

Pre-AP Chemistry

September 4, 2011

10. Periodic Table II

The Elements

1	2																	3	4																	5	6	7	8	9	10
H	He																	Li	Be																	B	C	N	O	F	Ne
3	4																	11	12																	13	14	15	16	17	18
Na	Mg																	Al	Si	P	S	Cl	Ar																		
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36																								
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr																								
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54																								
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe																								
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86																								
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn																								
87	88	89	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118																								
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Uuh	Uus	Uuo																								
Radioactive elements		57	58	59	60	61	62	63	64	65	66	67	68	69	70	71																									
		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu																									
		89	90	91	92	93	94	95	96	97	98	99	100	101	102	103																									
		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr																									

Review

- Specific rules tell us the ground state electron configuration of an element
- The Periodic Table is a useful tool for writing electron configurations

- What are the electron configurations of the following elements?

1. Na, K, Rb, Cs

2. Si, Ge, Sn, Pb

PERIODIC TABLE OF THE ELEMENTS

1 H 1.0079																	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 16.00	9 F 19.00	10 Ne 20.179
11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.938	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	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 (98)	44 Ru 101.1	45 Rh 102.91	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 126.91	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	*La 138.91	Hf 178.49	Ta 180.95	W 183.85	Re 186.21	Os 190.2	Ir 192.2	Pt 195.08	Au 196.97	Hg 200.59	Tl 204.38	Pb 207.2	Bi 208.98	Po (209)	At (210)	Rn (222)
87 Fr (223)	88 Ra 226.02	†Ac 227.03	Rf (261)	Db (262)	Sg (263)	Bh (262)	Hs (265)	Mt (266)	§ (269)	§ (272)	§ (277)	§Not yet named					

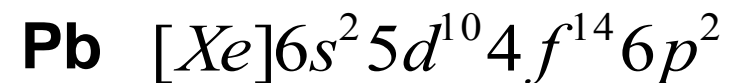
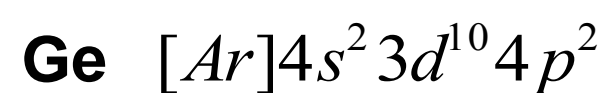
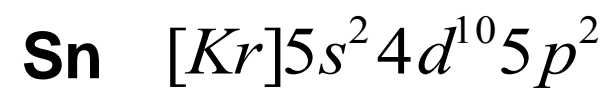
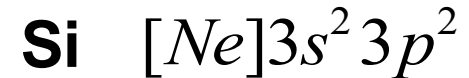
*Lanthanide Series	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.4	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
†Actinide Series	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

Review

- What pattern do you notice in the electron configurations of these elements?

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This pattern explains MANY elemental properties.

Outline

- Development of the Periodic Table
- Atomic Radii

- Development of the Periodic Table
 - Mendeleev
 - Modern
- Atomic Radii
 - Group Trend
 - Periodic Trend

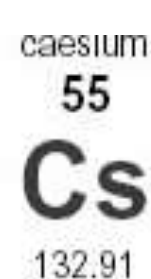
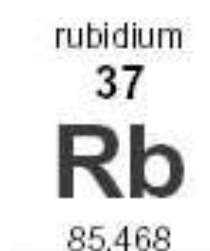
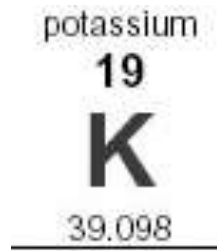
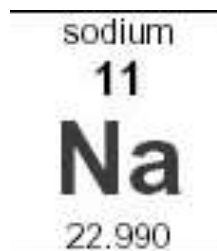
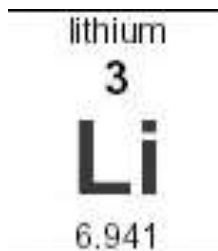
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Periodic Properties

- Patterns in electronic configuration explain ...



... The Periodic Table of Explosions in Water

Mendeleev's Idea

- *'When the elements are arranged in order of increasing atomic mass, certain sets of properties recur periodically.'*
- Dmitri Mendeleev's **Periodic Law** (1869)

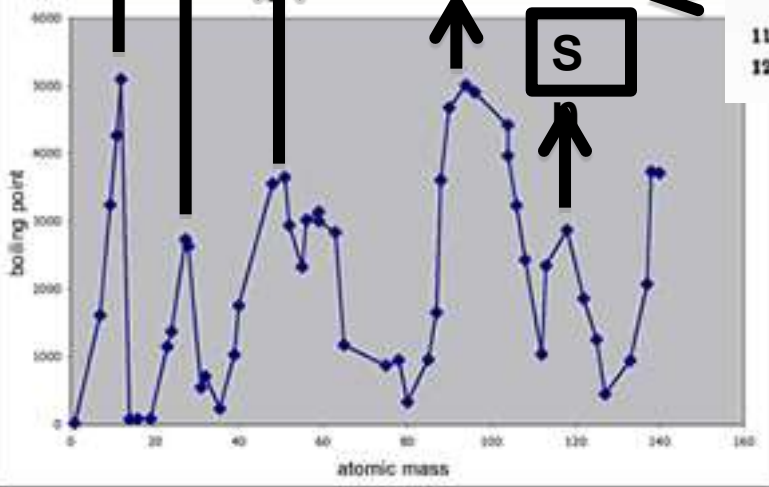
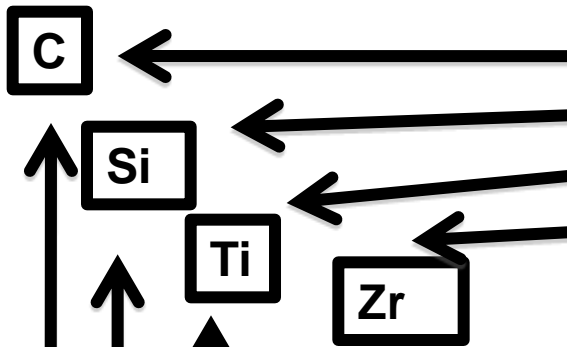
Reihen	Gruppe I. — R'O	Gruppe II. — R'O	Gruppe III. — R'O ³	Gruppe IV. RH ⁴ R'O ²	Gruppe V. RH ⁵ R'O ³	Gruppe VI. RH ⁶ R'O ³	Gruppe VII. RH R'O ⁷	Gruppe VIII. — R'O ⁸
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sa=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=196, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

The original Periodic Table

Mendeleev's Idea

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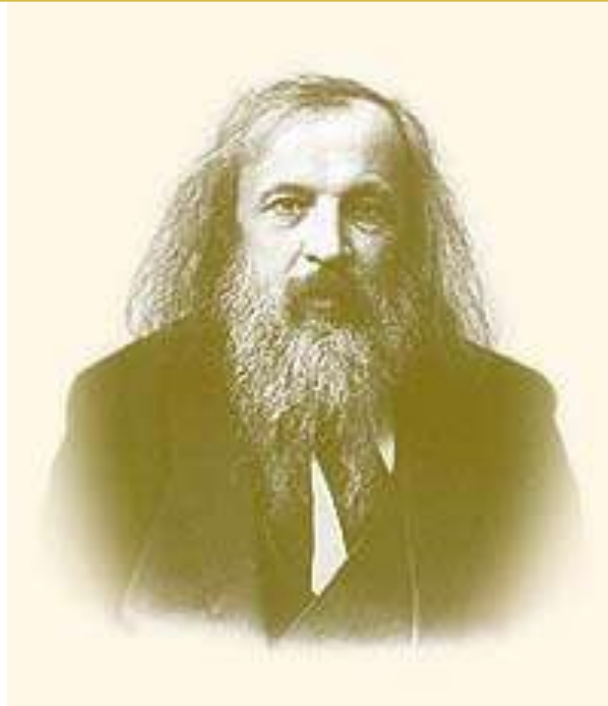
Reihen	Gruppe I. — R'O	Gruppe II. — RO	Gruppe III. — R'O ³	Gruppe IV. RH ⁴ RO ⁴	Gruppe V. RH ⁵ R'O ⁵	Gruppe VI. RH ⁶ RO ⁶	Gruppe VII. RH R'O ⁷	Gruppe VIII. — RO ⁴
1	H=1			C=12	N=14	O=16	F=19	
2	Li=7	Be=9	B=11	Si=28	P=31	S=32	Cl=35,5	
3	Na=23	Mg=24	Al=27	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
4	K=39	Ca=40	Sc=44	—=72	As=75	Se=78	Br=80	
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	Y=89	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sa=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	Sn=136	?Ce=140	—	—	—	—
9								
10			?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	—
12	—	—	—	Th=231	—	U=240	—	—



- All 'peak' elements are in **Group 4**
- Boiling point sharply increases before and sharply decreases after each peak
- Similar trend found for melting points

Mendeleev's Idea

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- Mendeleev's table was **not perfect**
- Some elements were placed in groups **out of order** of increasing mass to force properties to satisfy certain trends

- What primarily determines atomic mass? (Think particles.)
- What other atomic property might explain periodic trends?

Outline

- Development of the Periodic Table
- Atomic Radii

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 - Modern
- Atomic Radii
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Modern Periodic Table

- Elements on the periodic table are ordered by increasing atomic number

PERIODIC TABLE OF THE ELEMENTS

Z = 1	1 H 1.0079																	2 He 4.0026	Z = 2						
	3 Li 6.941	4 Be 9.012																	5 B 10.811	6 C 12.011	7 N 14.007	8 O 16.00	9 F 19.00	10 Ne 20.179	
	11 Na 22.99	12 Mg 24.30																	13 Al 26.98	14 Si 28.09	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948	
	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.938	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80							
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Z = 87	87 Fr (223)	88 Ra 226.02	†Ac 227.03	89 Rf (261)	104 Db (262)	105 Sg (263)	106 Bh (262)	107 Hs (265)	108 Mt (266)	109 § (269)	110 § (272)	111 § (277)	§Not yet named												
																			Z = 118						

*Lanthanide Series

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.4	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
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†Actinide Series

Modern Periodic Table

- ‘Coloring’ the table allows you to see patterns in elemental properties

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Metal

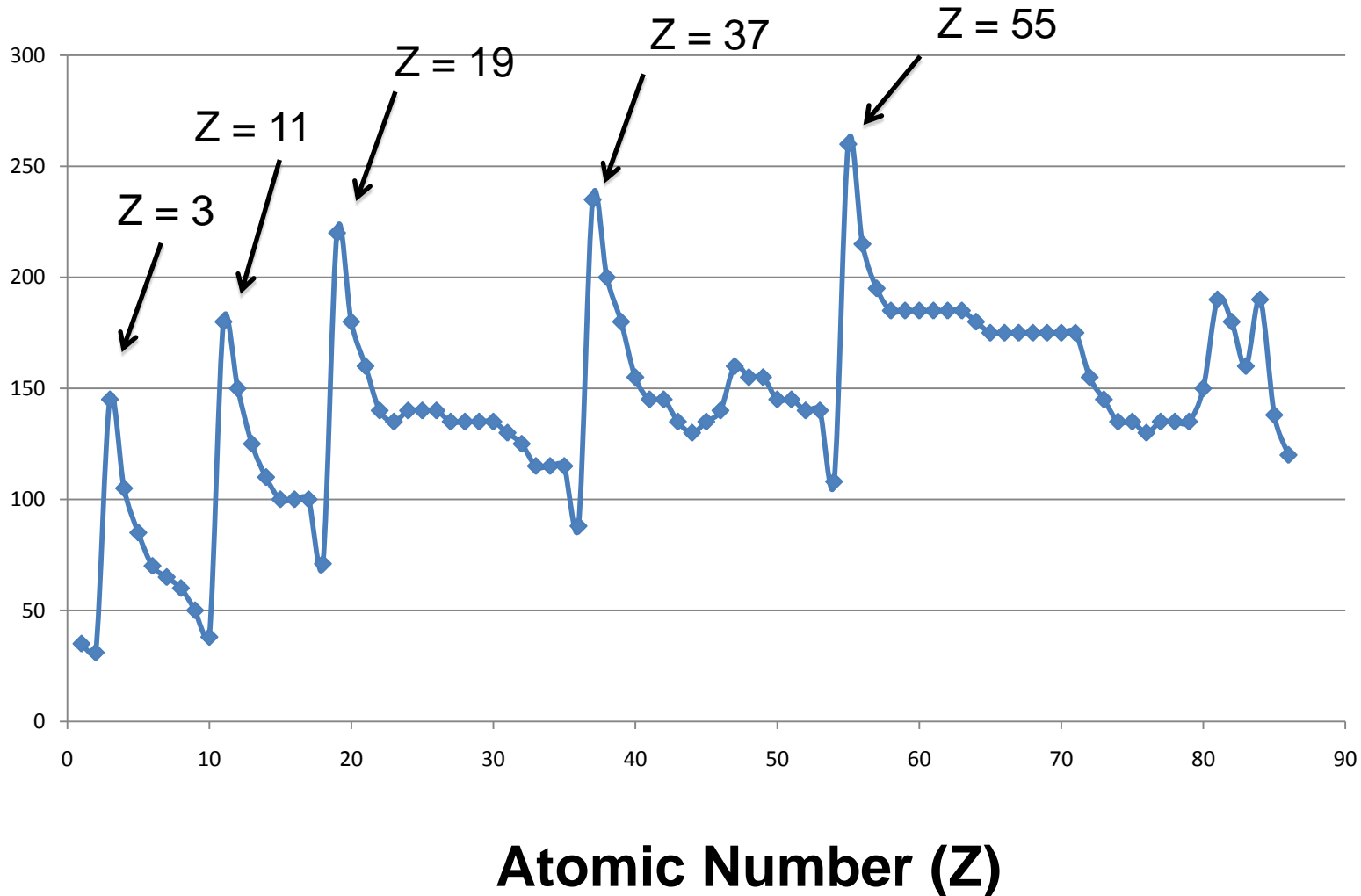
Non-Metal

Metalloid

Mini Quiz

- What trends do you notice?
- Which group of elements have the largest atomic radii?

**Atomic
Radius**



Atomic Number (Z)

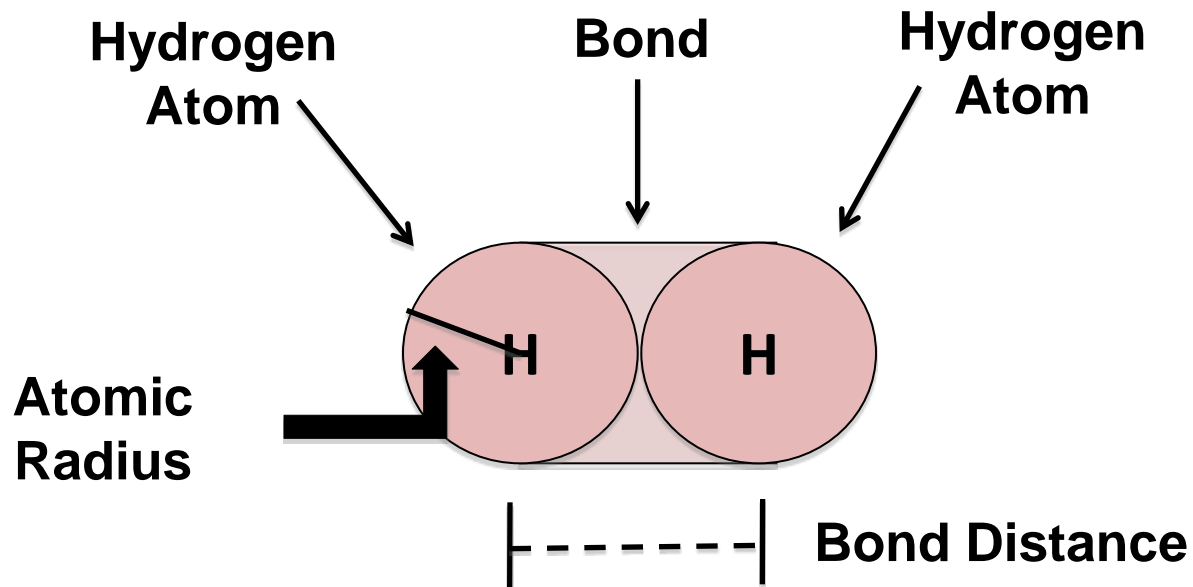
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Atomic Radii

- Multiple atoms can be held close together through **bonds** (we will talk more about bonds in the next unit)
- Atomic radii are measured by finding the distance between bonded atoms



Bond Distance = 74 pm

Atomic Radius = 37 pm

Atomic Radii

- Atomic radii increase going down and to the right of the periodic table







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†Actinide Series																	

- We need two ideas to understand this trend for groups (columns) and periods (rows)

Atomic Radii – Group Trend

n ↑ = atomic radius ↑

Element	Electron Configuration	Highest Occupied n		Atomic Radius (pm)	Relative Size
H	$1s^1$	n = 1			
Li	$[He]2s^1$	n = 2			
Na	$[Ne]3s^1$	n = 3			
K	$[Ar]4s^1$	n = 4			
Rb	$[Kr]5s^1$	n = 5			
Cs	$[Xe]6s^1$	n = 6			

Mini Quiz

Place the following elements in order of increasing atomic radius:

At

Br

Cl

F

I

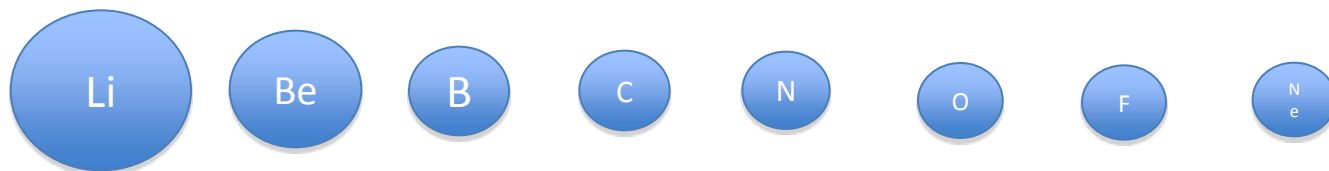
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Atomic Radii – Period Trend

- To understand the decreasing atomic radius across a period, it is helpful to introduce a new property: **effective nuclear charge (Z_{eff})**

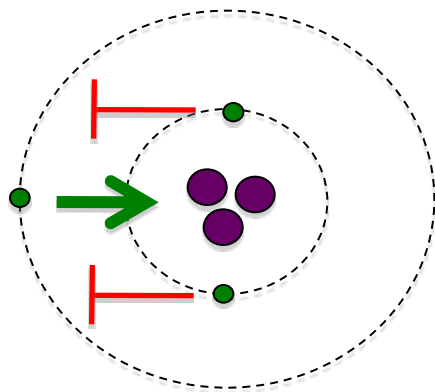


- Electrons in outer sub-shells do not ‘feel’ the full charge of the nucleus because they are ‘blocked’ by inner (**core**) electrons
- The charge felt by outer electrons is called the **effective nuclear charge (Z_{eff})**

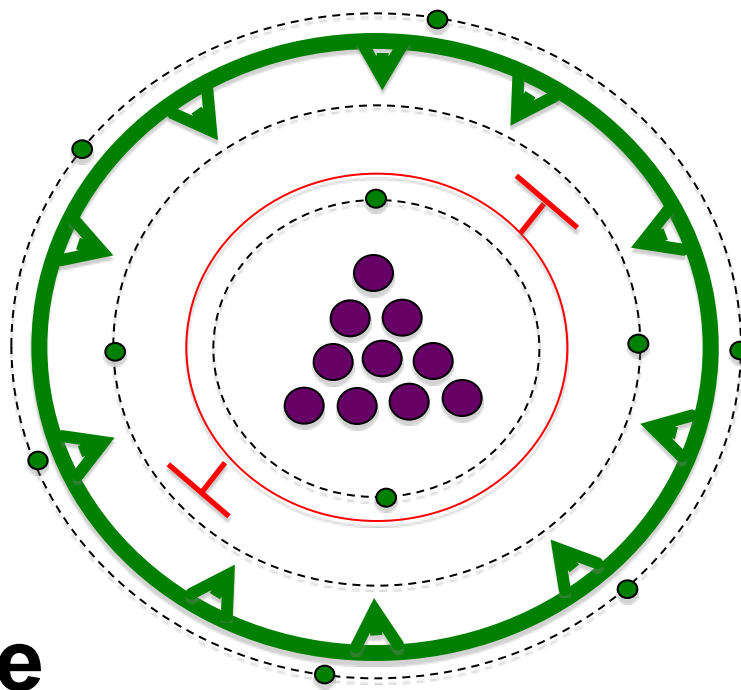
$$Z_{\text{eff}} = Z - (\# \text{ of core electrons})$$

Atomic Radii – Period Trend

- You can think of Z_{eff} as a describing a tug-of-war between the nucleus and the inner electrons



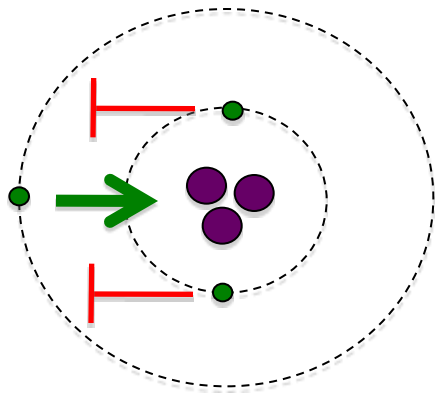
Li



Ne

Atomic Radii – Period Trend

- You can think of Z_{eff} as a describing a tug-of-war between the nucleus and the inner electrons

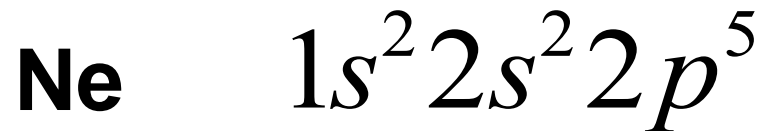
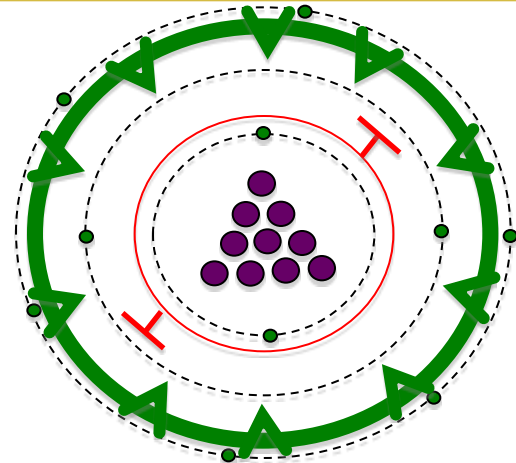


$Z = 3$ # core electrons = 2

$Z_{\text{eff}} = Z - (\text{\# core electrons})$

$Z_{\text{eff}} = 3 - 2$

$Z_{\text{eff}} = +1$



$Z = 10$ # core electrons = 2

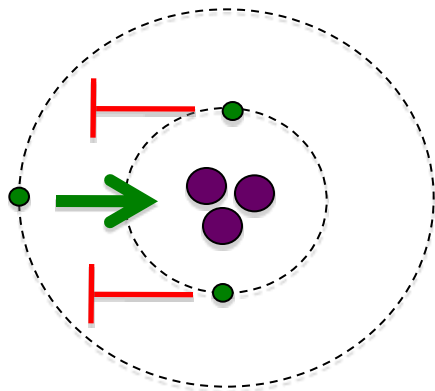
$Z_{\text{eff}} = Z - (\text{\# core electrons})$

$Z_{\text{eff}} = 10 - 2$

$Z_{\text{eff}} = +8$

Atomic Radii – Period Trend

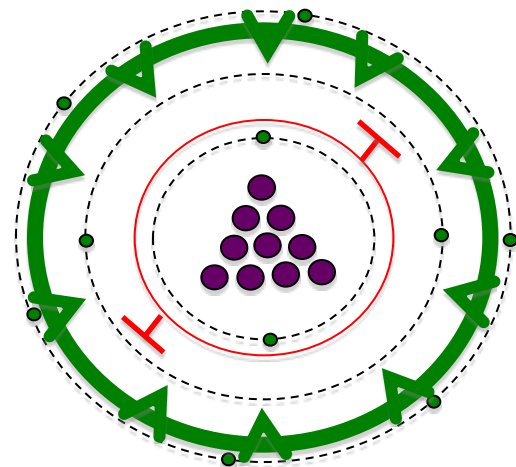
Within the same row (period) ...



Li

$$Z_{\text{eff}} = +1$$

Atomic Radius = 152 pm



Ne

$$Z_{\text{eff}} = +8$$

Atomic Radius = 71 pm

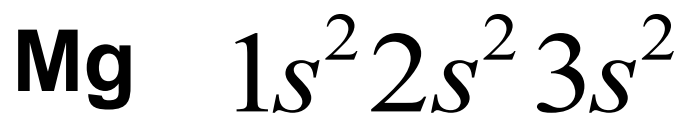
Higher Z_{eff} → stronger 'pull' on electrons from nucleus
→ outer electrons closer to nucleus

Mini Quiz

Fill in the blanks ...

sodium 11 Na 22.990	magnesium 12 Mg 24.305
-------------------------------------	--

aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
--	--------------------------------------	--	------------------------------------	---------------------------------------	------------------------------------



$Z = ?$ # core electrons = ?

$Z_{\text{eff}} = Z - (\text{\# core electrons})$

$Z_{\text{eff}} = ? - ?$

$Z_{\text{eff}} = + ?$

$Z = ?$ # core electrons = ?

$Z_{\text{eff}} = Z - (\text{\# core electrons})$

$Z_{\text{eff}} = ? - ?$

$Z_{\text{eff}} = + ?$

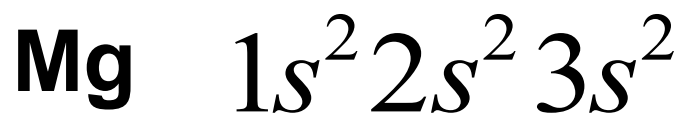
Which element do you predict has the larger atomic radius?

Mini Quiz

Fill in the blanks ...

sodium 11 Na 22.990	magnesium 12 Mg 24.305
-------------------------------------	--

aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
--	--------------------------------------	--	------------------------------------	---------------------------------------	------------------------------------



Z = 12 # core electrons = 10

$Z_{\text{eff}} = Z - (\text{\# core electrons})$

$Z_{\text{eff}} = 12 - 10$

$Z_{\text{eff}} = +2$

Z = 15 # core electrons = 10

$Z_{\text{eff}} = Z - (\text{\# core electrons})$

$Z_{\text{eff}} = 15 - 10$

$Z_{\text{eff}} = +5$

Which element do you predict has the larger atomic radius?

Atomic Radii – Period Trend

$Z_{\text{eff}} \uparrow = \text{atomic radius} \downarrow$

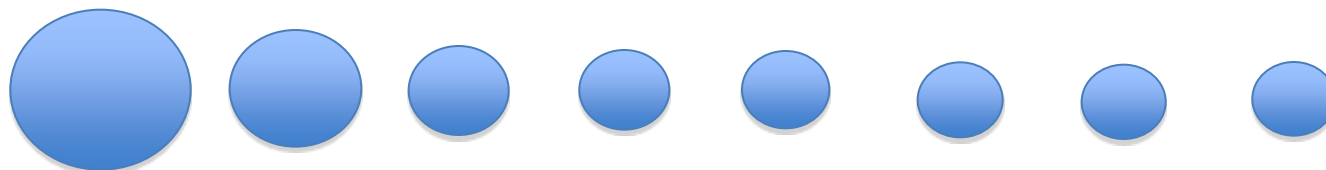
lithium 3 Li 6.941	beryllium 4 Be 9.0122	boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
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+1 +2 +3 +4 +5 +6 +7 +8

Z_{eff}

**Atomic Radius
(pm)**

152 112 85 77 75 73 72 71



Mini Quiz

- Which element has the bigger atomic radius?

Se

or

O

C

or

O

C

or

Se

Summary

- The periodic table is ordered by increasing atomic number
- Many elemental properties show periodic trends according to atomic number
- Atomic radii increase going down and to the left across the the periodic table

Homework

- TBA