

Chapter 6: The Periodic Table

6.1 Organizing the Elements

Searching For an Organizing Principle



Chemists used the properties of elements to sort them into groups.

Mendeleev's Periodic Table



- Mendeleev arranged the elements in his periodic table in order of increasing atomic mass.
- **The periodic table can be used to predict the properties of undiscovered elements.**

Mendeleev

- Predicted properties of undiscovered elements.

Predicted elements	Element and year discovered	Properties	Predicted properties	Observed properties
Ekasilicon	germanium 1886	melting point	high	900°C
		density of metal	5.5 g/ml.	5.47 g/ml.
		color of metal	dark gray	grayish white
		oxide formula	EeO_2	GeO_2
		density of oxide	4.7 g/mL	4.70 g/mL
chloride formula	EeCl_4	GeCl_4		

Moseley

- **Henry Moseley** (1913, British)
 - Organized elements by increasing **atomic number**.
 - Resolved discrepancies in Mendeleev's arrangement.



The Periodic Law



- In the modern periodic table, elements are arranged in order of increasing atomic number.

1																	2														
H																	He														
3	4											5	6	7	8	9	10														
Li	Be											B	C	N	O	F	Ne														
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	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112			114			
Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub			Uuq			

The Periodic Law

- The **periodic law**: When elements are arranged in order of increasing atomic number, there is a periodic repetition of their physical and chemical properties.
 - The properties of the elements within a period change as you move across a period from left to right.
 - The pattern of properties within a period repeats as you move from one period to the next.

6.1 Metals, Nonmetals, and Metalloids

- Three classes of elements are metals, nonmetals, and metalloids.
- **Across a period, the properties of elements become less metallic and more nonmetallic.**

Metals, Nonmetals, and Metalloids

- **Metals**
 - **Metals** are good conductors of heat and electric current.
 - 80% of elements are metals.
 - Metals have a high luster, are ductile, and are malleable.

Nonmetals

- In general, **nonmetals** are poor conductors of heat and electric current.
 - Most nonmetals are gases at room temperature.
 - A few nonmetals are solids, such as sulfur and phosphorus.
 - One nonmetal, bromine, is a dark-red liquid.

6-1 Metals, Nonmetals, and Metalloids

- **Metalloids**
 - **A metalloid** generally has properties that are similar to those of metals and nonmetals.
 - The behavior of a metalloid can be controlled by changing conditions.

6.1 Section Quiz

- 1. The modern periodic table has elements arranged in order of
 - a) colors.
 - b) melting and boiling points.
 - c) increasing atomic mass.
 - d) increasing atomic number.

6.1 Section Quiz

- 2. Mendeleev arranged the elements in his periodic table in order of increasing
 - a) atomic number.
 - b) number of protons.
 - c) number of electrons.
 - d) atomic mass

6.1 Section Quiz

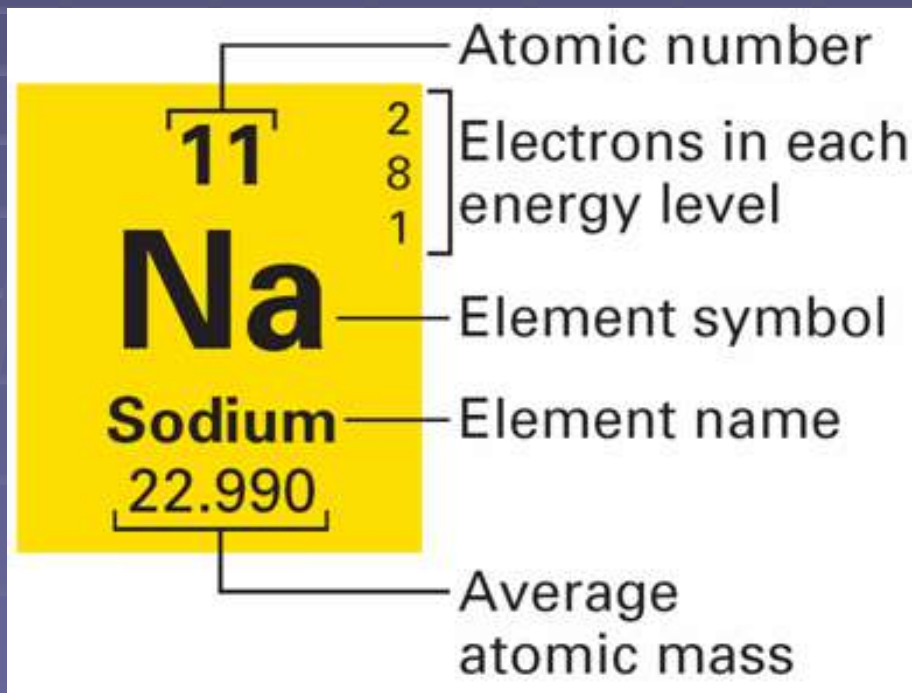
- 3. Which one of the following is NOT a general property of metals?
 - a) ductility
 - b) malleability
 - c) having a high luster
 - d) poor conductor of heat and electricity

6.2 Classifying the Elements

Squares in the Periodic Table



The periodic table displays the symbols and names of the elements, along with information about the structure of their atoms.



Squares in the Periodic Table

- The background colors in the squares are used to distinguish groups of elements.
 - The Group 1A elements are called **alkali metals**.
 - The Group 2A elements are called **alkaline earth metals**.
 - The nonmetals of Group 7A are called **halogens**.

- The Noble Gases - Nonreactive
 - The noble gases are the elements in Group 8A of the periodic table. The electron configurations for the first four noble gases in Group 8A are listed below.

Helium (He)	$1s^2$
Neon (Ne)	$1s^2 2s^2 2p^6$
Argon (Ar)	$1s^2 2s^2 2p^6 3s^2 3p^6$
Krypton (Kr)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$

The Representative Elements

- Elements in groups 1A through 7A are often referred to as **representative elements** because they display a wide range of physical and chemical properties.
- The s and p sublevels of the highest occupied energy level are not filled.
- The group number equals the number of electrons in the highest occupied energy level.

Transition Elements

- Transition Elements
 - There are two types of transition elements—transition metals and inner transition metals. They are classified based on their electron configurations.

Transition Elements

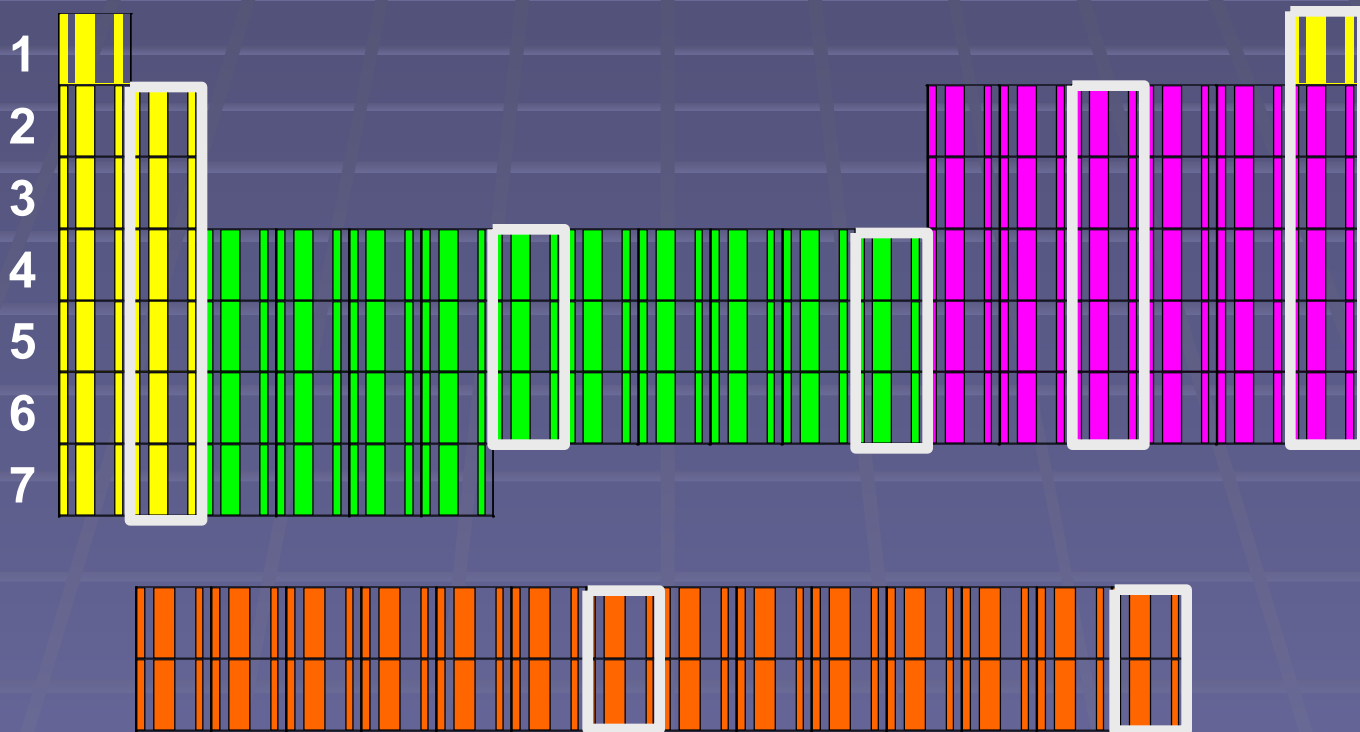
- In atoms of a **transition metal**, the highest occupied s sublevel and a nearby d sublevel contain electrons.
- In atoms of an **inner transition metal**, the highest occupied s sublevel and a nearby f sublevel generally contain electrons.

Using Energy Sublevels to Write Electron Configurations

Nitrogen is an element that organisms need to remain healthy. However, most organisms cannot obtain nitrogen directly from air. A few organisms can convert elemental nitrogen into a form that can be absorbed by plant and animal cells. These include bacteria that live in lumps called *nodules* on the roots of legumes. The photograph shows the nodules on a bean plant. Use Figure 6.12 to write the electron configuration for nitrogen (N), which has atomic number 7.

Stability

- Full energy level
 - Full sublevel (s, p, d, f)
 - Half-full sublevel



Write configurations for:

- 1) sulfur
- 2) gallium
- 3) hafnium
- 4) radium
- 5) fluorine
- 6) silicon
- 7) cesium
- 8) lead
- 9) iodine
- 10) bromine
- 11) tin
- 12) polonium

Which element is:

- 1) $[\text{Kr}]5s^24d^{10}5p^1$
- 2) $[\text{Xe}]6s^2$
- 3) $[\text{Ne}]3s^23p^6$
- 4) $[\text{Kr}]5s^1$
- 5) $[\text{Ar}]4s^23d^2$

Elements Handbook

- **Noble Gases**

- Look at the atomic properties of noble gases on page R36. Use what you know about the structure of atoms to explain why the color produced in a gas discharge tube is different for each gas.
- Read p.168: True Colors

6.2 Section Quiz

- 1. Which of the following information about elements is usually NOT included in a periodic table?
 - a)color
 - b)symbol
 - c)atomic number
 - d)atomic mass

6.2 Section Quiz

- 2. An alkali metal would have in the highest occupied energy level
 - a) an s^2 electron.
 - b) an s^1 electron.
 - c) p^2 electrons.
 - d) p^6 electrons.

6.2 Section Quiz

- 3. Which one of the following is incorrectly labeled?
 - a) Ne, noble gas
 - b) Cu, transition metal
 - c) Ga, transition metal
 - d) Cl, halogen

6.2 Section Quiz

- 4. Transition metals are characterized as being different than representative elements because they have electrons in which orbitals?

a) p

b) d

c) s

d) f

6.3 Periodic Trends

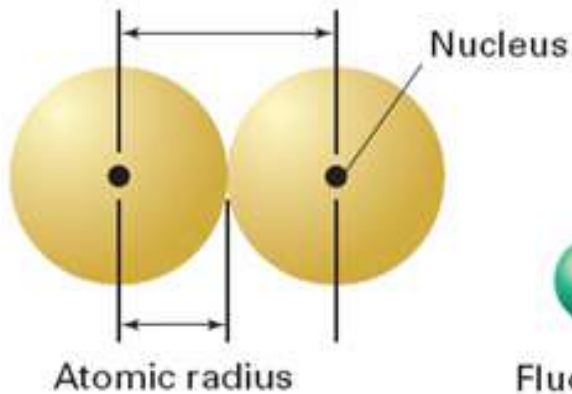
Reactivity

- Most reactive metals are at the bottom of the groups (Fr)
- Most reactive nonmetals are at the top of the groups (F)

Trends in Atomic Size

- The atomic radius is one half of the distance between the nuclei of two atoms of the same element when the atoms are joined.

Distance between nuclei



Hydrogen (H_2)
30 pm



Oxygen (O_2)
66 pm



Nitrogen (N_2)
70 pm



Fluorine (F_2)
62 pm



Chlorine (Cl_2)
102 pm



Bromine (Br_2)
120 pm



Iodine (I_2)
140 pm

Trends in Atomic Size



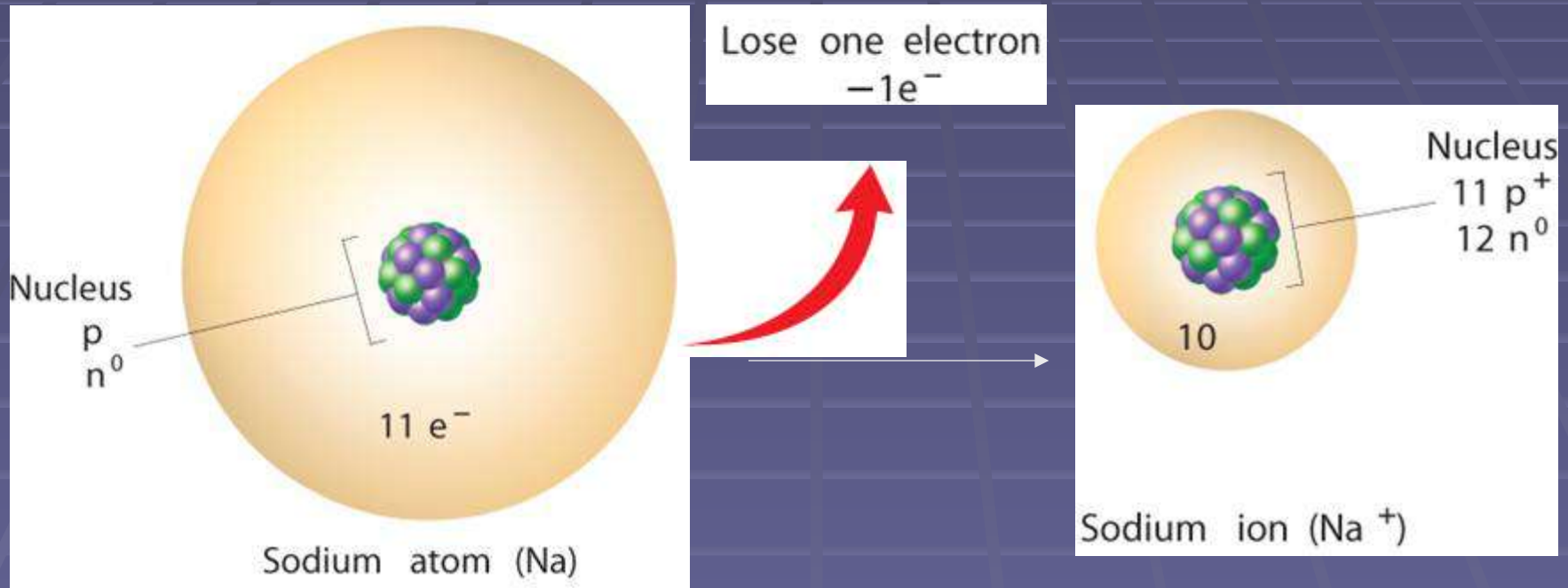
- In general, atomic size increases from top to bottom within a group and decreases from left to right across a period.
 - Increased nuclear charge
 - Shielding effect

Atomic Radii

- Which has the largest atomic radius: carbon, fluorine, beryllium or lithium?
- Which has the largest atomic radius: magnesium, silicon, sulfur or sodium? The smallest?



■ Positive and negative ions form when electrons are transferred between atoms.



Ions

- Some compounds are composed of particles called ions.
 - An **ion** is an atom or group of atoms that has a positive or negative charge.
 - A **cation** is an ion with a positive charge.
 - An **anion** is an ion with a negative charge.

Trends in Ionization Energy

- The energy required to remove an electron from an atom is called **ionization energy**.
 - The energy required to remove the first electron from an atom is called the first ionization energy.

Trends in Ionization Energy

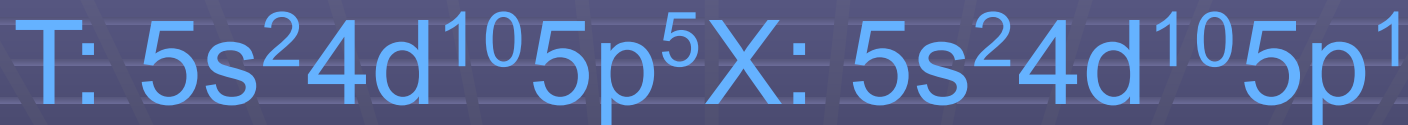
- Group and Periodic Trends in Ionization Energy
 - First ionization energy tends to decrease from top to bottom within a group and increase from left to right across a period.

Ionization Energy

- Choose the element with the higher first ionization energy:
 - Ca and Ba
 - Ca and Br
 - Ca and K
 - Ca and Mg

Ionization Energy

- Consider two main-group elements, A and B. Element A has a first ionization energy of 419 kJ/mol. Element B has a first ionization energy of 1000 kJ/mol. Decide if each element is more likely to be in the *s* block or *p* block. Which element is more likely to form a positive ion?



- Identify the block location of each hypothetical element
- Which elements are in the same period? In the same group?
- Which element would have the highest first ionization energy? The lowest?
- Which element would have the highest second ionization energy?
- Which element is most likely to form a 1+ ion?

Ionization Energy

- A period 3 representative element is part of the rough material on the side of a match box. Use the information in the table to identify the element.

Number	1 st	2 nd	3 rd	4 th	5 th	6 th
Ionization Energy	1010	1905	2910	4957	6265	21,238

Electron Affinity

- Electron affinity – energy change that occurs when an electron is acquired by a neutral atom
 - In general it becomes more negative across the p block (halogen's have large electron affinities)

Trends in Ionic Size

- Trends in Ionic Size
 - During reactions between metals and nonmetals, metal atoms tend to lose electrons, and nonmetal atoms tend to gain electrons. The transfer has a predictable effect on the size of the ions that form.

Trends in Ionic Size



- **Cations are always smaller than the atoms from which they form. Anions are always larger than the atoms from which they form.**

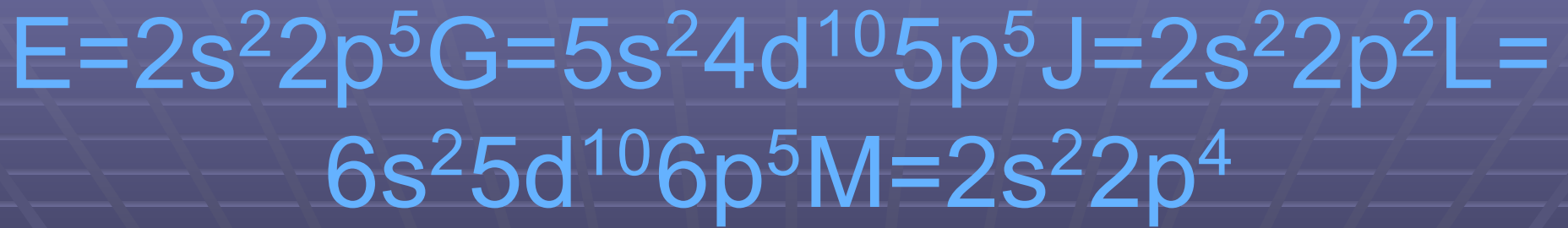
Trends in Electronegativity

- **Electronegativity** is the ability of an atom of an element to attract electrons when the atom is in a compound.
- In general, electronegativity values decrease from top to bottom within a group. For representative elements, the values tend to increase from left to right across a period.



Electronegativity

- Of gallium, bromine and calcium, which has the highest electronegativity?



- Identify the block location for each element. Which elements are in the same period and which are in the same group?
- Which would have the highest electron affinity? Which would form a 1- ion? Which would have the highest electronegativity?
- Compare the ionic radius of the typical ion formed by element G with the radius of the atom from which the ion was formed.
- Which contain seven valence electrons?

Summary of Trends



- **The trends that exist among these properties can be explained by variations in atomic structure.**

Writing Activity

- **Explaining Trends in Atomic Size**
 - Explain why the size of an atom tends to increase from top to bottom within a group. Explain why the size of an atom tends to decrease from left to right across a period.

6.3 Section Quiz

- 1. Which of the following sequences is correct for atomic size?
 - Mg > Al > S
 - Li > Na > K
 - F > N > B
 - F > Cl > Br

6.3 Section Quiz

- 2. Metals tend to
 - a) gain electrons to form cations.
 - b) gain electrons to form anions.
 - c) lose electrons to form anions.
 - d) lose electrons to form cations.

6.3 Section Quiz

- 3. Which of the following is the most electronegative?
 - a) Cl
 - b) Se
 - c) Na
 - d) I