

The Periodic Table

Chapter 8



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Ground State Electron Configurations of the Elements

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4f

5f

2

Classification of the Elements

1 1A H	2 2A He											13 3A B	14 4A C	15 5A N	16 6A O	17 7A F	18 8A Ne
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112	113	114	115	116	(117)	118

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

3

Electron Configurations of Cations and Anions Of Representative Elements

Na [Ne]3s¹ Na⁺ [Ne]
 Ca [Ar]4s² Ca²⁺ [Ar]
 Al [Ne]3s²3p¹ Al³⁺ [Ne]

Atoms lose electrons so that cation has a noble-gas outer electron configuration.

Atoms gain electrons so that anion has a noble-gas outer electron configuration.

H 1s¹ H⁻ 1s² or [He]
 F 1s²2s²2p⁵ F⁻ 1s²2s²2p⁶ or [Ne]
 O 1s²2s²2p⁴ O²⁻ 1s²2s²2p⁶ or [Ne]
 N 1s²2s²2p³ N³⁻ 1s²2s²2p⁶ or [Ne]

Electron Configurations of Cations of Transition Metals

When a cation is formed from an atom of a transition metal, electrons are always removed first from the ns orbital and then from the $(n - 1)d$ orbitals.

Fe: $[\text{Ar}]4s^23d^6$

Mn: $[\text{Ar}]4s^23d^5$

Fe^{2+} : $[\text{Ar}]4s^03d^6$ or $[\text{Ar}]3d^6$

Mn^{2+} : $[\text{Ar}]4s^03d^5$ or $[\text{Ar}]3d^5$

Fe^{3+} : $[\text{Ar}]4s^03d^5$ or $[\text{Ar}]3d^5$

7

Effective nuclear charge (Z_{eff}) is the “positive charge” felt by an electron.

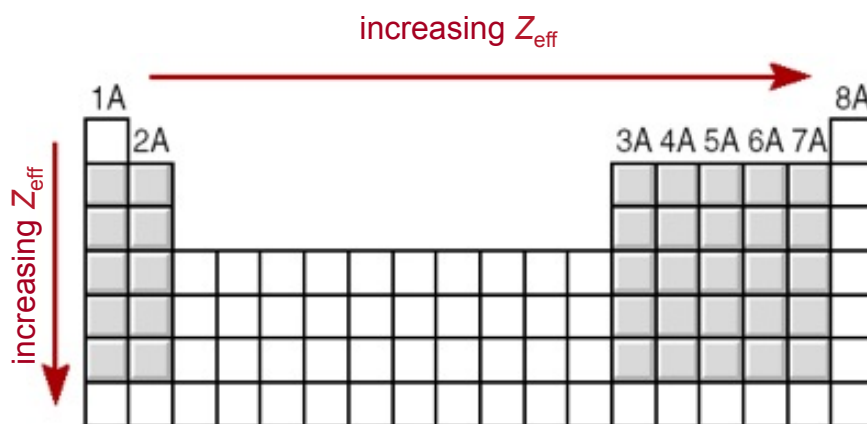
$$Z_{\text{eff}} = Z - \sigma \quad 0 < \sigma < Z \quad (\sigma = \text{shielding constant})$$

$$Z_{\text{eff}} \approx Z - \text{number of inner or core electrons}$$

	<u>Z</u>	<u>Core</u>	<u>Z_{eff}</u>	<u>Radius (pm)</u>
Na	11	10	1	186
Mg	12	10	2	160
Al	13	10	3	143
Si	14	10	4	132

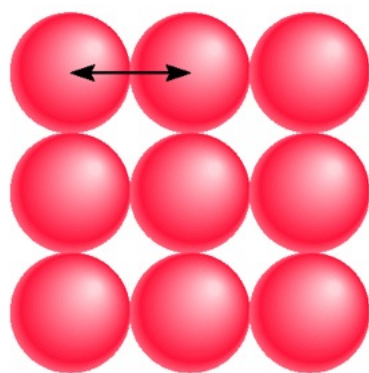
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Effective Nuclear Charge (Z_{eff})

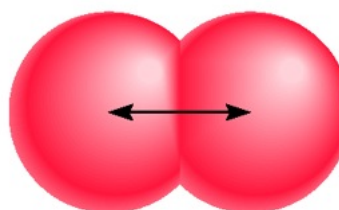


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Atomic Radii

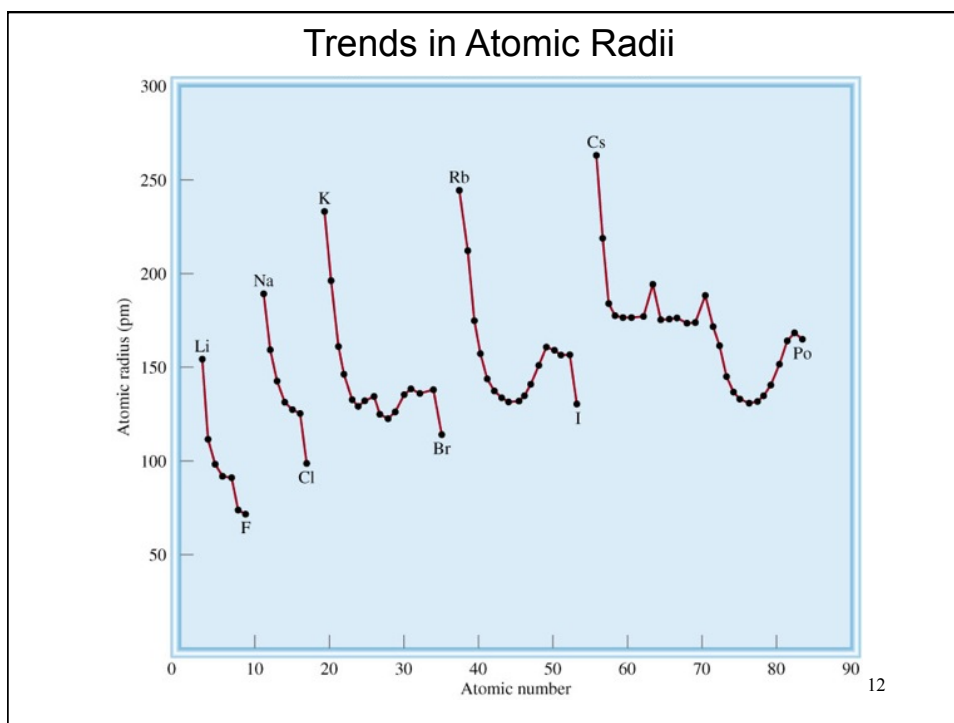
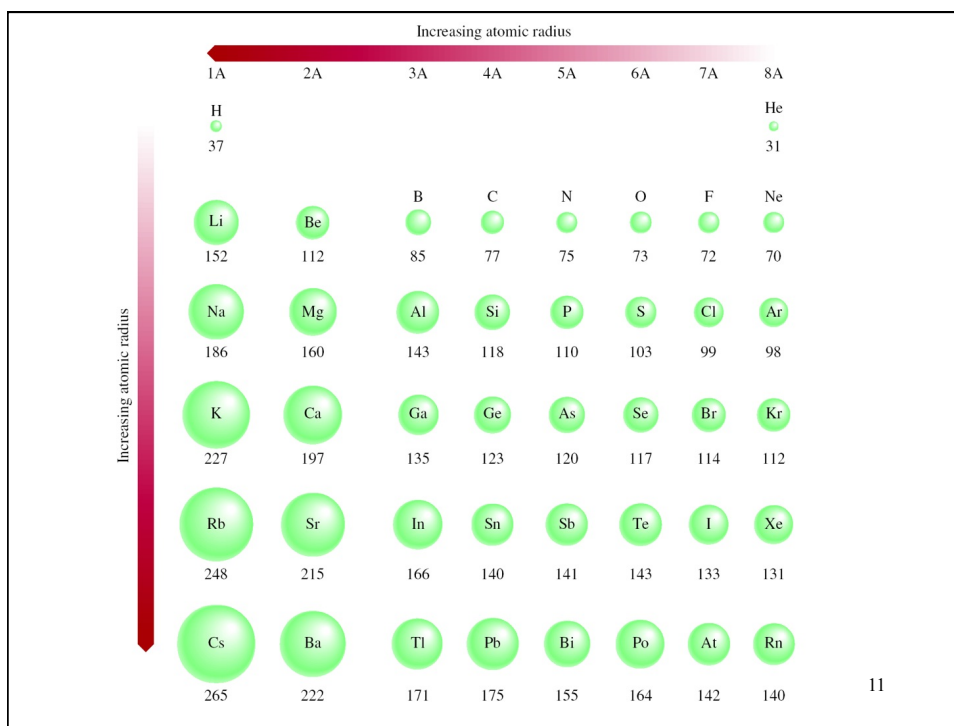


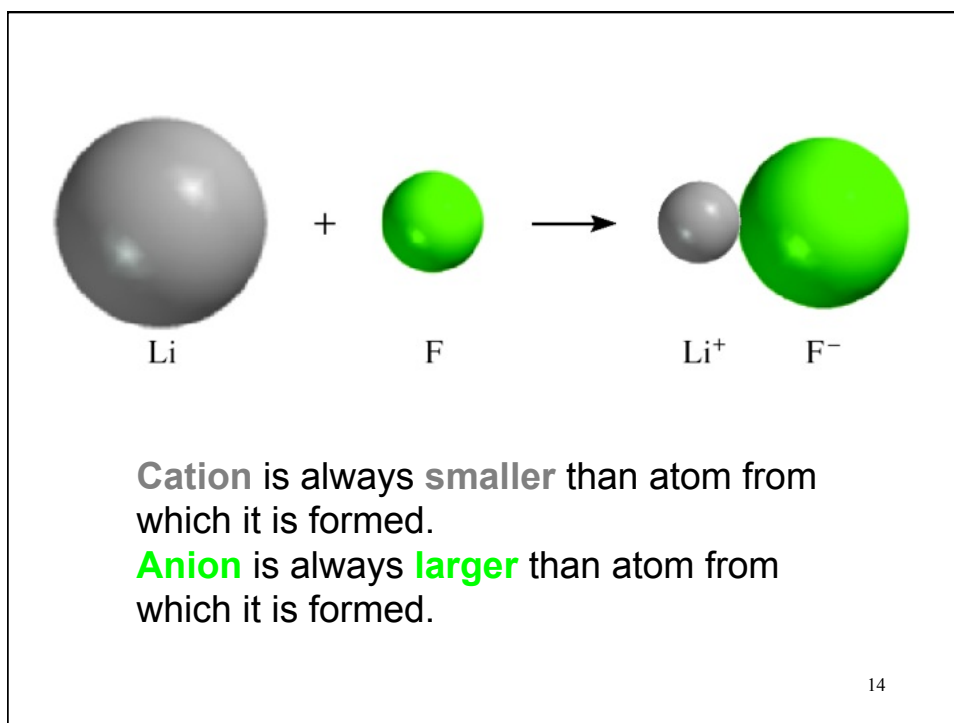
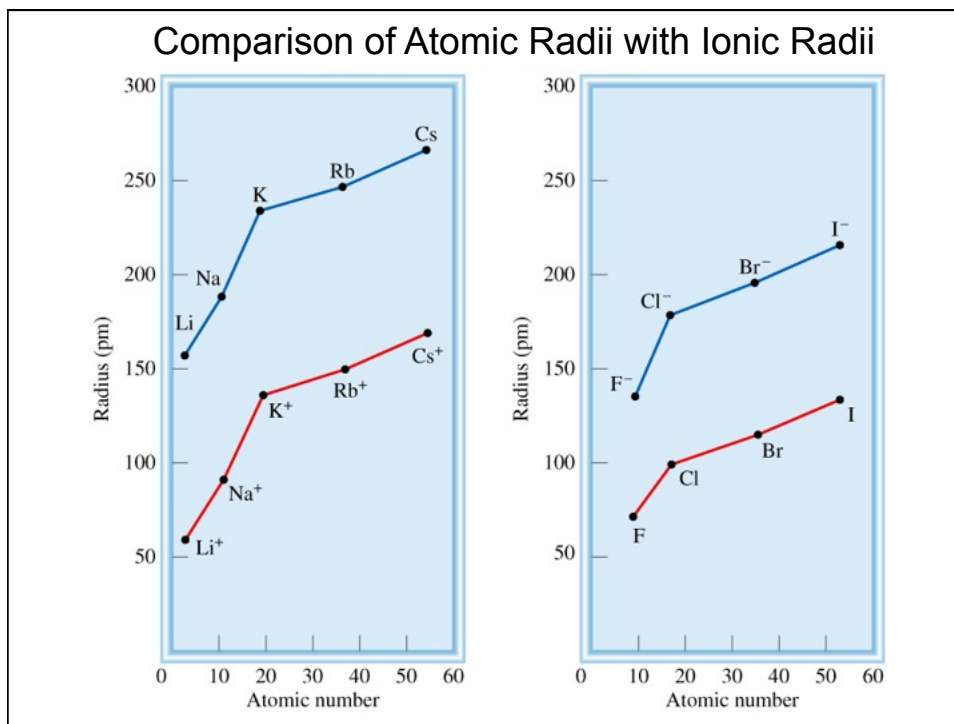
metallic radius

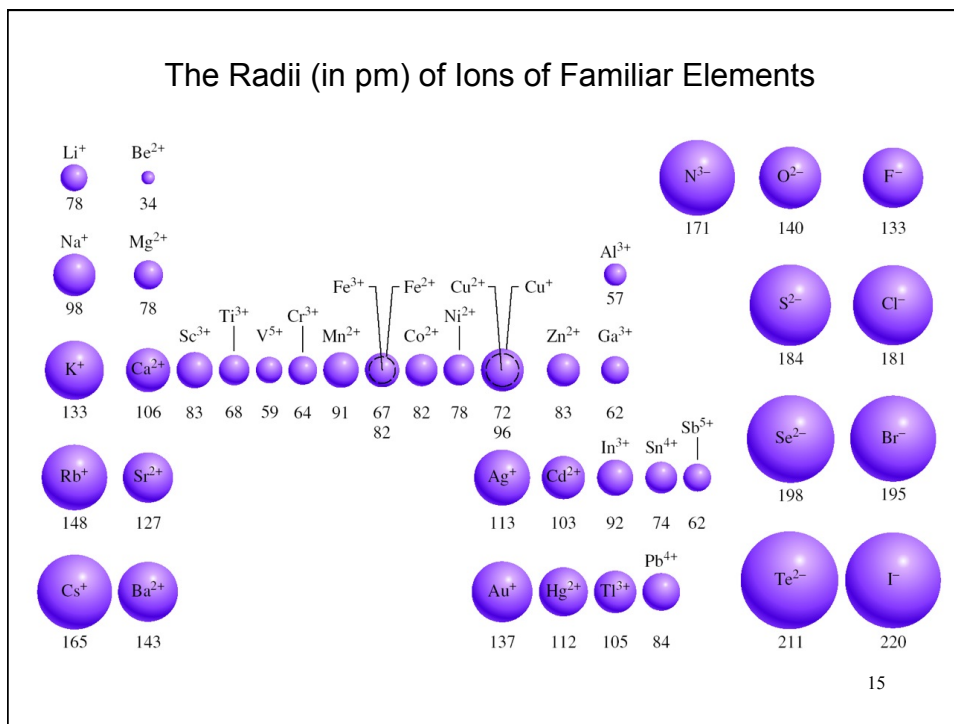


covalent radius

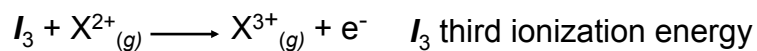
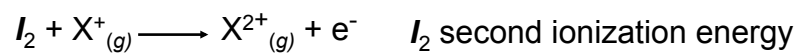
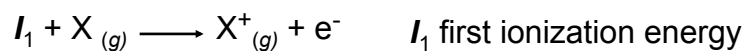
10







Ionization energy is the minimum energy (kJ/mol) required to remove an electron from a gaseous atom in its ground state.



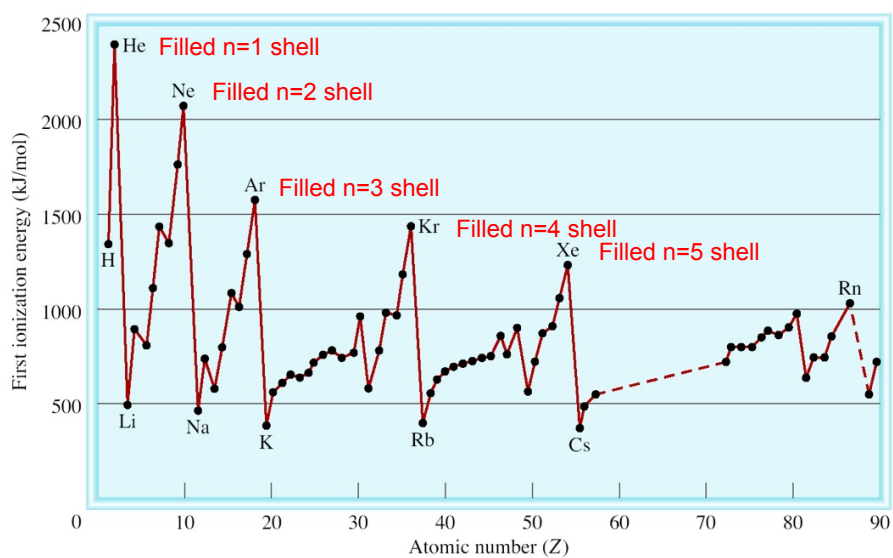
$$I_1 < I_2 < I_3$$

TABLE 8.2 The Ionization Energies (kJ/mol) of the First 20 Elements

Z	Element	First	Second	Third	Fourth	Fifth	Sixth
1	H	1,312					
2	He	2,373	5,251				
3	Li	520	7,300	11,815			
4	Be	899	1,757	14,850	21,005		
5	B	801	2,430	3,660	25,000	32,820	
6	C	1,086	2,350	4,620	6,220	38,000	47,261
7	N	1,400	2,860	4,580	7,500	9,400	53,000
8	O	1,314	3,390	5,300	7,470	11,000	13,000
9	F	1,680	3,370	6,050	8,400	11,000	15,200
10	Ne	2,080	3,950	6,120	9,370	12,200	15,000
11	Na	495.9	4,560	6,900	9,540	13,400	16,600
12	Mg	738.1	1,450	7,730	10,500	13,600	18,000
13	Al	577.9	1,820	2,750	11,600	14,800	18,400
14	Si	786.3	1,580	3,230	4,360	16,000	20,000
15	P	1,012	1,904	2,910	4,960	6,240	21,000
16	S	999.5	2,250	3,360	4,660	6,990	8,500
17	Cl	1,251	2,297	3,820	5,160	6,540	9,300
18	Ar	1,521	2,666	3,900	5,770	7,240	8,800
19	K	418.7	3,052	4,410	5,900	8,000	9,600
20	Ca	589.5	1,145	4,900	6,500	8,100	11,000

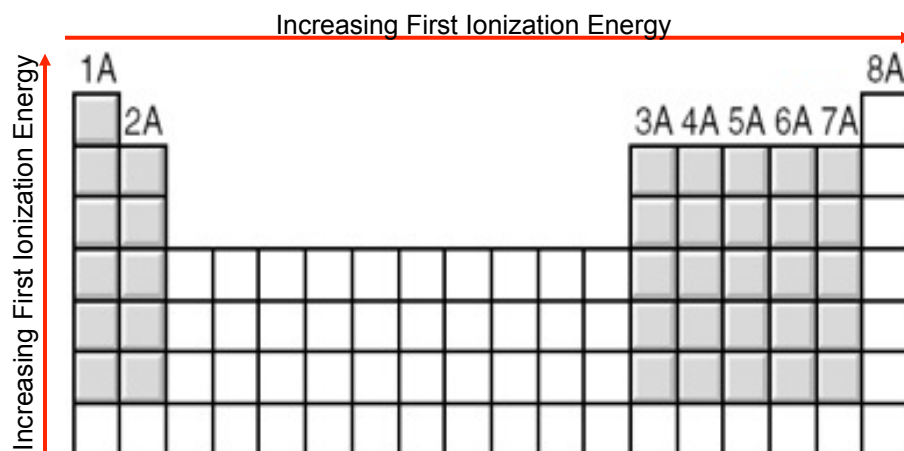
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Variation of the First Ionization Energy with Atomic Number



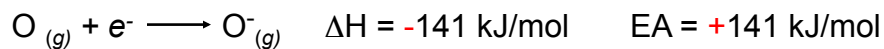
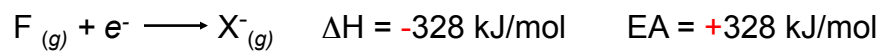
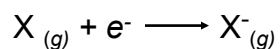
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General Trends in First Ionization Energies



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Electron affinity is the negative of the energy change that occurs when an electron is accepted by an atom in the gaseous state to form an anion.



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TABLE 8.3 Electron Affinities (kJ/mol) of Some Representative Elements and the Noble Gases*

1A	2A	3A	4A	5A	6A	7A	8A
H							He
73							< 0
Li	Be	B	C	N	O	F	Ne
60	≤ 0	27	122	0	141	328	< 0
Na	Mg	Al	Si	P	S	Cl	Ar
53	≤ 0	44	134	72	200	349	< 0
K	Ca	Ga	Ge	As	Se	Br	Kr
48	2.4	29	118	77	195	325	< 0
Rb	Sr	In	Sn	Sb	Te	I	Xe
47	4.7	29	121	101	190	295	< 0
Cs	Ba	Tl	Pb	Bi	Po	At	Rn
45	14	30	110	110	?	?	< 0

*The electron affinities of the noble gases, Be, and Mg have not been determined experimentally, but are believed to be close to zero or negative.

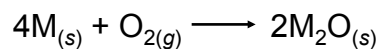
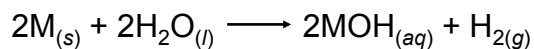
21

Diagonal Relationships on the Periodic Table

1A	2A	3A	4A
Li	Be	B	C
Na	Mg	Al	Si

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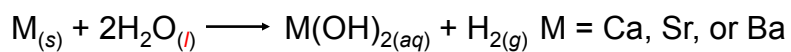
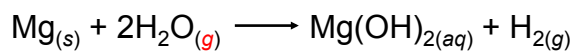
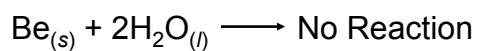
Group 1A Elements (ns^1 , $n \geq 2$)



A periodic table diagram showing the first two columns (1A and 2A) and the last six columns (3A to 8A). The elements in Group 1A (Li, Na, K, Rb, Cs) are highlighted in a light gray box. To the left of the table, a red arrow points downwards with the text "Increasing reactivity" next to it.

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Group 2A Elements (ns^2 , $n \geq 2$)



A periodic table diagram showing the first two columns (1A and 2A) and the last six columns (3A to 8A). The elements in Group 2A (Be, Mg, Ca, Sr, Ba) are highlighted in a light gray box. To the left of the table, a red arrow points downwards with the text "Increasing reactivity" next to it.

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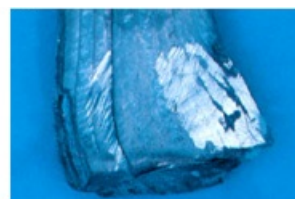
Group 2A Elements (ns^2 , $n \geq 2$)



Beryllium (Be)



Magnesium (Mg)



Calcium (Ca)



Strontium (Sr)



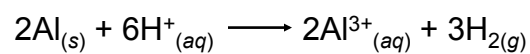
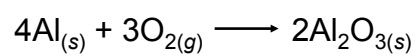
Barium (Ba)



Radium (Ra)

25

Group 3A Elements (ns^2np^1 , $n \geq 2$)

[illegible]

26

Group 4A Elements (ns^2np^2 , $n \geq 2$)



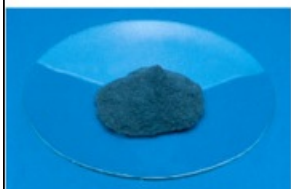
Carbon (graphite)



Carbon (diamond)



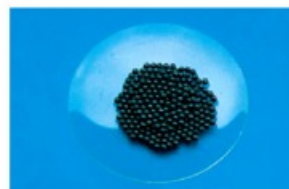
Silicon (Si)



Germanium (Ge)



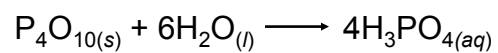
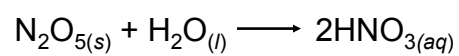
Tin (Sn)



Lead (Pb)

29

Group 5A Elements (ns^2np^3 , $n \geq 2$)



1A 2A 3A 4A 5A 6A 7A 8A

N

P

As

Sb

Bi

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Group 5A Elements (ns^2np^3 , $n \geq 2$)

Nitrogen (N₂)

White and red phosphorus (P)



Arsenic (As)



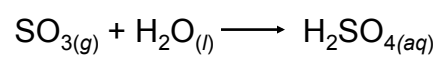
Antimony (Sb)



Bismuth (Bi)

31

Group 6A Elements (ns^2np^4 , $n \geq 2$)



The diagram shows a portion of the periodic table with columns labeled 1A, 2A, 3A, 4A, 5A, 6A, 7A, and 8A. The elements O, S, Se, Te, and Po are located in column 6A and are shaded gray.

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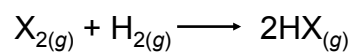
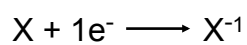
Group 6A Elements (ns^2np^4 , $n \geq 2$)

Sulfur (S_8)Selenium (Se_8)

Tellurium (Te)

33

Group 7A Elements (ns^2np^5 , $n \geq 2$)



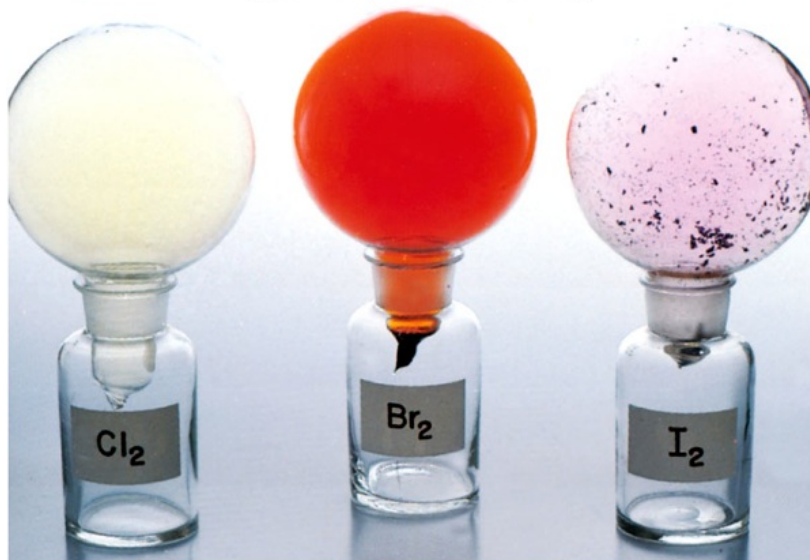
The diagram shows a simplified periodic table with the following structure:

- Groups:** 1A, 2A, 3A, 4A, 5A, 6A, 7A, 8A.
- Elements in Group 7A (highlighted):** F, Cl, Br, I, At.
- Reactivity Trend:** An arrow on the right points downwards, labeled "Increasing reactivity".

Increasing reactivity

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Group 7A Elements (ns^2np^5 , $n \geq 2$)



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Group 8A Elements (ns^2np^6 , $n \geq 2$)

Completely filled ns and np subshells.
Highest ionization energy of all elements.
No tendency to accept extra electrons.

1A 2A 3A 4A 5A 6A 7A 8A

H He

Li Be B C N O F Ne

Na Mg Al Si P S Cl Ar

K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr

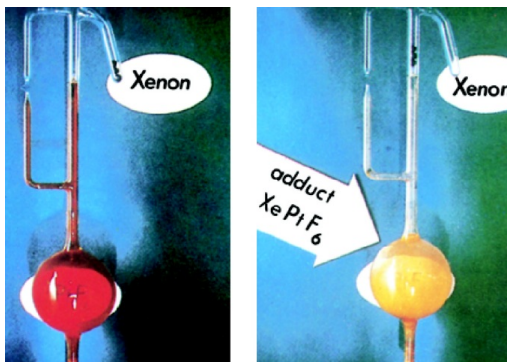
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe

Ba La Ce Pr Nd Pm Sm Eu Gd Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn

Fr Ra Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr

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Compounds of the Noble Gases



A number of xenon compounds XeF_4 , XeO_3 , XeO_4 , XeOF_4 exist.
A few krypton compounds (KrF_2 , for example) have been prepared.

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Properties of Oxides Across a Period

The diagram shows a simplified periodic table with the following elements and their positions:

- Group 1A:** One empty box.
- Group 2A:** Two boxes, with Na and Mg in the second row.
- Group 3A:** One empty box.
- Group 4A:** One empty box.
- Group 5A:** One empty box.
- Group 6A:** One empty box.
- Group 7A:** One empty box.
- Group 8A:** One empty box.
- Period 3:** Al, Si, P, S, Cl.

The word **basic** is circled in red and placed below the Na and Mg boxes. The word **acidic** is circled in red and placed below the Al, Si, P, S, and Cl boxes.

Element	Oxide	Formula	Color	Structure	Acidity	Basicity	Amphoteric	Redox
Na	Sodium oxide	Na_2O	White	Crystalline	Basic	Basic		Reducing agent
Mg	Magnesium oxide	MgO	White	Crystalline	Basic	Basic		Reducing agent
Al	Aluminum oxide	Al_2O_3	White	Crystalline	Amphoteric	Amphoteric	Amphoteric	Reducing agent
Si	Silicon dioxide	SiO_2	Colorless	Crystalline	Acidic			Oxidizing agent
P	Phosphorus pentoxide	P_2O_5	White	Crystalline	Acidic			Oxidizing agent
S	Sulfur dioxide	SO_2	Colorless	Gaseous	Acidic			Oxidizing agent
Cl	Chlorine dioxide	ClO_2	Yellow-green	Gaseous	Acidic			Oxidizing agent
Br	Bromine dioxide	BrO_2	Red-brown	Gaseous	Acidic			Oxidizing agent
I	Iodine dioxide	IO_2	Dark brown	Gaseous	Acidic			Oxidizing agent

	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀	SO ₃	Cl ₂ O ₇
Type of compound	←———— Ionic —————→			←———— Molecular —————→			
Structure	←— Extensive three-dimensional —→			←———— Discrete —————→ molecular units			
Melting point (°C)	1275	2800	2045	1610	580	16.8	−91.5
Boiling point (°C)	?	3600	2980	2230	?	44.8	82
Acid-base nature	Basic	Basic	Amphoteric	←———— Acidic —————→			

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