Chapter 6 – Periodic Table

6.1 Periodic Table Shape

The current periodic table is arranged in order of increasing atomic number. This represents the increasing number of protons in the nucleus. The current shape it takes also takes into account electron configuration and chemical properties or trends.

IA												IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H 1.01	IIA																2 He 4.00
3 Li 6.94	4 Be 9.01											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	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	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 47.88	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 65.38	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 (99)	44 Ru 101.07	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 126.90	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 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	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 (263)	107 Bh (264)	108 Hs (265)	109 Mt (266)	110 Ds (271)	111 Rg (272)	112 Cn (285)	113 Uut (284)	114 Fl (289)	115 Uup (288)	116 Lv (293)	117 Uus (294)	118 Uuo (294)

*Lanthinides	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.4	63 Eu 151.96	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
*Actinides	90 Th 232.04	91 Pa (231)	92 U 238.03	93 Np (237)	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)

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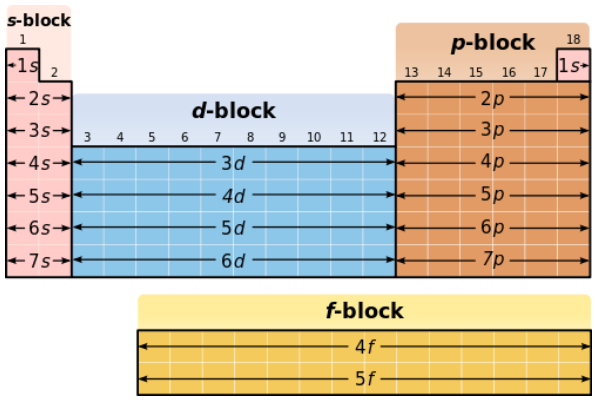
- Dimitri Mendeleev (1869) arranged elements in a tabular format in order of increasing atomic mass.
  ⇒ Elements with similar properties were grouped together in the same column or row.
  ⇒ Mendeleev even left some holes in table for elements that had not yet been discovered.

- H. G.J. Moseley arranged elements in order of ***increasing atomic number***, Z.
  (recall that Z = # of protons!)

Periodic Law – elements in the same column have similar properties

⇒ *Atomic mass usually increases when the number of protons increases*
except for Ni & Co, Ar & K, Te & I.

- Neils Bohr's introduction of electron energy levels altered the ***shape of the Periodic Table.***
  ⇒ The modern Periodic Table indicates filling of s, p, d and f sublevels.



6.2 Periods and Groups

PERIOD

- A ***horizontal row*** is called a period or series. (There are 7 rows = 7 periods.)

	IA												IIIA	IVA	VA	VIA	VIIA	VIIIA
	1 H 1.01	IIA																2 He 4.00
Period 2 ➔	3 Li 6.94	4 Be 9.01											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	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	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 47.88	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 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
Period 5 ➔	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 (99)	44 Ru 101.07	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 126.90	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 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	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 (263)	107 Bh (264)	108 Hs (265)	109 Mt (266)	110 Ds (271)	111 Rg (272)	112 Cn (285)	113 Uut (284)	114 Fl (289)	115 Uup (288)	116 Lv (293)	117 Uus (294)	118 Uuo (294)

*Lanthinides	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.4	63 Eu 151.96	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
*Actinides	90 Th 232.04	91 Pa (231)	92 U 238.03	93 Np (237)	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)

Note elements 58 to 71 actually fit in row 6 after La. Likewise elements 90-103 fit in row 7 after Ac.

GROUP

- A ***vertical column*** is called a group or family ⇒ elements in the same group exhibit similar properties.

Group IA ↓ Group VIA ↓

												IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H 1.01	IIA																2 He 4.00
3 Li 6.94	4 Be 9.01											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	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	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 47.88	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 65.38	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 (99)	44 Ru 101.07	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 126.90	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 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	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 (263)	107 Bh (264)	108 Hs (265)	109 Mt (266)	110 Ds (271)	111 Rg (272)	112 Cn (285)	113 Uut (284)	114 Fl (289)	115 Uup (288)	116 Lv (293)	117 Uus (294)	118 Uuo (294)

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Representative Elements: Main Group A Elements (elements in Groups IA-VIIIA)

Know the names for these groups:

Group IA: alkali metals
Group IIA: alkaline earth metals
Group VIIA: halogens
Group VIIIA: noble gases

Transition Metals: Group B elements (in middle of the Periodic Table highlighted green)

⇒ The behavior and properties of transition metals is not very predictable

IA												IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H 1.01	IIA																2 He 4.00
3 Li 6.94	4 Be 9.01											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	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
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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 (99)	44 Ru 101.07	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 126.90	54 Xe 131.29
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Inner Transition Elements (beneath the main body of Periodic Table)

Lanthanide series: Ce-Lu, also called rare earth metals

Actinide series: Th-Lr, radioactive elements that exist for only very short periods of time before decaying to other elements

Transuranium Elements – all elements with Z ≥ 93 are man-made in particle accelerators.

6.3 Metals, Nonmetals and Metalloids

Metal	Metalloid	Nonmetal

IA												IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H 1.01	IIA																2 He 4.00
3 Li 6.94	4 Be 9.01											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	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
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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 (99)	44 Ru 101.07	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 126.90	54 Xe 131.29
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87 Fr (223)	88 Ra (226)	89 Ac* (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (264)	108 Hs (265)	109 Mt (266)	110 Ds (271)	111 Rg (272)	112 Cn (285)	113 Uut (284)	114 Fl (289)	115 Uup (288)	116 Lv (293)	117 Uus (294)	118 Uuo (294)

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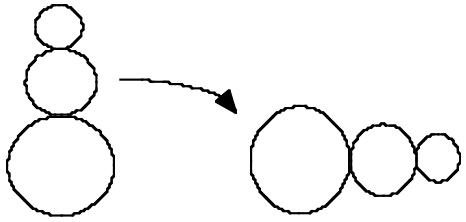
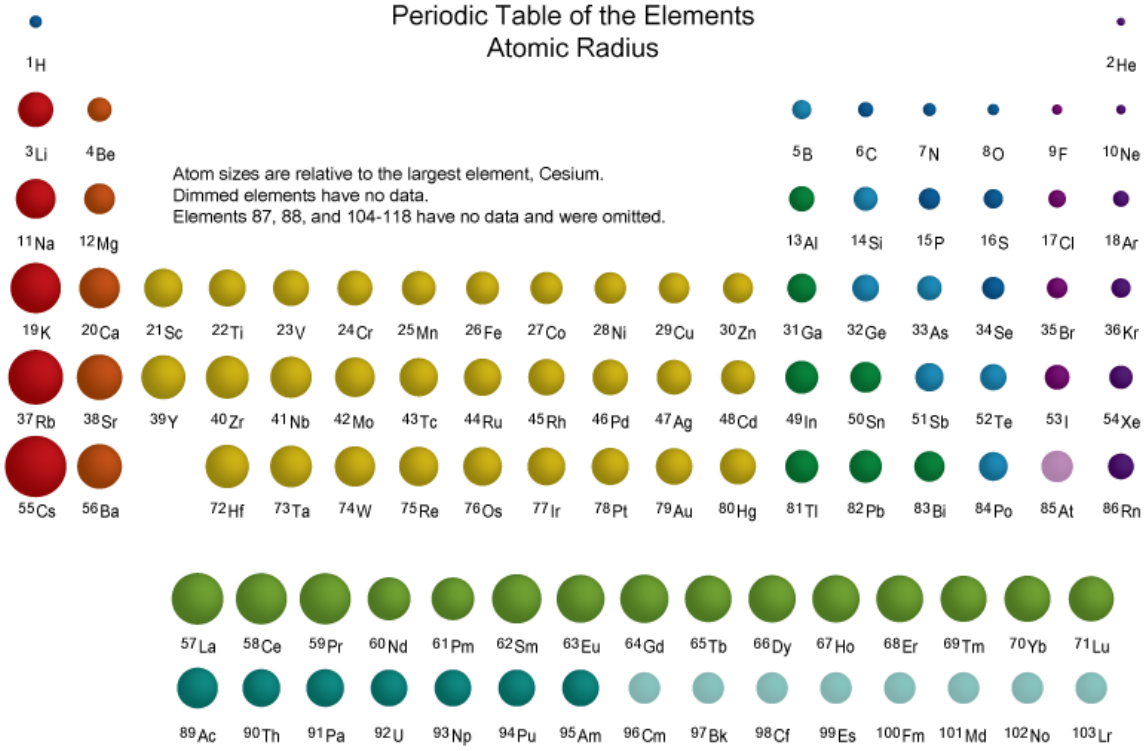
6.4 Atomic Size

Atomic Size: distance from nucleus to outermost electrons = radius

- Atomic Size for Neutral Atoms:
  - **Increases down a group**
    As we go ↓, there are more energy levels = bigger radius
  - **Decreases across a period (from left to right)**
    As we go →, the nuclear charge increases since there are more protons in the nucleus.
    As the positive nuclear charge increases, the negative electrons are pulled closer, so the atom is actually smaller despite an increase in mass
  - More mass does not mean bigger. Be prepared to explain that.
    - Trend from top to bottom is like a snowman
    - Trend from left to right is like a snowman that fell to the right





- Atomic Size for Ions:
  - **Cations**: Since cations result from the loss of e^-'s, cations are smaller than their respective neutral atoms.

    Ca atom is larger than Ca^{2+} ion, Ca > Ca^{2+}

  - **Anions**: Since anions result from the gain of e^-'s, anions are larger than their respective neutral atoms.

    N^{3-} ion is larger than N atom, N^{3-} > N

6.5 Ionization Energy

Ionization energy (IE): amount of energy required to remove an electron from a neutral atom.

Equation for IE: $Na_{(g)} \rightarrow Na^{+}_{(g)} + 1\ e^{-}$

Orbital Filling Diagrams to Explain:

Outermost electron that is removed

Na: [Ne] ↑ ____ ____ ____ ____
3s 3p

Na readily loses its outermost electron so it can become isoelectronic to a Noble Gas, Ne. Therefore its IE is low.

Outermost electron that is removed

Cl: [Ne] ↑↓ ____ ↑↓ ↑↓ ↑ ____
3s 3p

Cl does not benefit from losing its outermost electron like Na. Chlorine would rather gain one electron to become isoelectronic to the next Noble Gas, Ar. Therefore its IE is much higher.

Ionization energy trends

IE increases up a group

- Easier to remove electrons from a larger atom (e– 's are further from the nucleus)
  Consider He vs. Rn:
  Helium and radon are in the same group. He has 2 e^{-}'s and Rn has 86 e^{-}'s. Recall, it is the outermost electron (farthest from the nucleus) that is removed when discussing IE. Helium's outer electron is very close to the nucleus, so the proton pull on these electrons is strong and thus it takes a lot of energy to remove an electron from He. Radon's outer electron is very far from the nucleus, there are a lot of electrons between the nucleus and the outer electron, so the proton pull on that electron is not very strong. So removing the outer electron from Rn doesn't take that much energy.

IE increases across a period (from left to right)

- Most metals want to lose electrons to attain the noble gas configuration (greater stability) and thus they become cations. So metals already want to lose an outer electron, thus taking one away doesn't take much energy, therefore low IE for metals. So for a metal, losing an electron is a good thing.

- Nonmetal elements on the right side have higher IE's because they don't want to give up electrons. Nonmetals want to gain electrons to attain the noble gas configuration. So removing an electron from a nonmetal takes a lot of energy, therefor high IE for nonmetals. So for a nonmetal, losing an electron is a terrible thing. And removing an electron from a noble gas is the worst thing! Noble gases have very high IE as they already have stable s^2p^6 configurations and don't want to change.

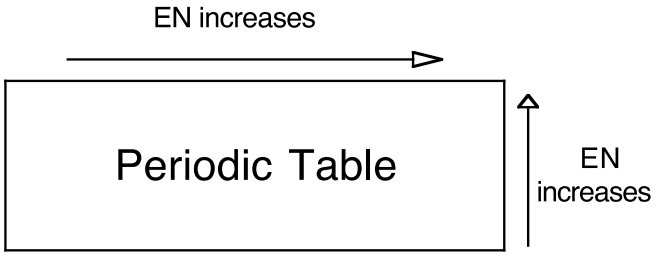
YouTube Video: Ionization Energy

6.6 Electronegativity

Electronegativity (EN): Ability of an atom to attract **bonded** electrons. Think of it like a magnet!

- **F is the most electronegative (EN) element**

⇒ Elements are less electronegative the further away from F (Except for H, which has EN between B and C).



⇒ Noble Gases are not included since they have ***no*** EN values. Do you know why? It is because they don't bond naturally, so can't attract bonded electrons.

CHAPTER 6 PRACTICE PROBLEMS

1. The noble gas in the third period is: _____
2. The halogen in the fourth period is: _____
3. Sodium reacts violently with water. Which elements below are also likely to react violently with water?
   K Mg Al Si P Li Cl Ar
4. Nitrogen reacts with hydrogen to form NH_3. Give the formula for the compound that forms when phosphorus reacts with hydrogen.
5. Metals tend to lose or gain electrons, becoming cations or anions?
6. Which atom has the larger atomic radius, K or Ca?
7. Which atom has the smaller atomic radius, F or I?
8. Which atom in each group has the higher ionization energy? O or S Li or O
9. Which element in group VA has the smallest atomic radius?
10. What element in period four has the lowest first ionization energy?
11. Circle the one for *each* set that has the larger atomic radius:
    B *or* O I *or* Cl Sr^{2+} *or* Sr P *or* P^{3-}

Answers To Practice Problems

1. Ar
2. Br
3. K, Li
4. PH_3
5. Metals lose electrons forming cations (positively charged ions).
6. K
7. F
8. O,O
9. N
10. K
11. B, I, Sr, P^{3-}