

THURSDAY, DECEMBER 7, 2023 AP CHEMISTRY
REUSING THIS YEAR STARTING DEC 11, 2023
CH. 7 PERIODIC PROPERTIES OF THE ELEMENTS 13

7.1 DEVELOPMENT OF THE PERIODIC TABLE

ELEMENTS ARE GROUPED IN COLUMNS BASED ON SIMILARITIES OF PROPERTIES.

LIKE WHAT?

OXIDE FORMULA

GROUP	1	2	13
	Li_2O	BeO	B_2O_3
	Na_2O	MgO	Al_2O_3
	K_2O	CaO	Ga_2O_3

CHLORIDE FORMULA

GROUP	1	2	13
	LiCl	BeCl_2	BCl_3
	NaCl	MgCl_2	AlCl_3
	KCl	CaCl_2	GaCl_3

VALENCE ELECTRON CONFIGURATION

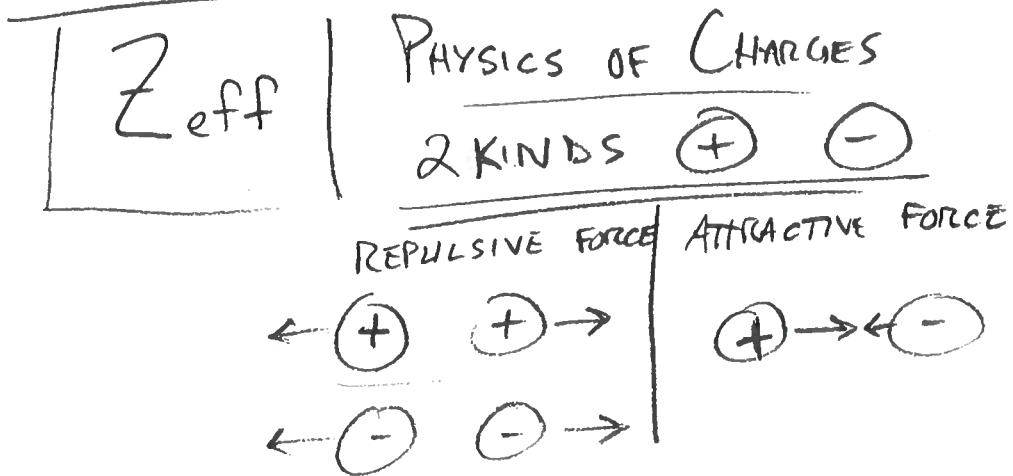
GROUP	1	2	13
	ns^1	ns^2	$ns^2 np^1$

THE SIMILARITY IN VALENCE SHELL ELECTRON CONFIGURATION IS WHY THE CHEMICAL AND PHYSICAL SIMILARITIES EXIST.

MENDELEEV PREDICTED AS-YET-UNDISCOVERED ELEMENTS AND PUT SOME ELEMENTS IN GROUPS DESPITE HAVING TO PUT THEM OUT OF ORDER ACCORDING TO ATOMIC MASS.

(STOPPED HERE TH 2022-12-07 AP CHEM X)

7.2 EFFECTIVE NUCLEAR CHARGE

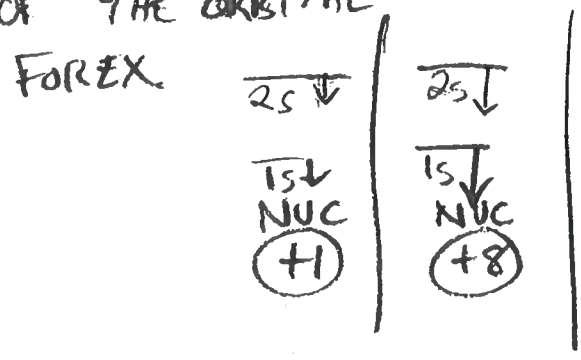


- ① AMOUNT OF FORCE IS DIRECTLY PROPORTIONAL TO THE AMOUNT OF CHARGE: q .
- ② AMT OF FORCE IS INVERSELY PROP. TO DISTANCE BTWN CHARGES, SQUARED: r^2 .

$$F_{ELEC} = K \frac{q_1 q_2}{r^2}$$

$$\left(F_{GRAN} = G \frac{m_1 m_2}{r^2} \right)$$

THE FORCE EXPERIENCED BY ELECTRONS IN THEIR ORBITALS DEPENDS ON THE CHARGE OF THE NUCLEUS AND THE SIZE OF THE ORBITAL

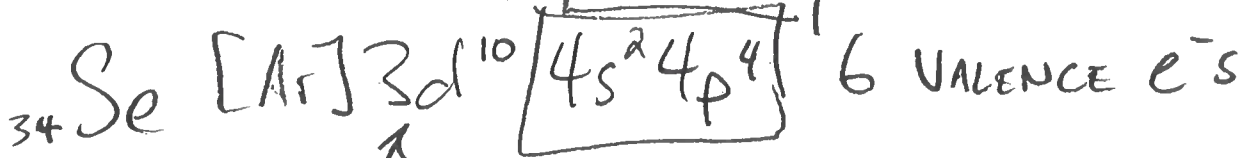
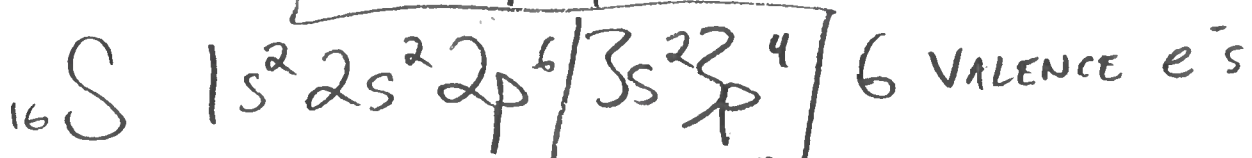
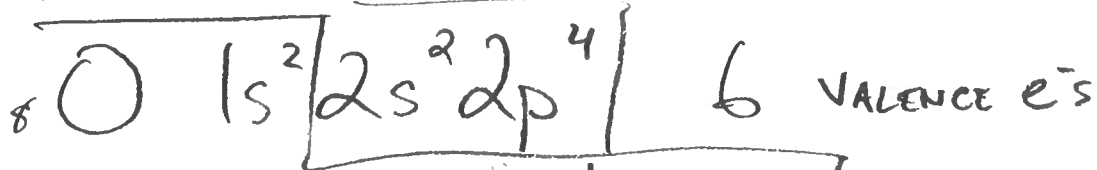


VALENCE ELECTRONS ARE OUR MAIN CONCERN B/C THEY ARE THE ONES THAT DETERMINE THE BEHAVIOR OF AN ELEMENT.

*** VALENCE e^- ORBITALS ARE THOSE WITH THE HIGHEST VALUE OF n FOR e^- S IN THE GROUND STATE.**

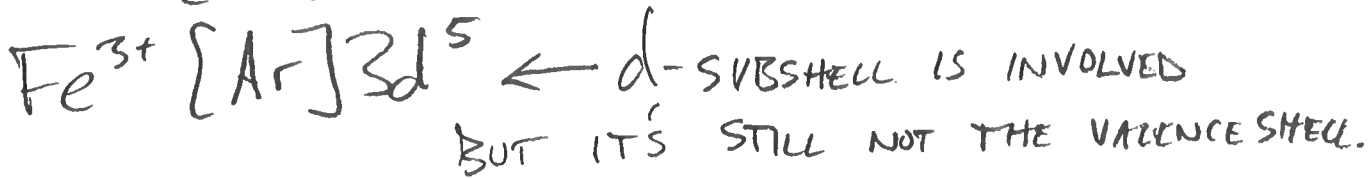
LOWER VALUES OF n ARE CORE ELECTRONS.

Valence e⁻s



↑ NOT VALENCE B/C IT HAS n=3, NOT n=4

WE CAN'T FULLY IGNORE d-SUBSHELL e⁻s IN TRANSITION METALS, DESPITE ns² BEING THE VALENCE SHELL FOR ALL OF THEM.



Core e⁻s

CORE ELECTRONS ARE MAINLY THOSE IN THE NOBLE GAS CORE BUT ALSO INCLUDE d-SUBSHELL & f-SUBSHELL ELECTRONS.

EFFECTIVE NUCLEAR CHARGE (Z_{eff})



Z_{eff} IS THE NET POSITIVE CHARGE ACTING ON AN e⁻ IN A GIVEN SHELL. IT IS BASED ON THE NUCLEAR CHARGE (+Z) AND THE NEG. CHARGE OF ELECTRONS IN LOWER SHELLS (-S) (3).

$$Z_{\text{eff}} = Z - S$$

SHIELDING CONSTANT (S)

THE NO OF e^- 'S IN LOWER SHELLS. COMPARED TO THE

Z_{eff} FOR VALENCE ELECTRONS SHELL WE CONSIDER WHETHER VALENCE OR LOWER



ACROSS
A
ROW

↑
VALENCE SHELL

FOR A GIVEN ROW IN THE PER. TABLE Z_{eff} INCR. AS WE GO $L \rightarrow R$ B/C ALL ELEMENTS IN THE SAME ROW HAVE THE SAME CORE ELECTRONS.



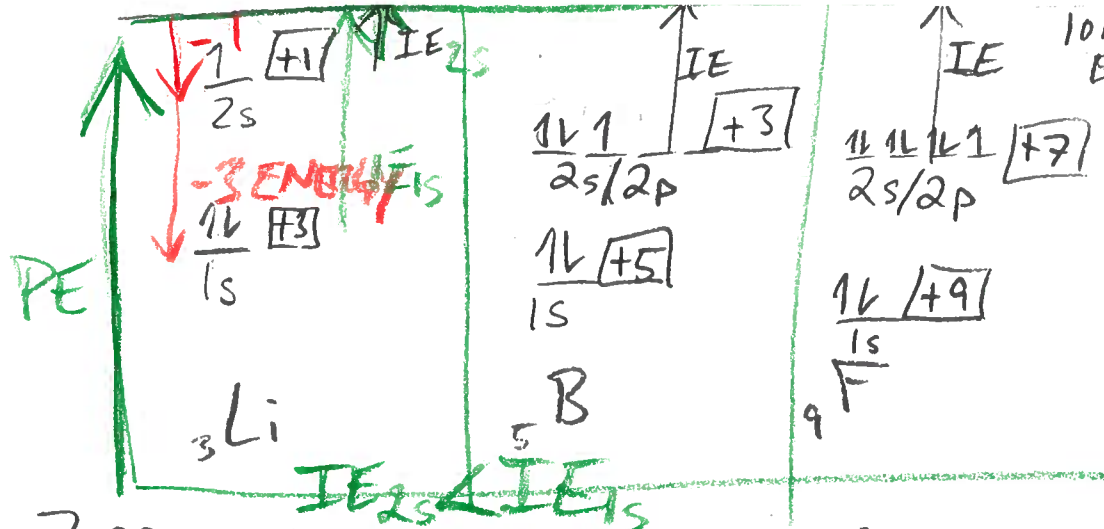
DOWN
A
GROUP

↑
VALENCE e^- 'S

FOR A GIVEN GROUP IN THE PER. TABLE Z_{eff} REMAINS CONSTANT. (THOUGH LARGER SHELLS DO REDUCE ATTRACTIVE FORCE)

* ELECTRONS IN THE SAME SHELL ONLY MAKE A MINOR CONTRIBUTION TO SHIELDING SO WE IGNORE THEM WHEN WE CALC. S.



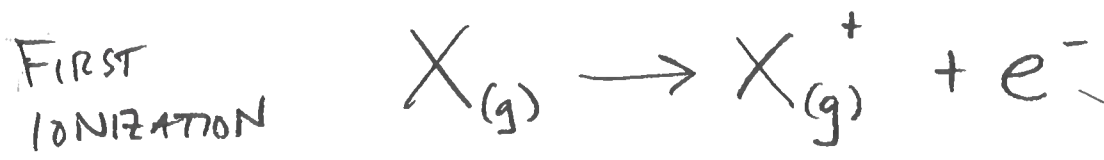


Th 2023-12-07
AP CHEM

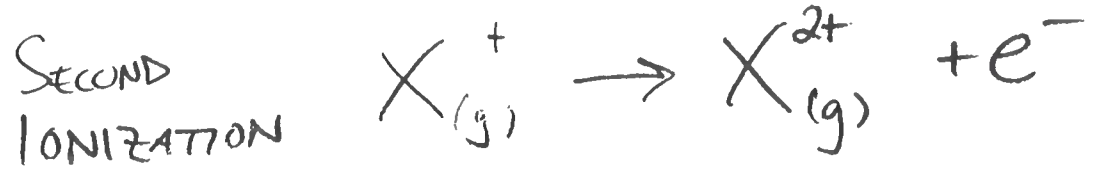
Z_{eff} INCR. AS WE CONSIDER SHELLS BELOW THE VALENCE SHELL.

7.4 IONIZATION ENERGY (SKIPPING 7.3 ATOMIC SIZE FOR NOW)

IONIZATION IS THE REMOVAL OF ONE ELECTRON FROM AN ATOM OR ION. AN ATOM CAN UNDERGO SUCCESSIVE IONIZATIONS.



I_1
(NEUTRAL $\rightarrow +1$)



I_2
($+1 \rightarrow +2$)

THE ELECTRON WE REMOVED

$I_n =$ IONIZATION ENERGY
 $n = 1, 2, 3, \dots$
 $n = 1$ FORM $+1$ ION...

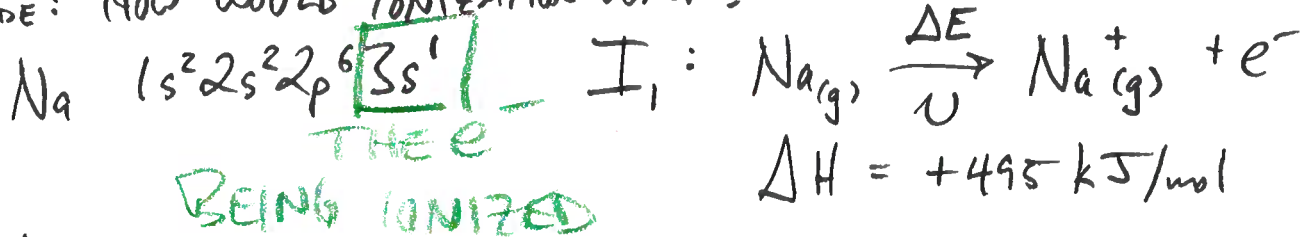
IONIZATION ENERGY MEASUREMENTS HELP US TO UNDERSTAND...

(1) THE ELECTRON SHELL & SUBSHELL STRUCTURE OF ATOMS.

(2) BONDING AND ION FORMATION IN CHEMICAL REACTIONS, FOR EX. WHY A Na^{2+} ION NEVER FORMS.

WHY DOESN'T A Na^{2+} ION FORM?

ASIDE: HOW WOULD IONIZATION WORK?



IMAGINE THIS ΔE IS ACCOMPLISHED USING E-M RADIATION. WHAT λ & ν ?

$\frac{495 \text{ kJ}}{1 \text{ mol}} \cdot \frac{1000 \text{ J}}{1 \text{ kJ}} \cdot \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ PHOTON}} = 8.22 \times 10^{-19} \text{ J/PHOTON} = E$
 $E = h\nu$

$\nu = \frac{E}{h} = 1.24 \times 10^{15} \text{ Hz}$ $\lambda = \frac{c}{\nu} = 2.42 \times 10^{-7} \text{ m}$
242 nm (UV)

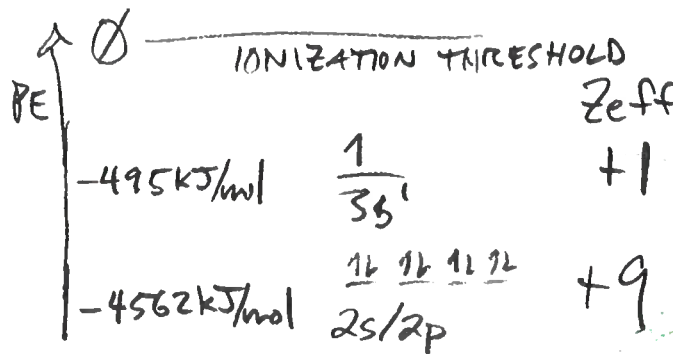


HOW MUCH BIGGER IS I₂ COMPARED TO I₁?

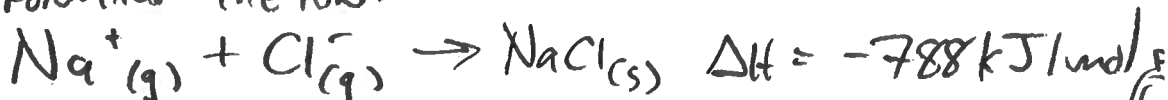
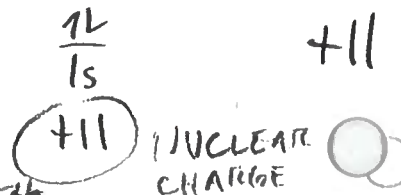
$\frac{4562}{495} = 9.2 \text{ TIMES BIGGER} \dots \text{ WHY } \sim 9 \times \text{ BIGGER?}$

IT'S $\sim 9 \times$ BIGGER B/C THE $n=2$ ELECTRONS HAVE $Z_{\text{eff}} = +9$ VS. $n=3$, WHICH HAS $Z_{\text{eff}} = +1$.

NINE TIMES THE CHARGE, 9 TIMES THE ENERGY.



THE REASON A Na^{2+} ION CANNOT FORM IN A CHEM. RXN. IS THAT BOND FORMATION DOES NOT RELEASE ENOUGH ENERGY TO PAY OFF THE "DEBT" OF FORMING THE ION.



PERIODIC TRENDS FOR FIRST IONIZATION ENERGY

SEE TABLE 7.2 pg 268

FOR PERIOD 3	Z	Z_{eff} VALENCE e^- 's	EC. OF THE IONIZED e^-	I_1 (kJ/mol)
Na	+11	+1	[Ne]3s ¹ ①	496
Mg	+12	+2	[Ne]3s ² ①②	738
Al	+13	+3	[Ne]3s ² 3p ¹ ① <small>3s 3p</small>	578 ←
Si	+14	+4	[Ne]3s ² 3p ² ①②	786
P	+15	+5	[Ne]3s ² 3p ³ ①①①	1012
S	+16	+6	[Ne]3s ² 3p ⁴ ①①①	1000 ←
Cl	+17	+7	[Ne]3s ² 3p ⁵ ①①①	1251
Ar	+18	+8	[Ne]3s ² 3p ⁶	1521

CONCLUSIONS OR OBSERVATIONS

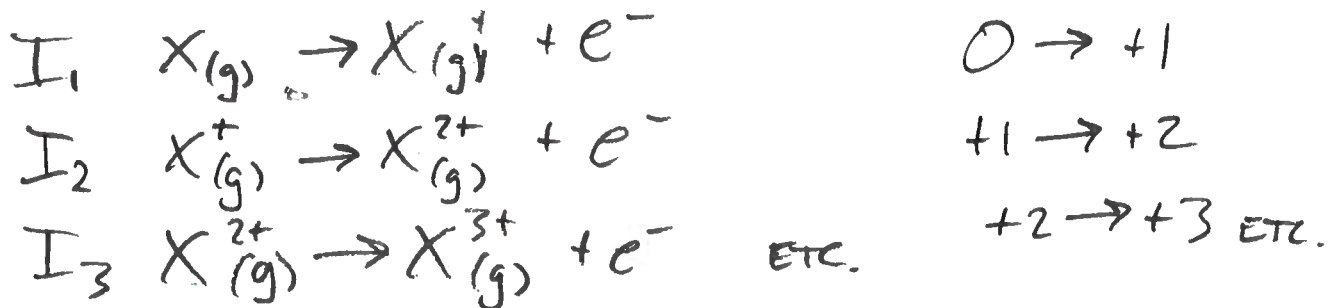
I_1 INCREASES GOING L → R ACROSS A PERIOD. THE REASON IS THAT Z_{eff} INCR. WHILE ADD'L e^- 's ARE ADDED TO THE SAME PRINCIPAL QUANTUM NUMBER (SHELL). VALENCE

I_1 FOR Al IS LESS THAN I_1 FOR Mg B/C FOR Al WE REMOVE A 3p e^- , WHICH IS NEC. HIGHER IN PE THAN 3s, SO IT IS EASIER TO IONIZE. STOPPED HERE (GOOD)

I_1 FOR S IS LESS THAN I_1 FOR P B/C IN S WITH 3p⁴ THERE IS AN e^- PAIR WHICH RAISES PE. F2024-12-13 ⑦

SUCCESSIVE IONIZATIONS

(THIS IS LIKE THE PHOTOELECTRON SPECTROSCOPY ACTIVITY WE DID)



DATA

	I_1	I_2	I_3	I_4	(kJ/mol)
Na	496	4562	—	—	
Z_{eff}	+1	+9			
	$3s^1$	$2p^6$			
Mg	738	1451	7733		
Z_{eff}	+2	+2	+10		
	$3s^2$	$3s^1$	$2p^6$		
Al	578	1817	2745	11,577	
Z_{eff}	+3	+3	+3	+11	
	$3p^1$	$3s^2$	$3s^1$	$2p^6$	

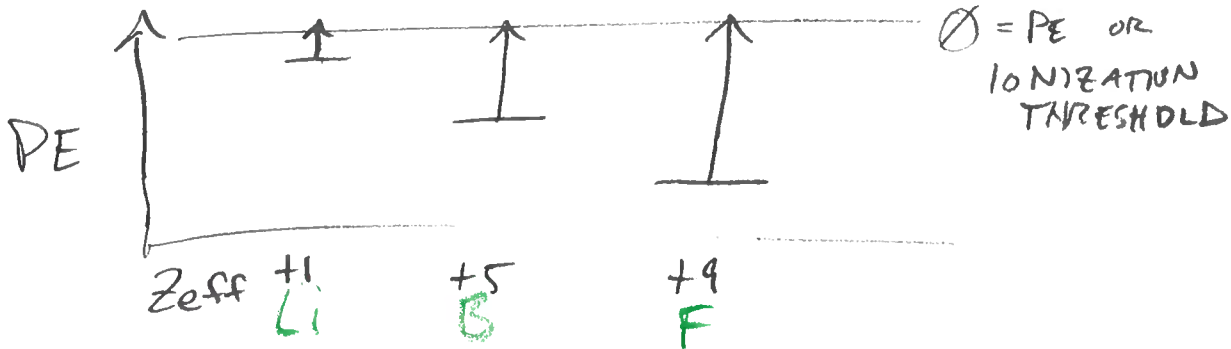
{ VALENCE ELECTRONS ↑ CORE ELECTRONS

CORE ELECTRONS HAVE A MUCH HIGHER IONIZATION ENERGY THAN VALENCE ELECTRONS. THIS IS WHY CORE E'S ARE NOT INVOLVED IN BONDING.

KNOW THESE PATTERNS AND BE ABLE TO EXPLAIN THEM.

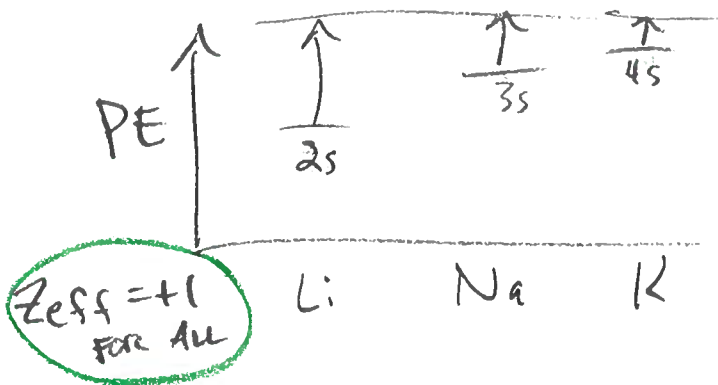
TRENDS IN FIRST IONIZATION ENERGY

- ① I_1 INCR. $L \rightarrow R$ ACROSS A PERIOD
 B/C Z_{eff} INCR. FOR VALENCE ELECTRONS



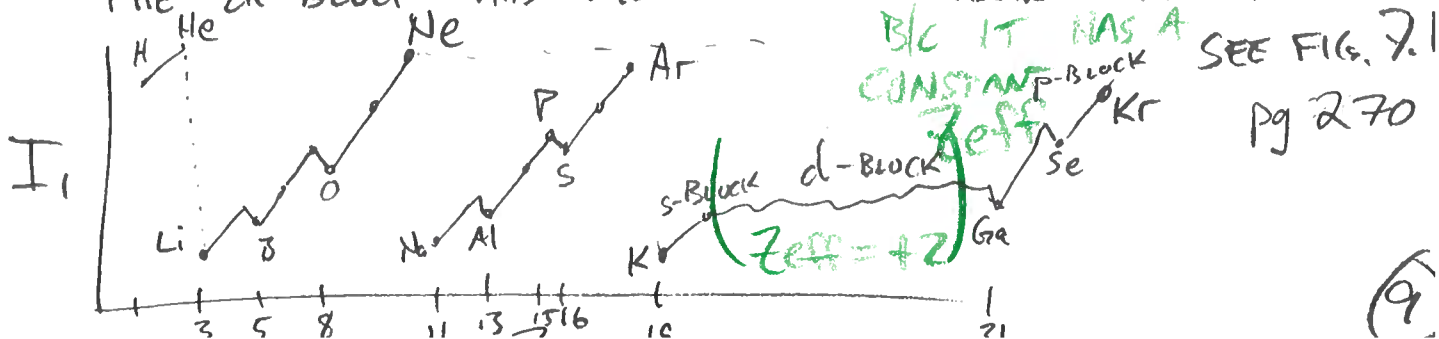
- ② WITHIN A GROUP I_1 DECREASES FROM TOP TO BOTTOM.
 ELEMENTS IN A GROUP HAVE THE SAME Z_{eff} .

EACH NEW ROW ADDS AN ENTIRE QUANTUM SHELL.
 THIS FORCES VALENCE e^- 'S TO BE FARTHER FROM THE NUCLEUS WHERE THE FORCE ON THEM IS LESS, WHICH MAKES THEM EASIER TO IONIZE.



- ③ THE S-BLOCK AND P-BLOCK TREND FOR I_1 IS A STEEP INCR. FROM $L \rightarrow R$ IN A ROW.

THE d-BLOCK HAS MUCH MORE GRADUAL CHANGE.



IN THE d-BLOCK THE FIRST e^- IONIZED IS IN HIGHER S-SUBSHELL THAT PRECEDES EACH ROW

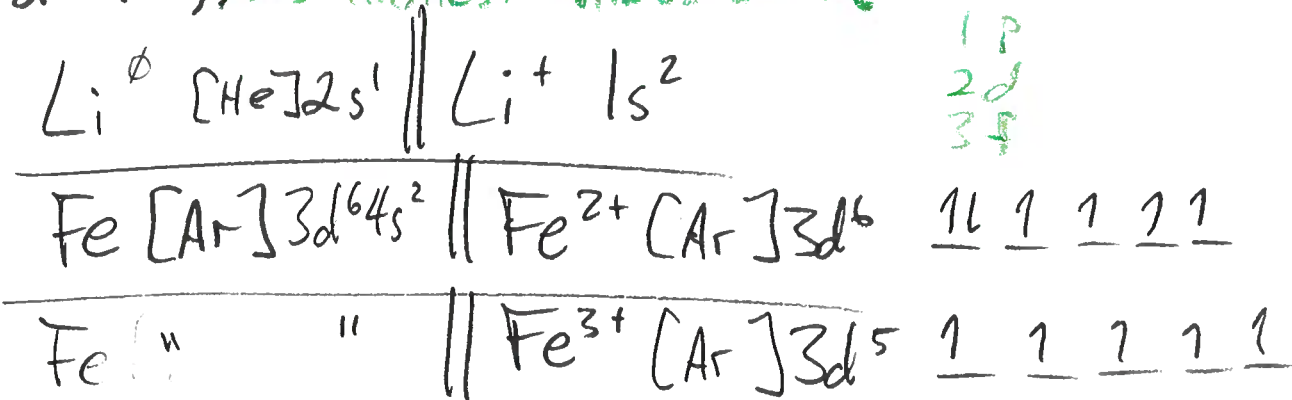
4s BEFORE 3d
 5s BEFORE 4d
 6s BEFORE 5d

FOR THE ns ELECTRONS THE d-SUBSHELL e^- 'S ACT LIKE ADDITIONAL SHIELDING, KEEPING Z_{eff} NEARLY CONSTANT ACROSS THE ROW OF THE d-BLOCK.

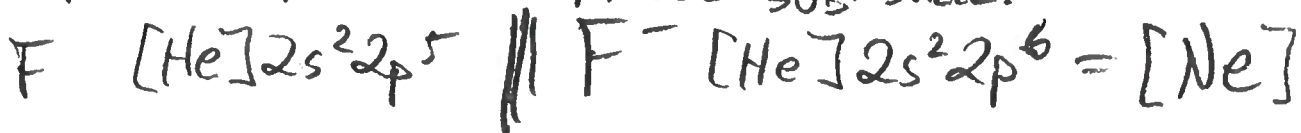
FOR S- AND P-BLOCK ELEMENTS ADDED e^- 'S DO NOT ADD TO SHIELDING.

ELECTRON CONFIG. FOR IONS

WHEN POSITIVE IONS FORM THE ELECTRON(S) LOST COME FROM THE HIGHEST OCCUPIED ORBITAL (HIGHEST VALUE OF n) AND HIGHEST VALUE OF $l = 0, 1, 2, 3$



WHEN NEGATIVE IONS FORM AN e^- JOINS THE HIGHEST PARTIALLY FILLED SUB-SHELL.



WHY CAN'T WE FORM F^{2-} OR Ne^{-} ?

WE CAN'T MAKE THOSE IONS B/C THERE IS NO ELEC. FORCE TO ATTRACT THEM TO THE ATOM.

F	VS	F^{-}/Ne		F^{2-}/Ne^{-}
Z_{eff}		$\frac{1L1L1L}{2L2L2L} (+8)$		$\frac{3s}{\emptyset} = Z_{eff}$
+7 $\frac{1L}{2s}$ $\frac{2L1L1L}{2p}$		+7 $\frac{2L}{2s}$ $\frac{2L2L2L}{2p}$ (+8)		2p F Ne
+9 $\frac{1L}{1s}$		+9 $\frac{1L}{1s}$ (+10)		2s +7 +8
NUC: +9		+9 +10		1s +9 +10
(Z)				

THE Z_{eff} FOR $3s$ (IN F^{-} OR Ne) IS ZERO. AND

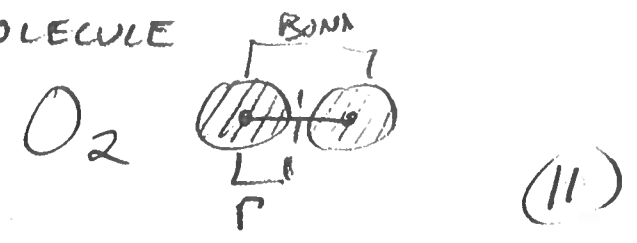
ANYWAY, THE ION IS ALREADY NEG. SO ANOTHER e^{-} WOULD BE REPELLED.

7.3 SIZES OF ATOMS AND IONS

UNITS ANGSTROMS (Å) $1m = 1 \times 10^{10} \text{Å}$
 PICOMETER (pm) $1m = 1 \times 10^{12} \text{pm}$
 (WE USE nm FOR MOLECULES)

ATOMIC SIZE MEASUREMENTS

- ① THE RADIUS OF GAS-PHASE ATOMS. AKA THE NON-BONDING RADIUS OR VAN DER WAALS RADIUS.
- ② THE BONDING RADIUS, WHICH IS $\frac{1}{2}$ THE BOND LENGTH FOR A DIATOMIC MOLECULE



PERIODIC TRENDS FOR ATOMIC RADII

~~RADII~~

DESCR. SEE FIG. 7.7 pg 263 STUDY IT

① RADIUS DECR. $L \rightarrow R$ ACROSS A ROW

B/C Z_{eff} INCR. DUE TO THE FACT THAT EACH ELEMENT GAINS A PROTON BUT THE ADDED e^- DOES NOT INCR. SHIELDING (S) IN $Z_{eff} = Z - S$
THE STRONGER FORCE MAKES THE QUANTUM SHELLS SMALLER.

② RADIUS INCR. TOP TO BOTTOM IN A GROUP
B/C EACH ATOM HAS THE SAME Z_{eff} BUT ADDS AN ENTIRE QUANTUM SHELL.

PERIODIC TRENDS IN IONIC RADII

FIG. 7.8 pg 266 STUDY IT

ISOELECTRONIC SERIES OF IONS ARE IONS WHICH ALL HAVE THE SAME NUMBER OF ELECTRONS (OR THE SAME ELEC. CONFIG.).

CATIONS ARE SMALLER THAN THE PARENT NEUTRAL ATOM.

ANIONS ARE BIGGER.

ION SIZE DECREASES WITH INCR. CHARGE FOR IONS IN AN ISOELECTRONIC SERIES.

ION	N^{3-}	O^{2-}	F^-	Ne	Na^+	Mg^{2+}	Al^{3+}	$10e^-$ [Ne]
RADIUS (Å)	1.40	1.26	1.19	0.58	1.16	0.86	0.68	ALL ION
Z_{eff}	+5	+6	+7	+8	+9	+10	+11	NOT

($2s^2 2p^6$) VALENCE Z_{eff}

NOT TRENDY B/C IT'S NOT AN IONIC BONDING RADIUS.

VALENCE Z_{eff} (12)

RE: ISOELECTRONIC SERIES

ION SIZE DECR. FOR INCR. CHARGE OF THE ION
 (-3 → +3) B/C THE Z_{eff} INCR. AND THE
 INCR. FORCE OF ATTRACTION PULLS THE e^- SHELLS
 CLOSER TO THE NUCLEUS.

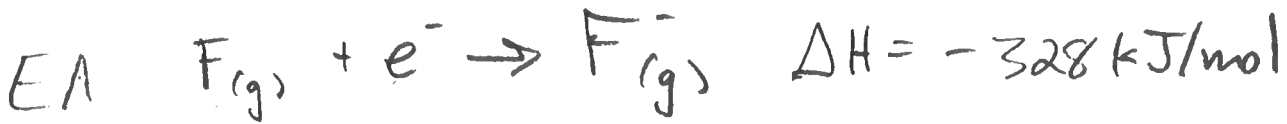
WHEN COMPARING IONS IN THE SAME GROUP THEY INCR.
 IN SIZE AS YOU GO DOWN THE GROUP. THIS IS
 B/C EACH NEW ROW ADDS AN ENTIRE QUANTUM SHELL.

STOPPED HERE GROUP X F 2024-12-13 TO DO

7.5 ELECTRON AFFINITY (EA) "ADVANCED PERIODIC TRENDS" ACTIVITY

EA IS THE NAME FOR THE ENERGY RELEASED

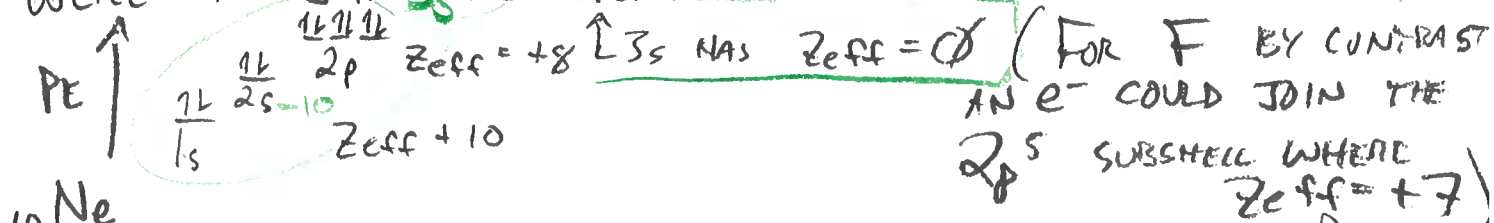
WHEN AN e^- JOINS A NEUTRAL ATOM. +1681 kJ



NOBLE GASES HAVE A POSITIVE (OR ZERO) ELECTRON AFFINITY

B/C THERE IS NO WAY TO RELEASE ENERGY IF AN e^-

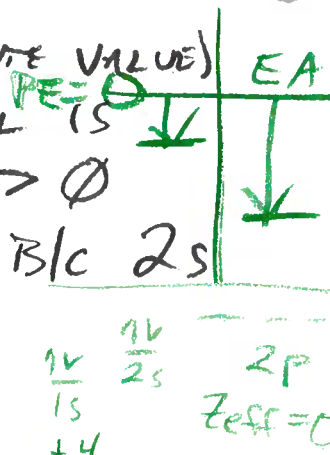
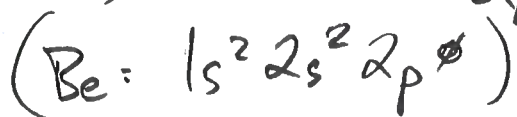
WERE TO JOIN THE ATOM.



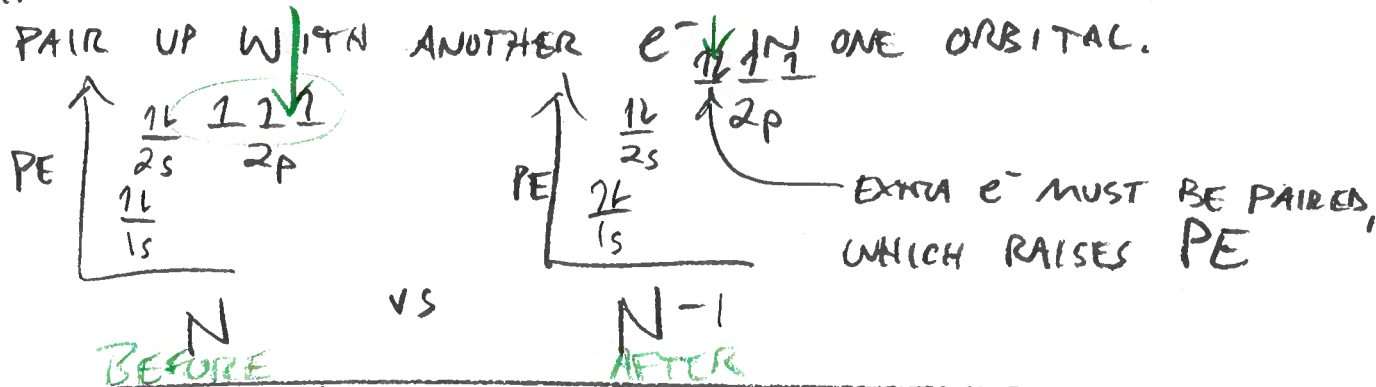
I'LL ADD SOME NOTES ABOUT EA LATER AND ABOUT 7.6-7.8

ENERGY IS RELEASED WHEN AN e^- GOES FROM ZERO PE (OR POSITIVE) OUTSIDE THE ATOM TO NEG. PE WITHIN THE ATOM.

THIS IS WHY EA IS SMALLER (ABSOLUTE VALUE) FOR ATOMS WHERE THE DESTINATION ORBITAL IS HIGHER IN PE. FOR EX., Be HAS EA > 0 B/C AN e^- WOULD HAVE TO JOIN 2p B/C 2s IS FULL AND 2p IS TOO HIGH IN PE.



IN A SIMILAR WAY EA FOR GROUP 15 (N, P...) IS SMALLER (ABS. VALUE) THAN IT OTHERWISE MIGHT HAVE BEEN B/C TO JOIN THE ATOM AN e^- MUST PAIR UP WITH ANOTHER e^- IN ONE ORBITAL.

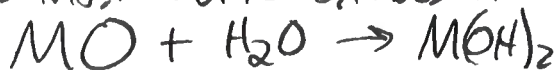


7.6 - 7.8 DESCRIPTIVE CHEMISTRY

BE FAMILIAR WITH TYPICAL RXNS FOR GROUPS IN THE PER. TABL THIS WILL BE USEFUL B/C AS RXNS ARE USED AS EXAMPLES YOU'LL HAVE A LITTLE BACKGROUND TO MAKE IT FEEL MORE FAMILIAR.

SOME KEY THINGS?
METALS

- LOW IONIZATION ENERGIES
- FORM CATIONS IN RXNS w/ NON-METALS
- SHINY, GOOD CONDUCTORS, DUCTILE & MALLEABLE
- MOST METAL OXIDES ARE BASIC



$MO + 2HCl \rightarrow MCl_2 + H_2$ NON-METALS

- HIGH IONIZATION ENERGIES
- FORM ANIONS IN RXNS w/ METALS
- NOT SHINY, SOME ARE COLORED
S YELLOW C BLACK Cl₂ YEL. GRN
- NOT CONDUCTIVE EXCEPT GRAPHITE (4)
- NON-METAL OXIDES ARE ACIDIC

EXAMPLE OXIDE REACTIONS

METAL OXIDE + H₂O → BASE



NON-METAL OXIDE + H₂O → ACID

