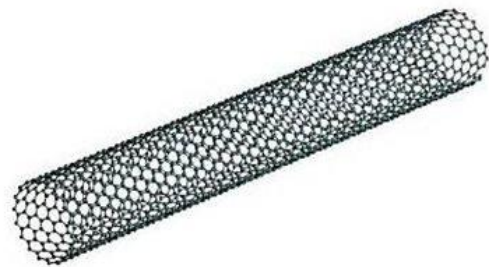


Nanotechnology Undergraduate Education (NUE) - NSF

Introduction to Nanotechnology Undergraduate Education (NUE) - NSF



David W. Stollberg, Ph.D., P.E.

EOSL

5 Jun 2011



PERIODIC TABLE

GROUP →

IA IIA IIIA IVA VA VIA VIIA ← VIII A → IB IIB IIIB IVB VB VIB VIIB VIIIB

1 H 1.0079													Metals					Nonmetals					2 He 4.0026
3 Li 6.941	4 Be 9.012												5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180					
11 Na 22.99	12 Mg 24.305	<i>d</i> Transition Elements											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948					
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.610	33 As 74.921	34 Se 78.960	35 Br 79.904	36 Kr 83.80						
37 Rb 85.468	38 Sr 87.620	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.940	43 Tc (97.907)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29						
55 Cs 132.91	56 Ba 137.33	57 La* 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.20	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (208.99)	85 At (209.99)	86 Rn (222.02)						
87 Fr (223.02)	88 Ra (226.03)	89 Ac** (227.03)	104 Unq (261.11)	105 Unp (262.11)	106 Unh (262.12)																		

Gas

Liquid

34
Se
78.96

Atomic number
Atomic mass (g mol⁻¹)

f Transition Elements

*Lanthanides (Rare Earths)	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (144.91)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.94	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
---------------------------------------	---------------------------	---------------------------	---------------------------	-----------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------

**Actinides	90 Th 232.04	91 Pa (231.04)	92 U (238.05)	93 Np (237.05)	94 Pu (244.06)	95 Am (243.06)	96 Cm (247.07)	97 Bk (247.07)	98 Cf (242.06)	99 Es (252.08)	100 Fm (257.10)	101 Md (258.10)	102 No (259.10)	103 Lr (260.11)
--------------------	---------------------------	-----------------------------	----------------------------	-----------------------------	-----------------------------	-----------------------------	-----------------------------	-----------------------------	-----------------------------	-----------------------------	------------------------------	------------------------------	------------------------------	------------------------------

Primary Bonds

- **Ionic**
 - Charge transfer
 - From the extremes of the periodic chart, i.e., Groups IA and VIIA (NaCl), large difference in electronegativity, boundary approximately 1.7, see Appendix B.
- **Covalent**
 - Sharing electrons in an attempt to make a complete shell, Group IV elements (C, Si, Ge) and diatomic elements such as H_2 , Cl_2 , and F_2 .
- **Metallic**
 - Shared by all the atoms in the substance.



PERIODIC TABLE

sp^3 hybridized orbitals

Halogens
Noble gases

GROUP →

IA	IIA	IIIA	IVA	VA	VIA	VIIA	← VIIIA →	IB	IIB	IIIB	IVB	VB	VIB	VII B	VIII B		
1 H 1.0079															2 He 4.0026		
3 Li 6.941	4 Be 9.012																
11 Na 22.99	12 Mg 24.305																
<p>Increasing electronegativity, increased tendency to add electrons</p> <p>→</p> <p><i>d</i> Transition Elements</p>																	
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.64	33 As 74.921	34 Se 78.960	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.620	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.940	43 Tc (97.907)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La* 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.20	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (208.99)	85 At (209.99)	86 Rn (222.02)
87 Fr (223.02)	88 Ra (226.03)	89 Ac** (227.03)	104 Unq (261.11)	105 Unp (262.11)	106 Unh (262.12)												

↑ Increasing atomic radius

Metals | Nonmetals

Alkali metals | Alkaline earth metals

Gas | Liquid

34 Se 78.96

Atomic number | Atomic mass (g mol⁻¹)

f Transition Elements

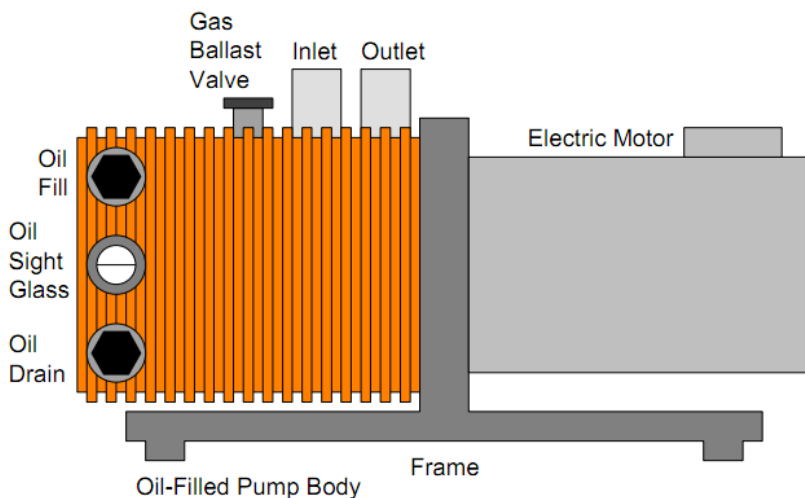
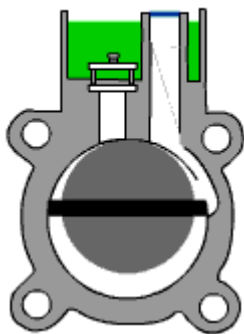
58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (144.91)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.94	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa (231.04)	92 U (238.05)	93 Np (237.05)	94 Pu (244.06)	95 Am (243.06)	96 Cm (247.07)	97 Bk (247.07)	98 Cf (242.06)	99 Es (252.08)	100 Fm (257.10)	101 Md (258.10)	102 No (259.10)	103 Lr (260.11)

**Actinides

Mechanical Rotary Vane Pump

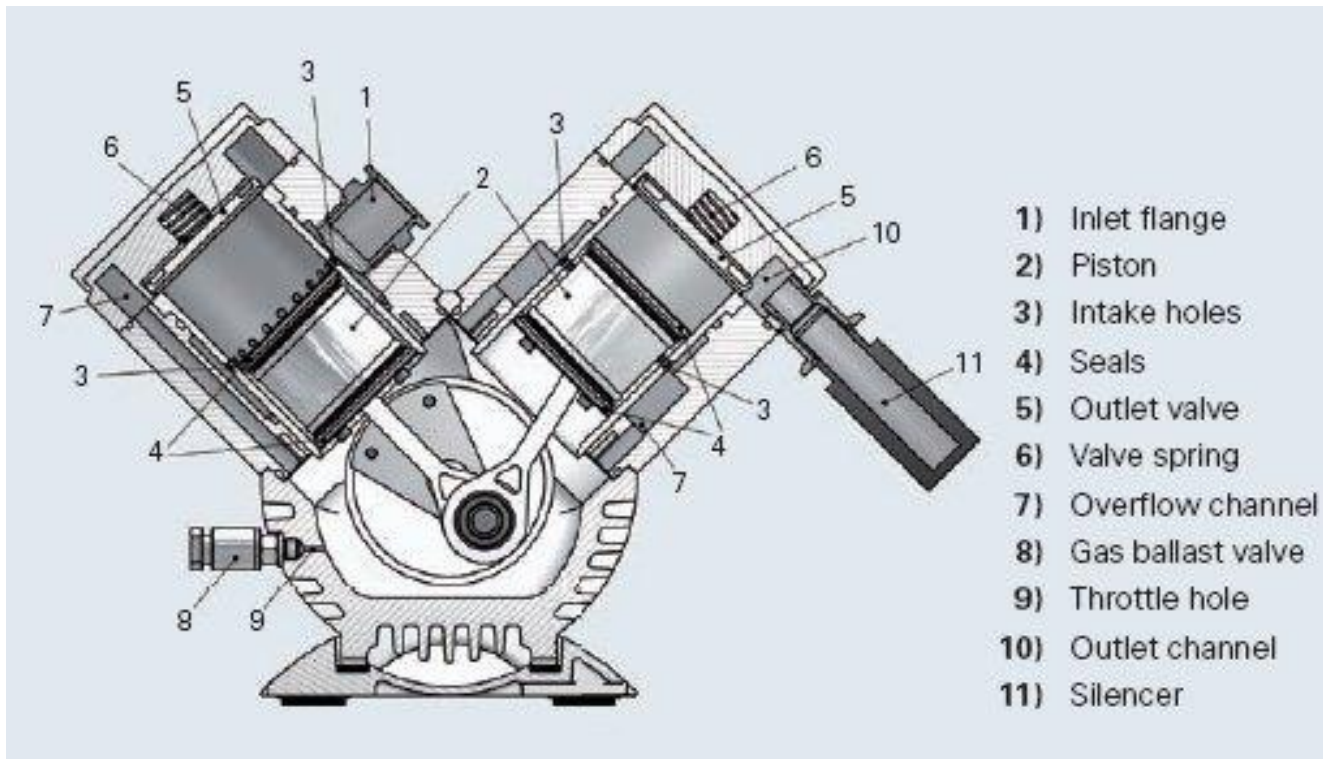
<http://www.repairfaq.org/sam/vacuum/rvpnotes.htm>

Rotary Vane Mechanical Pumps - 1



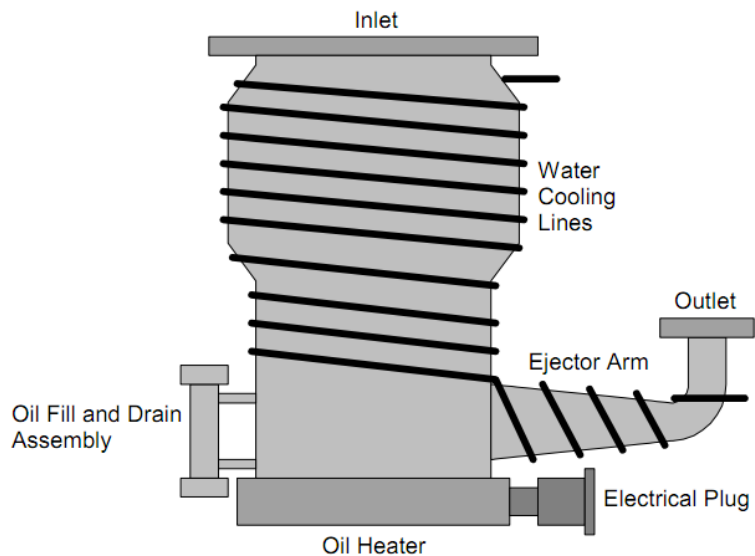
R. B. Darling / EE-527

Mechanical Rotary Piston Pump

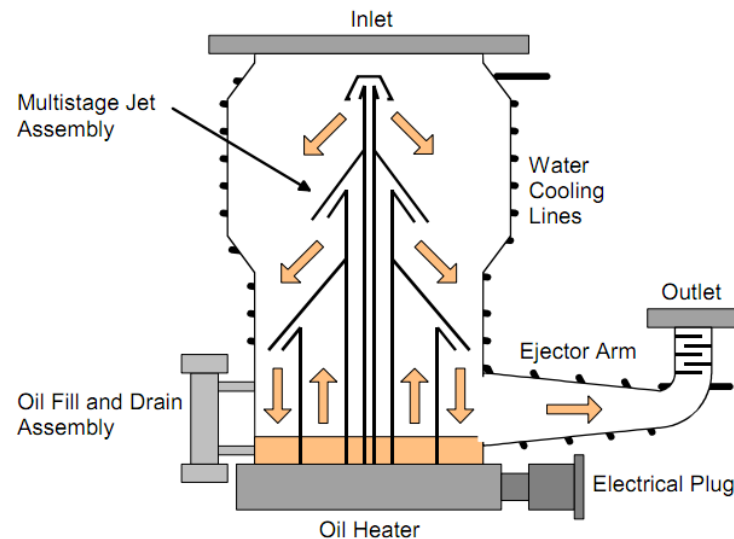


Diffusion Pump

Diffusion Pumps - 1



Diffusion Pumps - 2

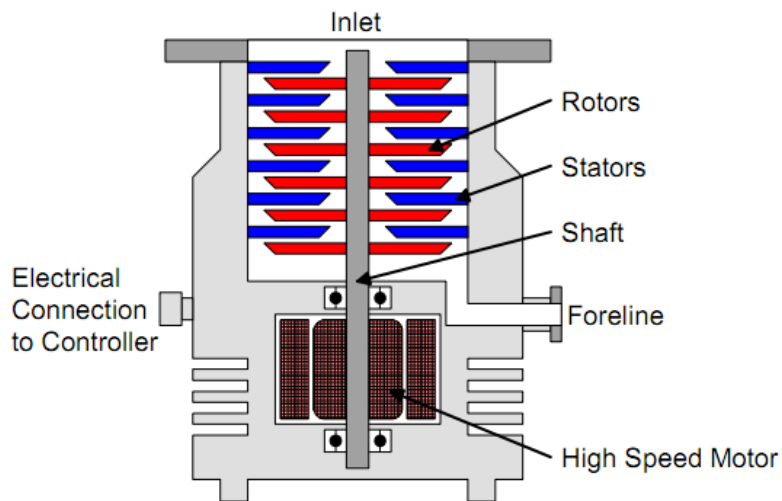


R. B. Darling / EI

R. B. Darling / EE-527

Turbomolecular

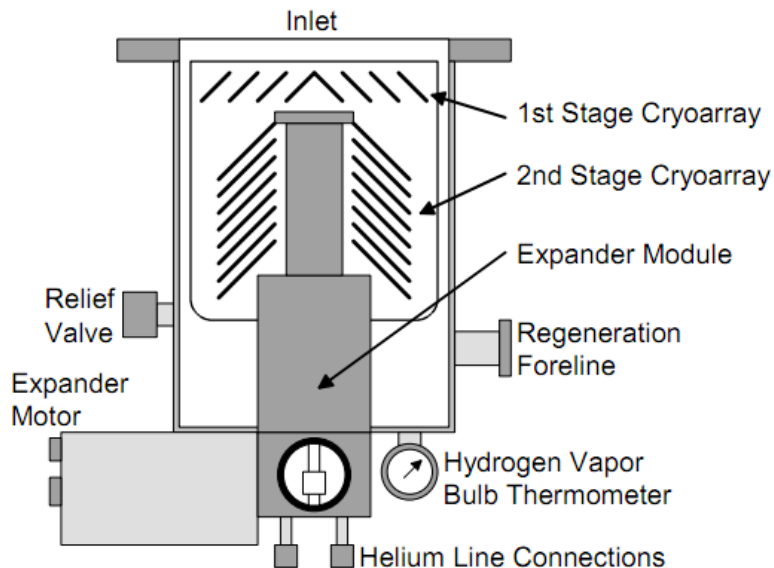
Turbomolecular Pumps - 1



R. B. Darling / EE-527

Cryopump

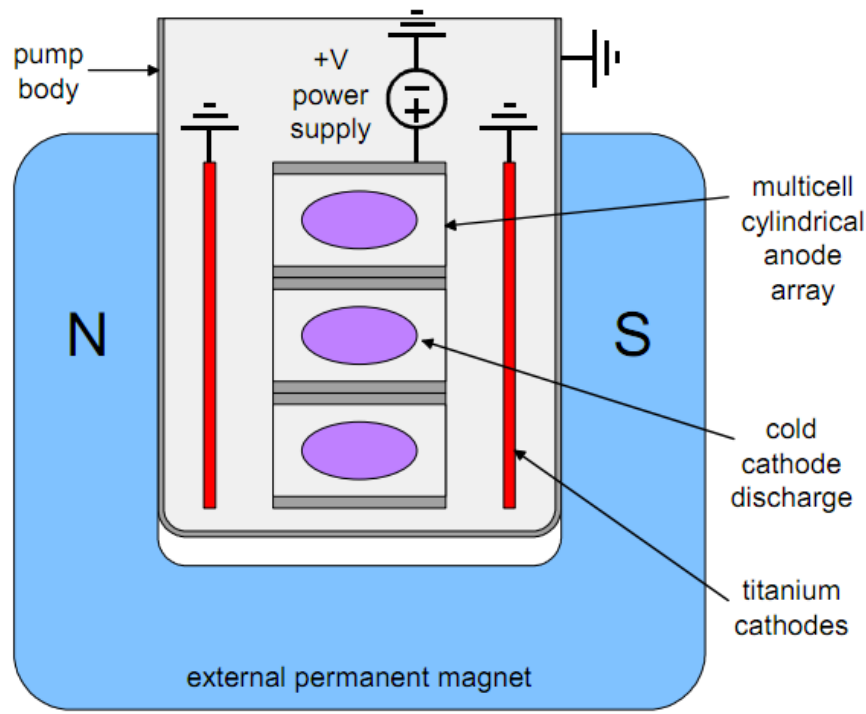
Cryopumps - 2



R. B. Darling / EE-527

Ion Pump

Ion Pumps - 1



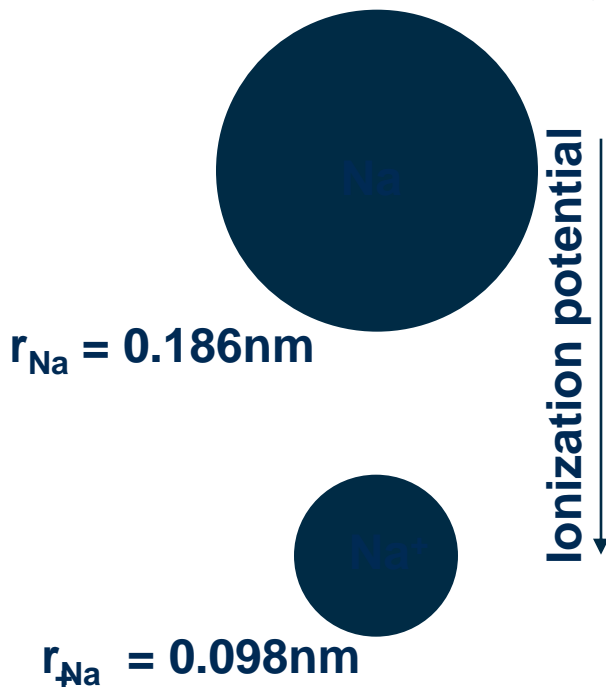
Diode Ion Pump

R. B. Darling / EE-527

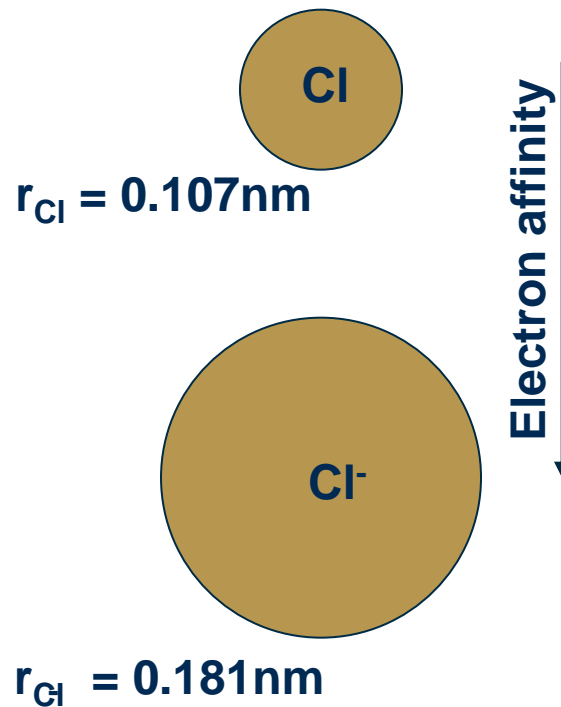
Equipment

- <http://eosl.gtri.gatech.edu/Capabilities/tabid/508/Default.aspx><http://eosl.gtri.gatech.edu/Capabilities/tabid/508/Default.aspx>
- <http://grover.mirc.gatech.edu/equipment/>
- <http://www.youtube.com/watch?v=9p2wwOTpCCI>
- (ALD)

Primary Bonds

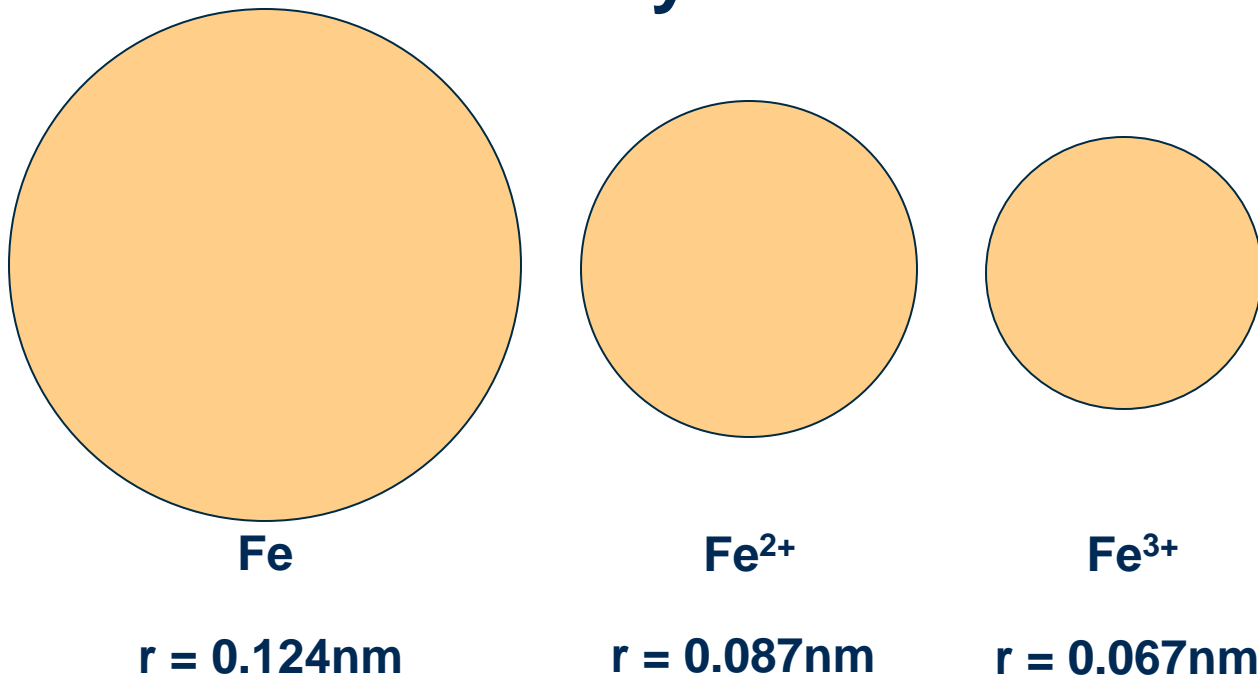


Energy required: 5.14 eV



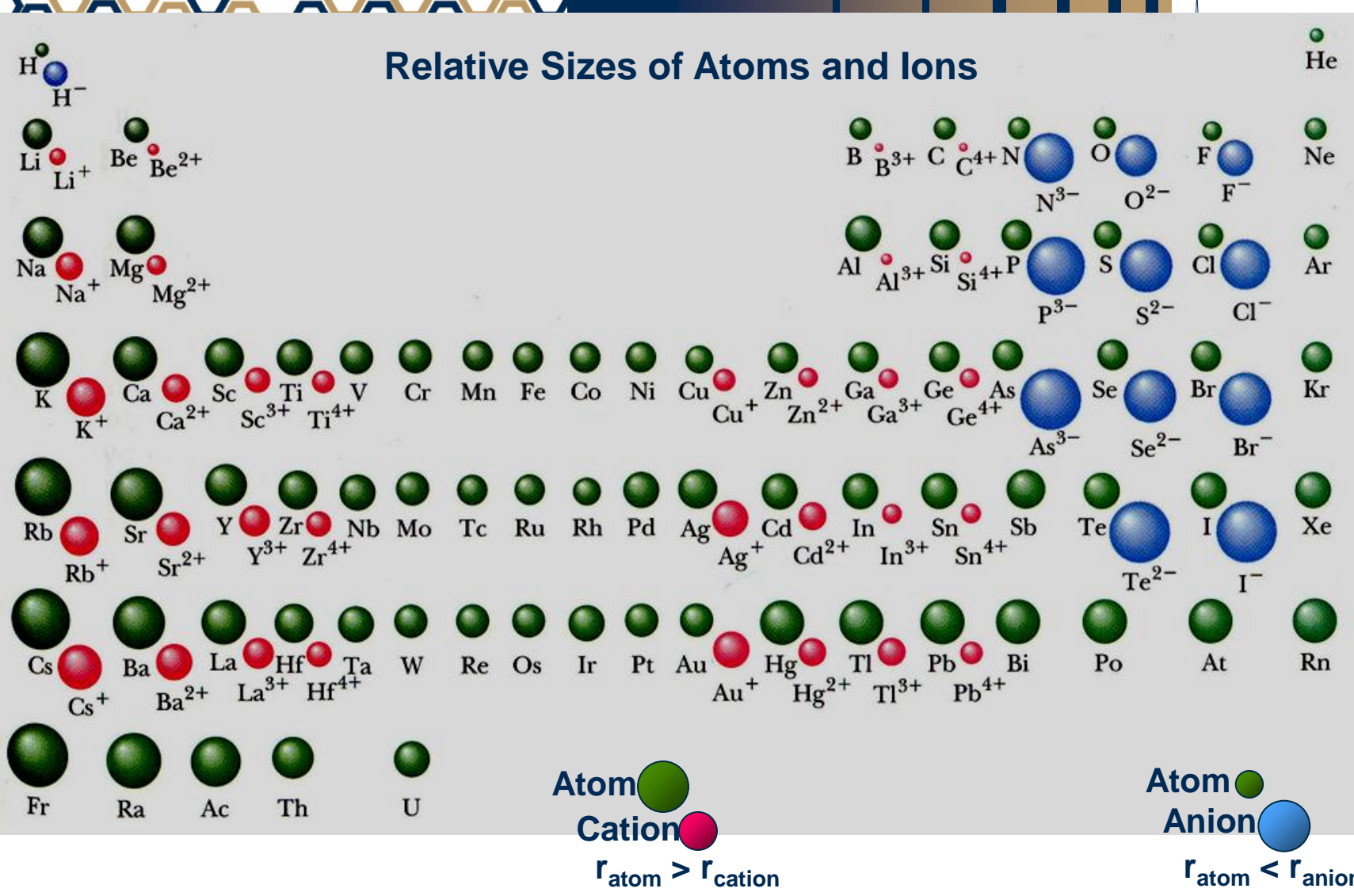
Energy released: 4.02 eV

Primary Bonds



Schematic showing the relative size of the electron clouds of iron and two common valence states

Relative Sizes of Atoms and Ions



Neutral atoms are shown in green, cations are red, and anions are blue. Note the relative change when a neutral atom becomes a cation, compared to an anion.