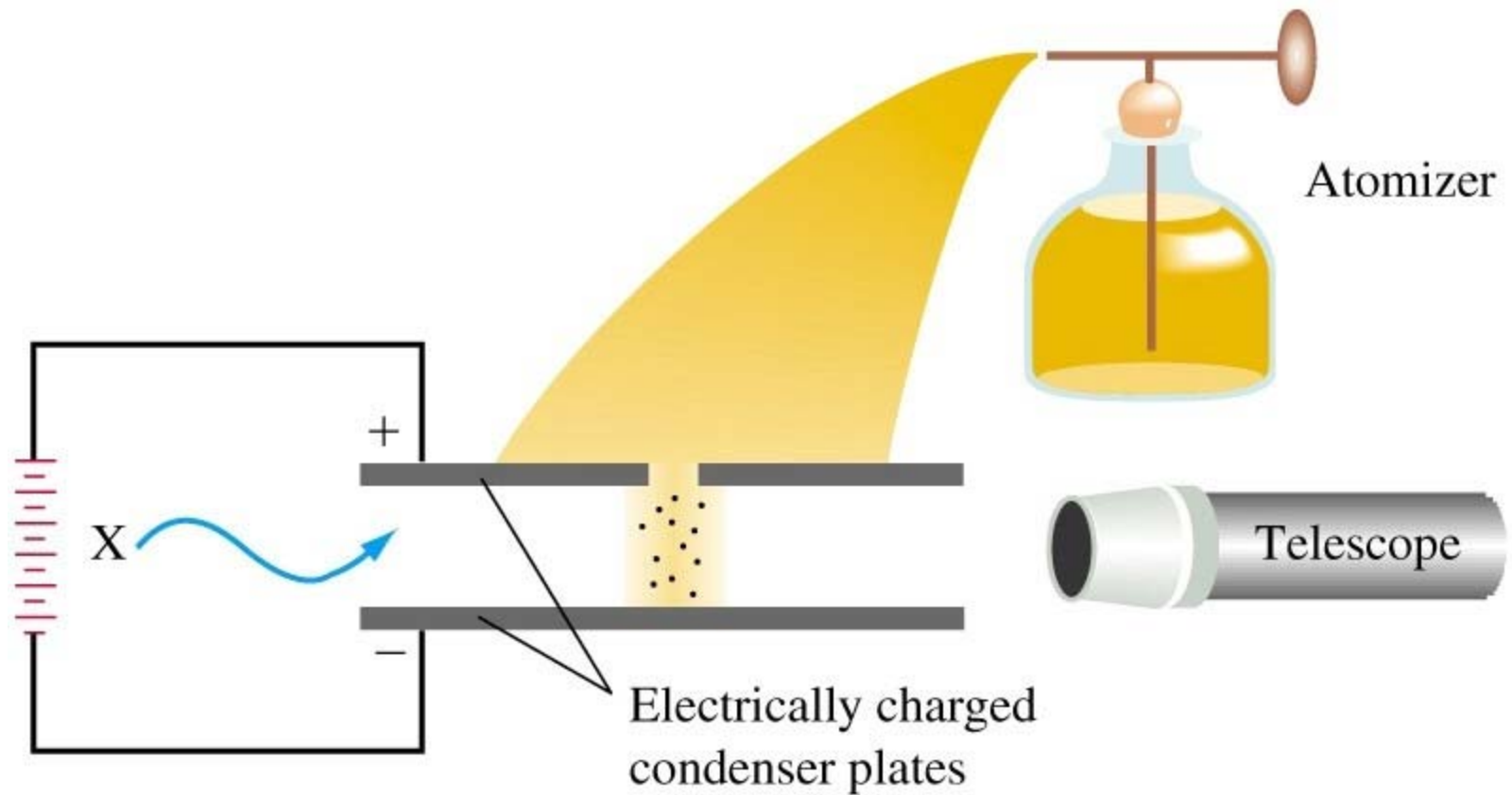
<b>1</b>	<b>un</b>		
<b>2</b>	<b>bi</b>		
<b>3</b>	<b>tri</b>		
<b>4</b>	<b>quad</b>		
<b>5</b>	<b>pent</b>	<b>+</b>	<b>ium</b>
<b>6</b>	<b>hex</b>		
<b>7</b>	<b>sept</b>		
<b>8</b>	<b>oct</b>		
<b>9</b>	<b>enn</b>		
<b>0</b>	<b>nil</b>		

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

Strathern, Paul. *Mendeleyev's Dream: The Quest for the Elements*.  
Thomas Dunne Books, 21 April 2001. ISBN: 0312262043.

## Table 1.3 The Structure of Atoms

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



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

# **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 Mendeleev

*today's selection:*

Polovtsian Dance No. 17 from *Prince Igor*