Introductory Chemistry

Nivaldo J. Tro

Chapter 4

Atoms and Elements

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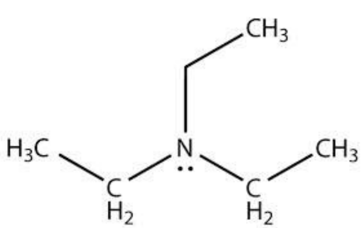
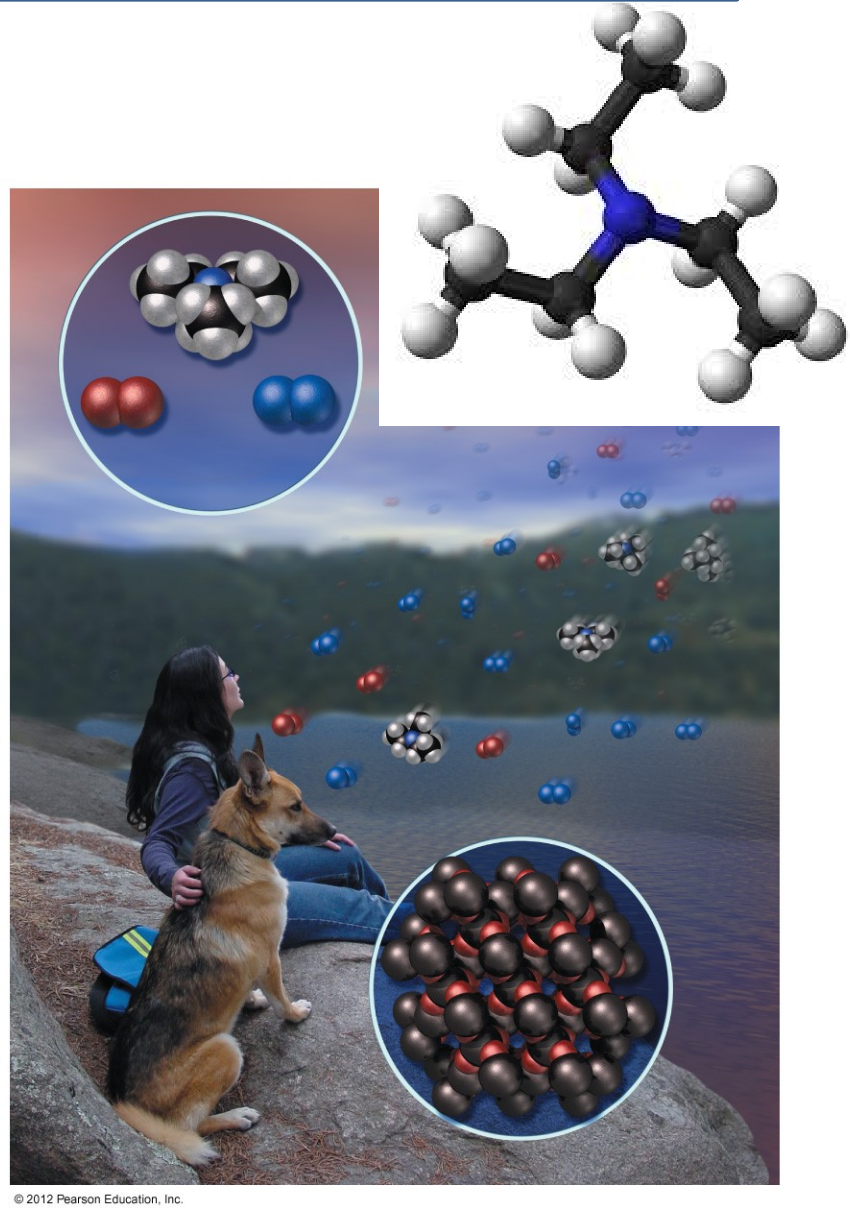
Modified text by Dr. Bytautas (Galveston College, updated January 25, 2025)

4.1 Experiencing Atoms at Tiburon

- Typical seaside rocks are composed of silicates, compounds of silicon and oxygen atoms.
- Seaside air contains nitrogen and oxygen molecules.
- Seaside air may contain substances called amines.
- The amine shown here, triethylamine, is emitted by decaying fish.
- Triethylamine contributes to the fishy smell of the seaside.



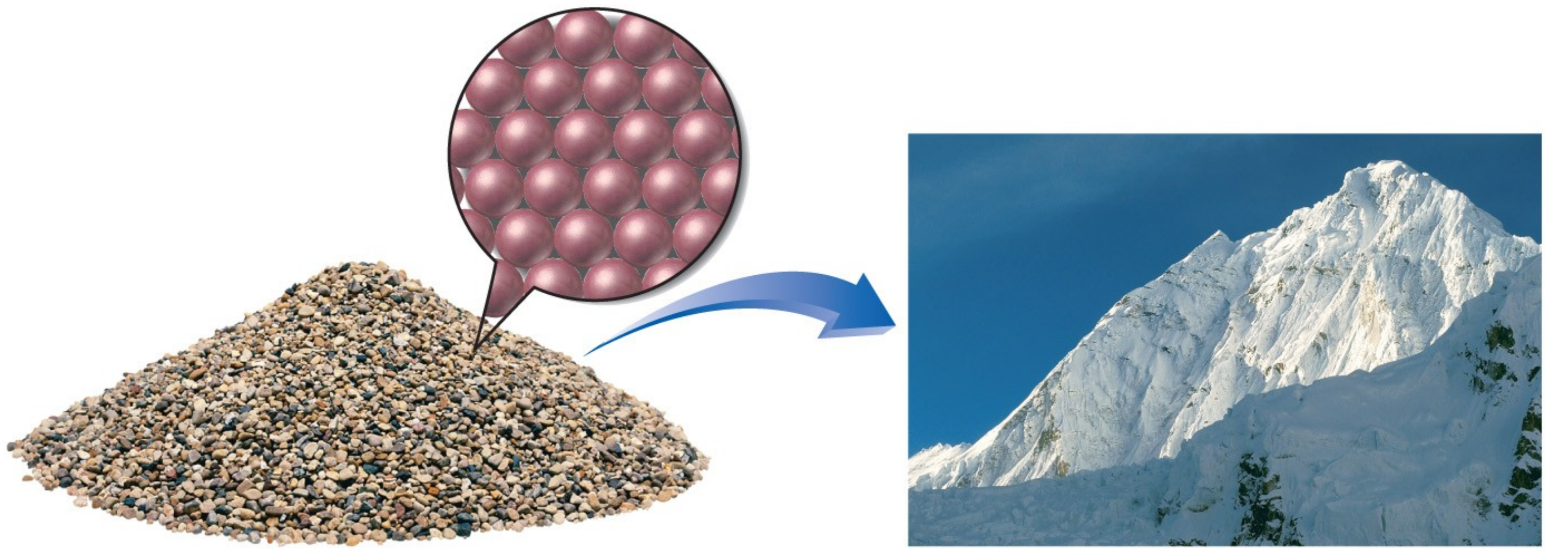


4.1 Experiencing Atoms at Tiburon

- **Atoms** are **incredibly small.**
- **A single pebble from the shoreline contains more atoms than you could count.**
- **The number of atoms in a single pebble far exceeds the number of pebbles on the bottom of San Francisco Bay.**

4.1 **Experiencing Atoms at Tiburon**

- To get an idea of how small atoms are, imagine this: if every atom within a small pebble were the size of the pebble itself, the pebble would be larger than Mount Everest.



Atoms and elements

- **Atoms compose matter; their properties determine matter's properties.**
- **An <u>atom</u> is the <u>smallest identifiable unit</u> of an <u>element.</u>**
- **An *<u>element</u>* is a substance that cannot be broken down into simpler substances.**
- **There are about 91 different elements in nature, and consequently about 91 different kinds of atoms.**
- **Scientists have succeeded in making about 20 synthetic elements (not found in nature).**
- **The exact number of naturally occurring elements is controversial because some elements previously considered only synthetic may actually occur in nature in very small quantities.**

4.2 Indivisible: The Atomic Theory

- Leucippus (fifth century B.C.) and Democritus (460–370 B.C.) recorded ideas of atoms.
- **Democritus** suggested that if you divide matter into smaller and smaller pieces, you end up with tiny, **indestructible particles.**
- Democritus called them ***atomos,*** **or "atoms," meaning "indivisible."**
- Democritus is the first person on record to have postulated that matter was composed of atoms.
- A picture of Democritus with Diogenes, as imagined by a medieval artist.

4.2 Indivisible: The Atomic Theory

In 1808—over 2000 years later—John Dalton formalized a theory of atoms that gained broad acceptance.

Dalton's atomic theory has three parts:

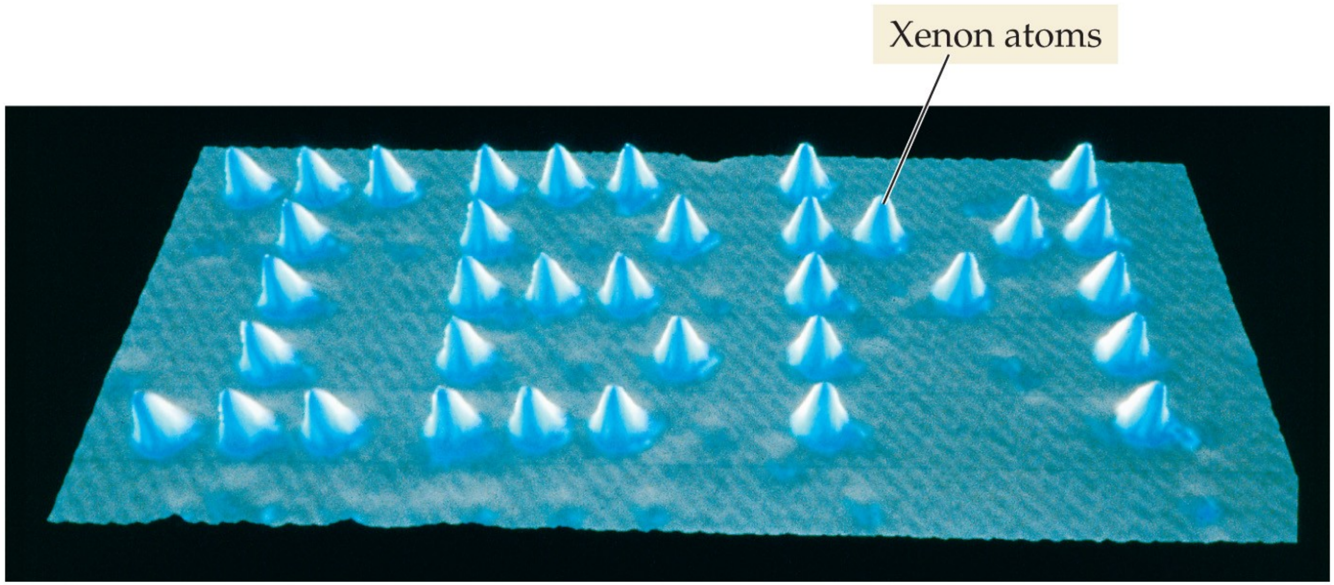
1. **Each element is composed of tiny indestructible particles called atoms.**
2. **All atoms of a given element have the same mass and other properties that distinguish them from the atoms of other elements.**
3. **Atoms combine in simple, whole-number ratios to form compounds.**

Watch a presentation by Professor Davis (on you-tube):
"Dalton's atomic theory"

https://www.youtube.com/watch?v=OUoV--CuLDA

4.2 Indivisible: The Atomic Theory

- Modern evidence for the atomic theory:
- Scientists at IBM used a special microscope, called a scanning tunneling microscope (STM), to move xenon atoms to form the letters I, B, and M.
- The cone shape of these atoms is due to the peculiarities of the instrumentation. Atoms are, in general, spherical in shape.



Recommended videos:

“Cathode Ray Tube”
https://www.youtube.com/watch?v=O9Goyscbazk

“Rutherford Gold Foil Experiment - Backstage Science”
https://www.youtube.com/watch?v=XBqHkraf8iE

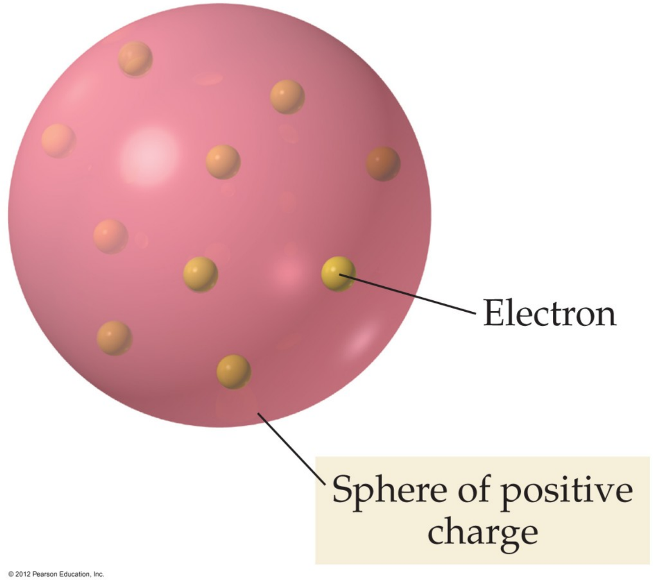
“Discovery of the Nucleus. Rutherford’s experiment”
https://www.youtube.com/watch?v=dNp-vP17asI

4.3 The Nuclear Atom: Atoms Have Parts

- An English physicist named J. J. Thomson (1856–1940) discovered a smaller and more fundamental particle called the electron.

Thomson discovered:

- Electrons are negatively charged.
- Electrons are much smaller and lighter than atoms.
- Electrons are uniformly present in many different kinds of substances.
- He proposed that atoms must contain positive charge that balanced the negative charge of electrons.

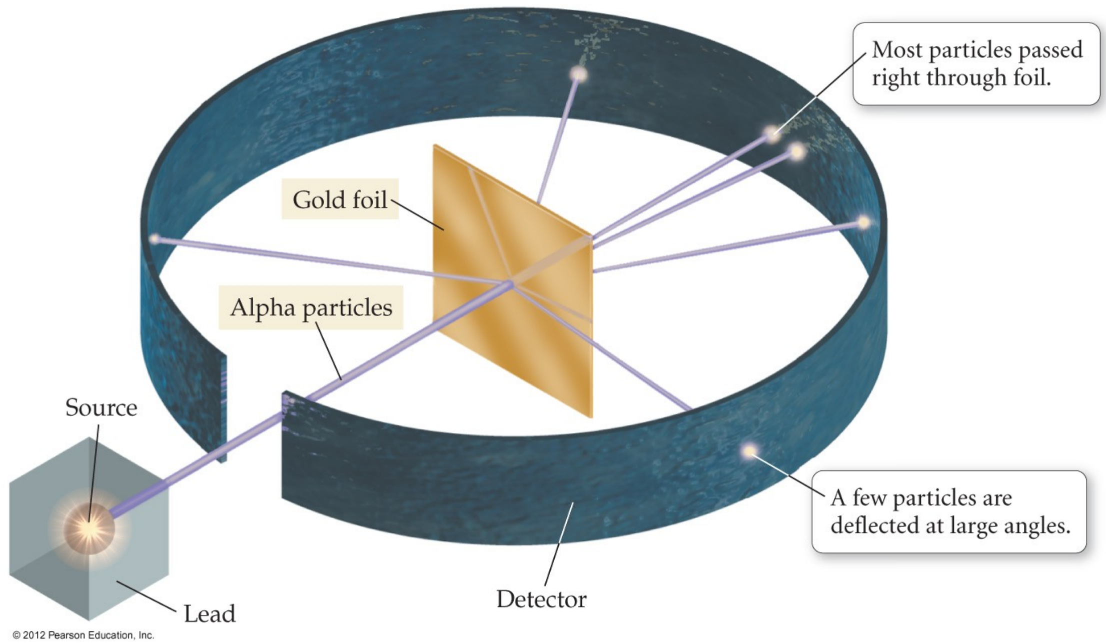


Plum pudding model of the atom: In the model suggested by J. J. Thomson, negatively charged electrons (yellow) were held in a sphere of positive charge (red).

4.3 The Nuclear Atom: Atoms Have Parts

Rutherford's gold foil experiment (1909): Tiny particles called alpha-particles were directed at a thin sheet of gold foil.

Most of the particles passed directly through the foil. A few, however, were deflected — some of them at sharp angles.



4.3 The Nuclear Atom: Atoms Have Parts

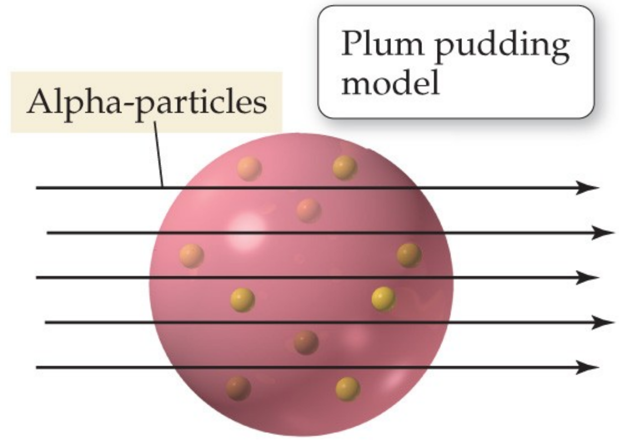
- Discovery of the atomic nucleus

(a) Expected result of Rutherford's gold foil experiment:

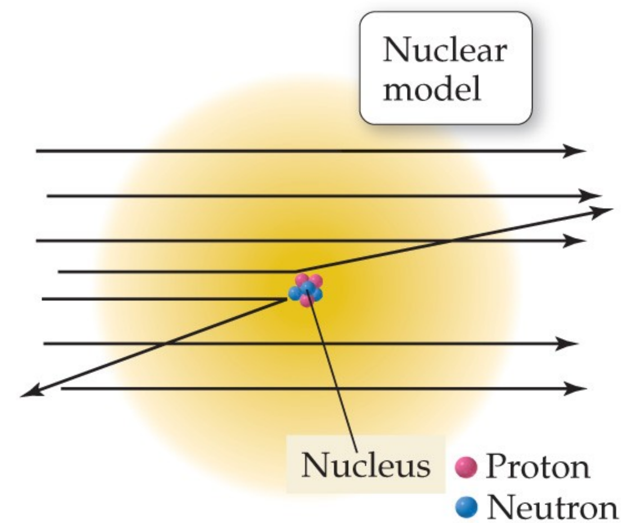
- If the plum pudding model were correct, the alpha-particles would pass right through the gold foil with minimal deflection.

(b) Actual result of Rutherford's gold foil experiment:

- A small number of alpha-particles were deflected or bounced back.



(a) Rutherford's expected result

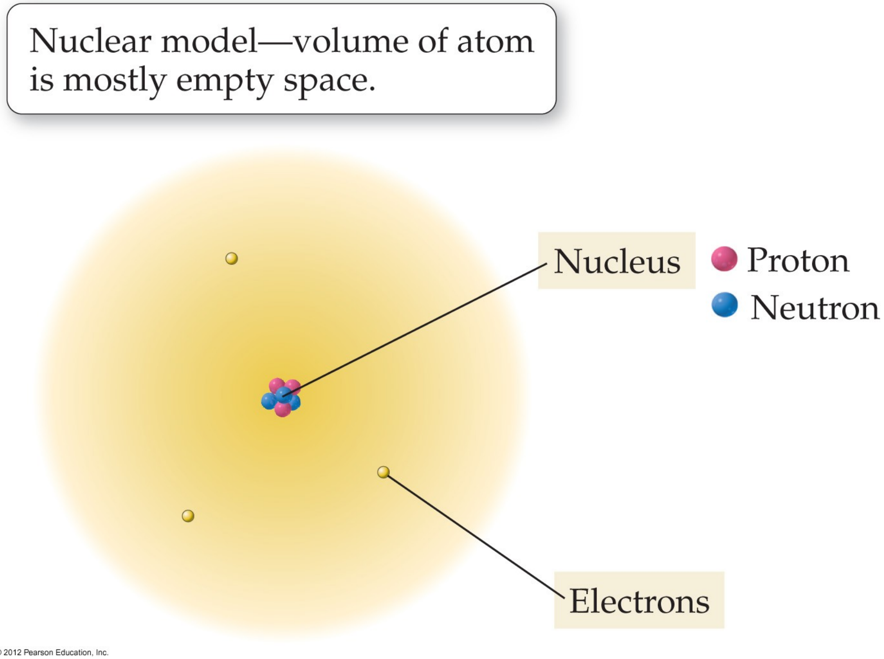


(b) Rutherford's actual result

Rutherford developed the nuclear theory of the atom.

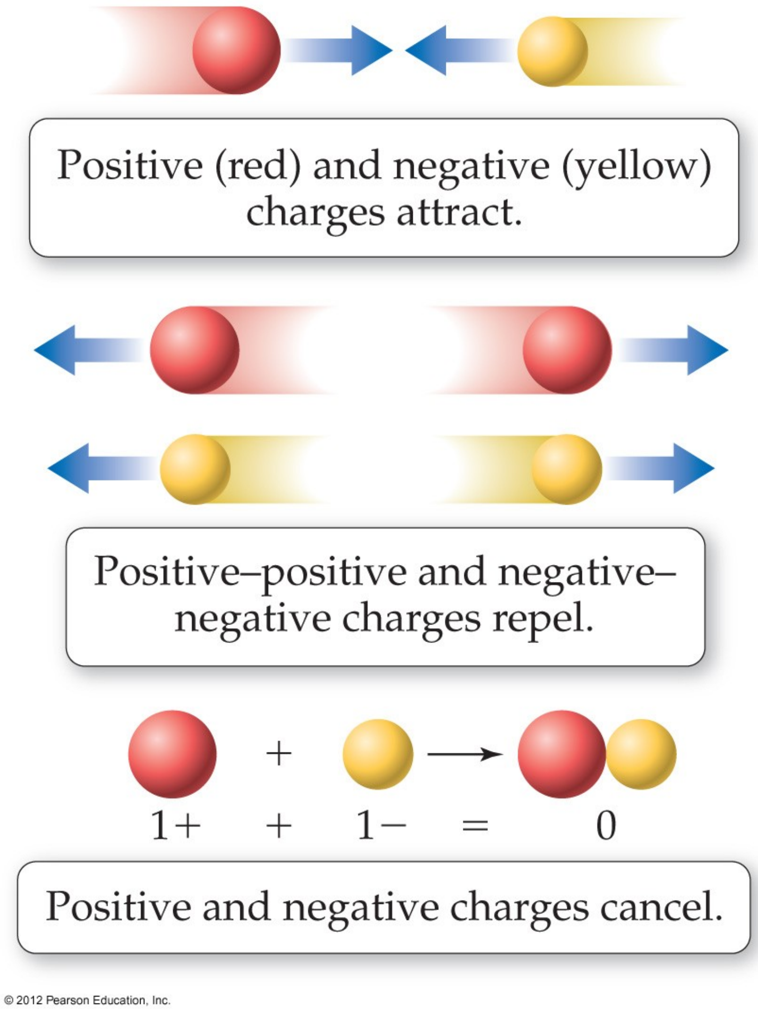
1. Most of the atom's mass and all of its positive charge are contained in a small core called the ***nucleus*.**
2. Most of the volume of the atom is empty space through which the tiny, negatively charged electrons are dispersed.
3. The number of negatively charged electrons outside the nucleus is equal to the number of positively charged particles (*protons*) inside the nucleus, so that the atom is electrically neutral.

In this image, the nucleus is greatly enlarged and the electrons are portrayed as particles.



A Summary of the Nature of Electrical Charge

- Electrical charge is a fundamental property of protons and electrons.
- Positive and negative electrical charges attract each other.
- Positive–positive and negative–negative charges repel each other.
- Positive and negative charges cancel each other so that a proton and an electron, when paired, are charge-neutral.



4.4 The Properties of Protons, Neutrons, and Electrons

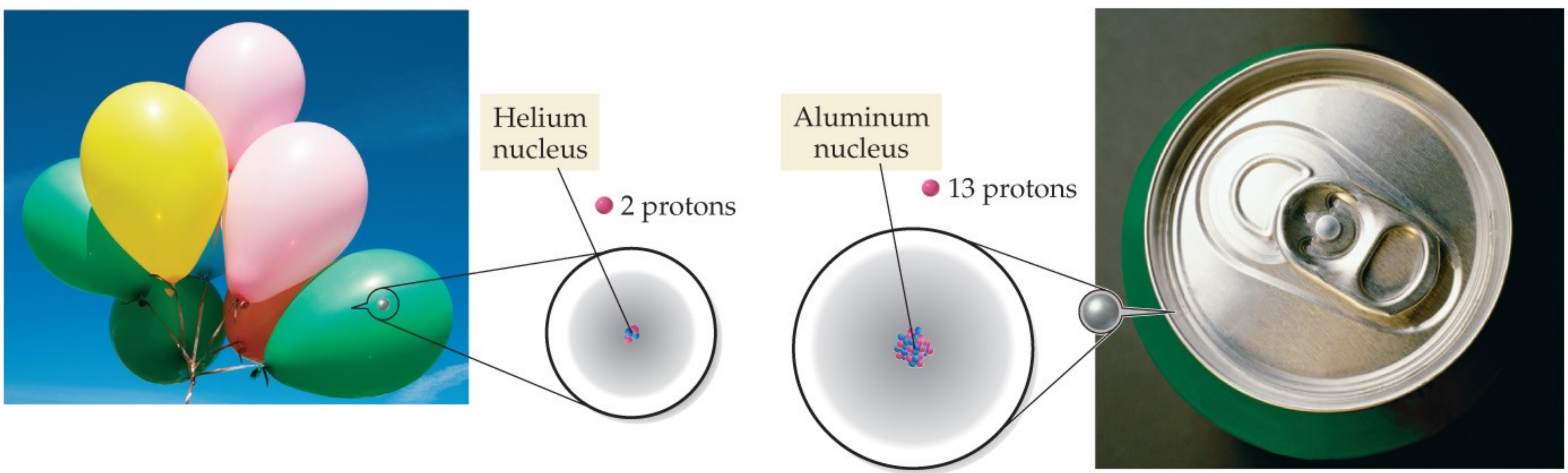
- Protons and neutrons have very similar masses.
- Electrons have almost negligible mass.

TABLE 4.1 Subatomic Particles

	Mass (kg)	Mass (amu)	Charge
proton	1.67262×10^{-27}	1.0073	1+
neutron	1.67493×10^{-27}	1.0087	0
electron	0.00091×10^{-27}	0.00055	1−

4.5 Elements: Defined by Their Numbers of Protons

- It is the number of protons in the nucleus of an atom that identifies it as a particular element.
- The number of protons in the nucleus of an atom is its **atomic number** and is given the symbol **Z**.



The **periodic table of the elements** lists all known elements according to their atomic numbers.

4
Be
9.01
beryllium

Atomic number (Z)
Chemical symbol
Atomic mass (defined in section 4.9)
Name

Periods

	1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 **H** 1.01 hydrogen																	2 **He** 4.00 helium
2	3 **Li** 6.94 lithium	4 **Be** 9.01 beryllium											5 **B** 10.81 boron	6 **C** 12.01 carbon	7 **N** 14.01 nitrogen	8 **O** 16.00 oxygen	9 **F** 19.00 fluorine	10 **Ne** 20.18 neon
3	11 **Na** 22.99 sodium	12 **Mg** 24.31 magnesium											13 **Al** 26.98 aluminum	14 **Si** 28.09 silicon	15 **P** 30.97 phosphorus	16 **S** 32.07 sulfur	17 **Cl** 35.45 chlorine	18 **Ar** 39.95 argon
4	19 **K** 39.10 potassium	20 **Ca** 40.08 calcium	21 **Sc** 44.96 scandium	22 **Ti** 47.88 titanium	23 **V** 50.94 vanadium	24 **Cr** 52.00 chromium	25 **Mn** 54.94 manganese	26 **Fe** 55.85 iron	27 **Co** 58.93 cobalt	28 **Ni** 58.69 nickel	29 **Cu** 63.55 copper	30 **Zn** 65.39 zinc	31 **Ga** 69.72 gallium	32 **Ge** 72.61 germanium	33 **As** 74.92 arsenic	34 **Se** 78.96 selenium	35 **Br** 79.90 bromine	36 **Kr** 83.80 krypton
5	37 **Rb** 85.47 rubidium	38 **Sr** 87.62 strontium	39 **Y** 88.91 yttrium	40 **Zr** 91.22 zirconium	41 **Nb** 92.91 niobium	42 **Mo** 95.94 molybdenum	43 **Tc** (99) technetium	44 **Ru** 101.07 ruthenium	45 **Rh** 102.91 rhodium	46 **Pd** 106.42 palladium	47 **Ag** 107.87 silver	48 **Cd** 112.41 cadmium	49 **In** 114.82 indium	50 **Sn** 118.71 tin	51 **Sb** 121.75 antimony	52 **Te** 127.60 tellurium	53 **I** 126.90 iodine	54 **Xe** 131.29 xenon
6	55 **Cs** 132.91 cesium	56 **Ba** 137.33 barium	57 **La** 138.91 lanthanum	72 **Hf** 178.49 hafnium	73 **Ta** 180.95 tantalum	74 **W** 183.85 tungsten	75 **Re** 186.21 rhenium	76 **Os** 190.2 osmium	77 **Ir** 192.22 iridium	78 **Pt** 195.08 platinum	79 **Au** 196.97 gold	80 **Hg** 200.59 mercury	81 **Tl** 204.38 thallium	82 **Pb** 207.2 lead	83 **Bi** 208.98 bismuth	84 **Po** (209) polonium	85 **At** (210) astatine	86 **Rn** (222) radon
7	87 **Fr** (223) francium	88 **Ra** (226) radium	89 **Ac** (227) actinium	104 **Rf** (261) rutherfordium	105 **Db** (262) dubnium	106 **Sg** (263) seaborgium	107 **Bh** (262) bohrium	108 **Hs** (265) hassium	109 **Mt** (266) meitnerium	110 **Ds** (281) darmstadtium	111 **Rg** (280) roentgenium	112 **Cn** (285)	113 — (284)	114 — (289)	115 — (288)	116 — (292)	117 ** (292)	118 — (294)

Lanthanides	58 **Ce** 140.12 cerium	59 **Pr** 140.91 praseodymium	60 **Nd** 144.24 neodymium	61 **Pm** (147) promethium	62 **Sm** 150.36 samarium	63 **Eu** 151.97 europium	64 **Gd** 157.25 gadolinium	65 **Tb** 158.93 terbium	66 **Dy** 162.50 dysprosium	67 **Ho** 164.93 holmium	68 **Er** 167.26 erbium	69 **Tm** 168.93 thulium	70 **Yb** 173.04 ytterbium	71 **Lu** 174.97 lutetium
Actinides	90 **Th** (232) thorium	91 **Pa** (231) protactinium	92 **U** (238) uranium	93 **Np** (237) neptunium	94 **Pu** (244) plutonium	95 **Am** (243) americium	96 **Cm** (247) curium	97 **Bk** (247) berkelium	98 **Cf** (251) californium	99 **Es** (252) einsteinium	100 **Fm** (257) fermium	101 **Md** (258) mendelevium	102 **No** (259) nobelium	103 **Lr** (260) lawrencium

**Element 117 is currently under review by IUPAC.

Recommended (OPTIONAL) You Tube Lecture:

- **Investigating Periodic Table with experiments with Peter Wothers (By Royal Institution,**
- (Understanding the Systematic properties of elements, 1hour, 25 minutes)

- https://www.youtube.com/watch?v=kqe9tEcZkno

4.5 Elements:
Origins of the Names of the Elements

- **Most chemical symbols are based on the English name of the element.**
- **Some symbols are based on Latin names.**
- **The symbol for potassium is K, from the Latin *kalium*, and the symbol for sodium is Na, from the Latin *natrium*.**
- **Additional elements with symbols based on their Greek or Latin names include the following:**

lead	**Pb**	***plumbum***
mercury	**Hg**	***hydrargyrum***
iron	**Fe**	***ferrum***
silver	**Ag**	***argentum***
tin	**Sn**	***stannum***
copper	**Cu**	***cuprum***

4.5 Elements:
Origins of the Names of the Elements

- Early scientists gave newly discovered elements names that reflected their properties:
- *Argon,* from the Greek *argos*, means "inactive," referring to argon's chemical inertness.
- Other elements were named after countries:
- *Polonium* after Poland
- *Francium* after France
- *Americium* after the United States of America.
- Other elements were named after scientists.
- Every element's name, symbol, and atomic number are included in the periodic table (inside the front cover) and in an alphabetical listing (inside the back cover) in this book.

Curium is named after **Marie Curie**, a chemist who helped discover radioactivity and also discovered two new elements. Curie won two Nobel Prizes for her work.

Curium
96
Cm
(247)

Bromine originates from the Greek word *bromos*, meaning “stench.”

Bromine vapor, seen as the red-brown gas in this photograph, has a strong odor.

4.6 Looking for Patterns: The Periodic Law and the Periodic Table

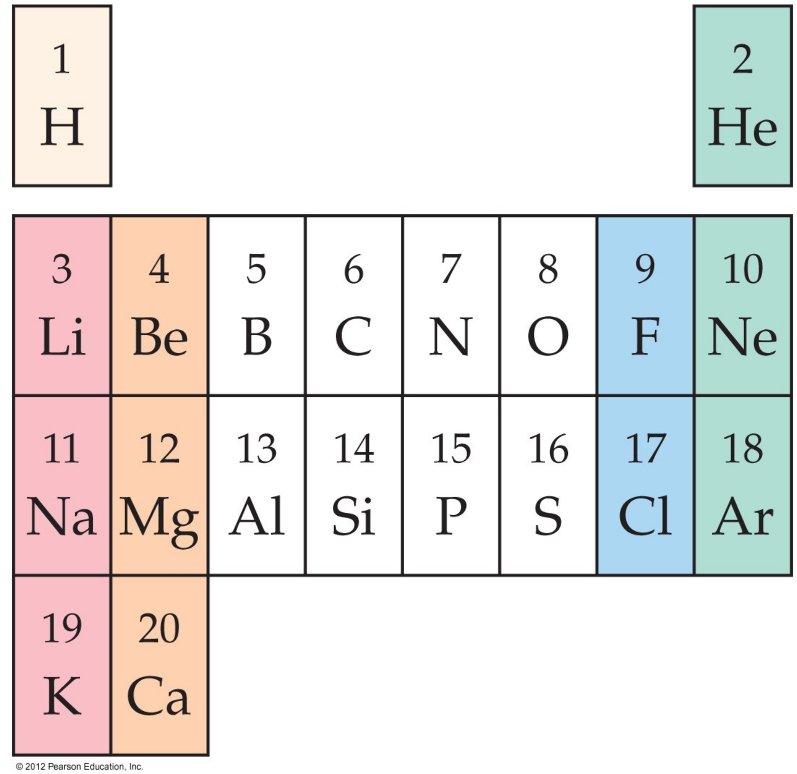
- **Dmitri Mendeleev,** a Russian chemistry professor, proposed from observation that when the **elements are arranged in order of increasing relative mass,** certain sets of properties recur **periodically.**

Watch:
“Patterns of reactivity” (You Tube)

https://www.youtube.com/watch?v=kOhrYt2r_PI

4.6 Looking for Patterns: The Periodic Law and the Periodic Table

- The color of each element represents its properties. Arrange them in rows so that **similar properties align in the same vertical columns.** This figure is similar to **Mendeleev's first periodic table.**

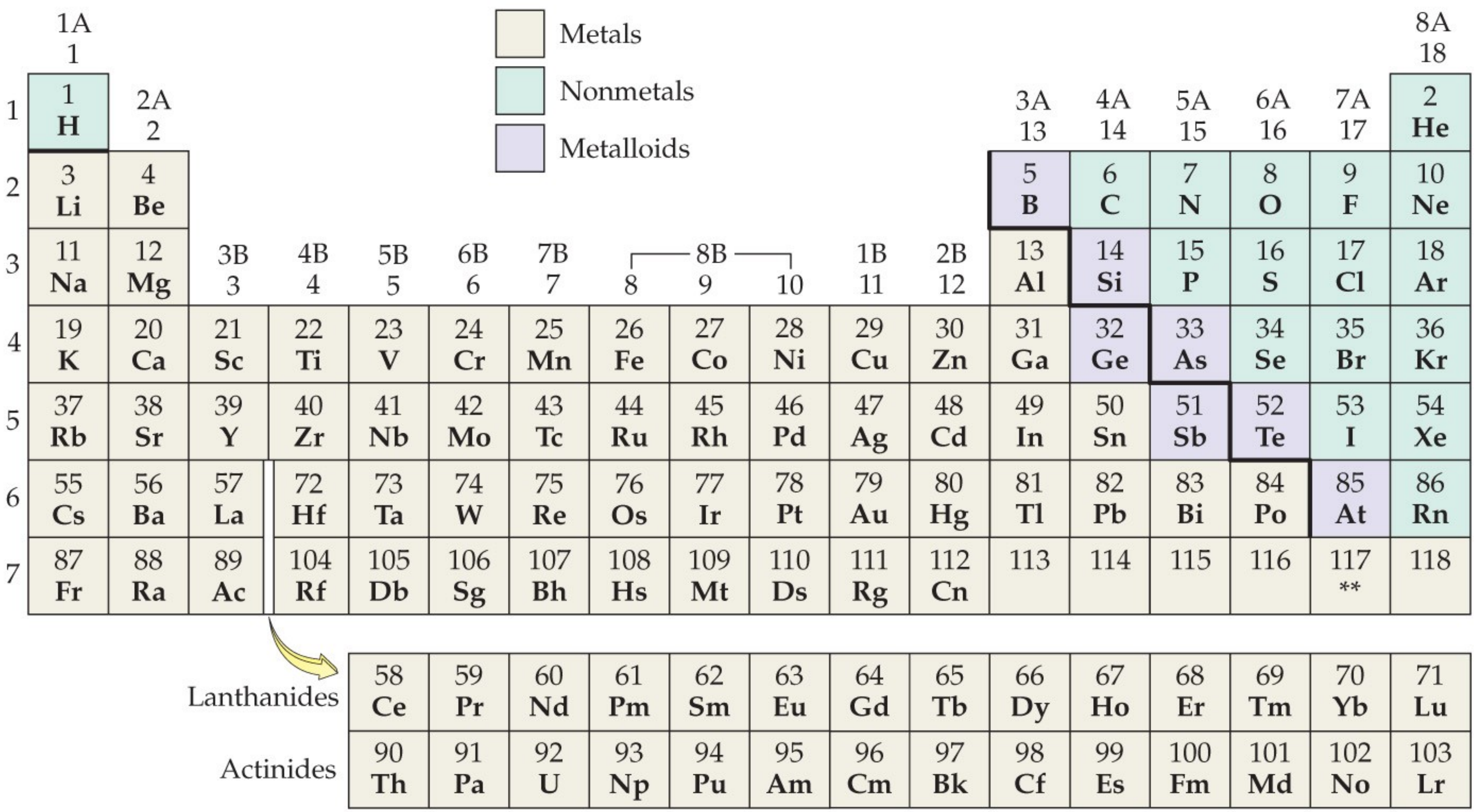


4.6 Looking for Patterns: The Periodic Law and the Periodic Table

- Mendeleev's periodic law was based on observation.
- Like all scientific laws, the periodic law summarized many observations but did not give the underlying reason for the observation—only theories do that.
- For now, we accept the periodic law as it is, but in Chapter 9 we will examine a powerful theory that explains the law and gives the underlying reasons for it.

4.6 Looking for Patterns: The Periodic Law and the Periodic Table

The elements in the periodic table can be broadly classified as metals, nonmetals, and metalloids.



4.6 Looking for Patterns: Metals

- Metals occupy the left side of the periodic table and have similar properties:
- Metals are good conductors of heat and electricity.
- Metals can be pounded into flat sheets (malleability).
- Metals can be drawn into wires (ductility).
- Metals are often shiny (lustrous).
- Metals tend to lose electrons when they undergo chemical changes.
- Good examples of metals are iron, magnesium, chromium, and sodium.

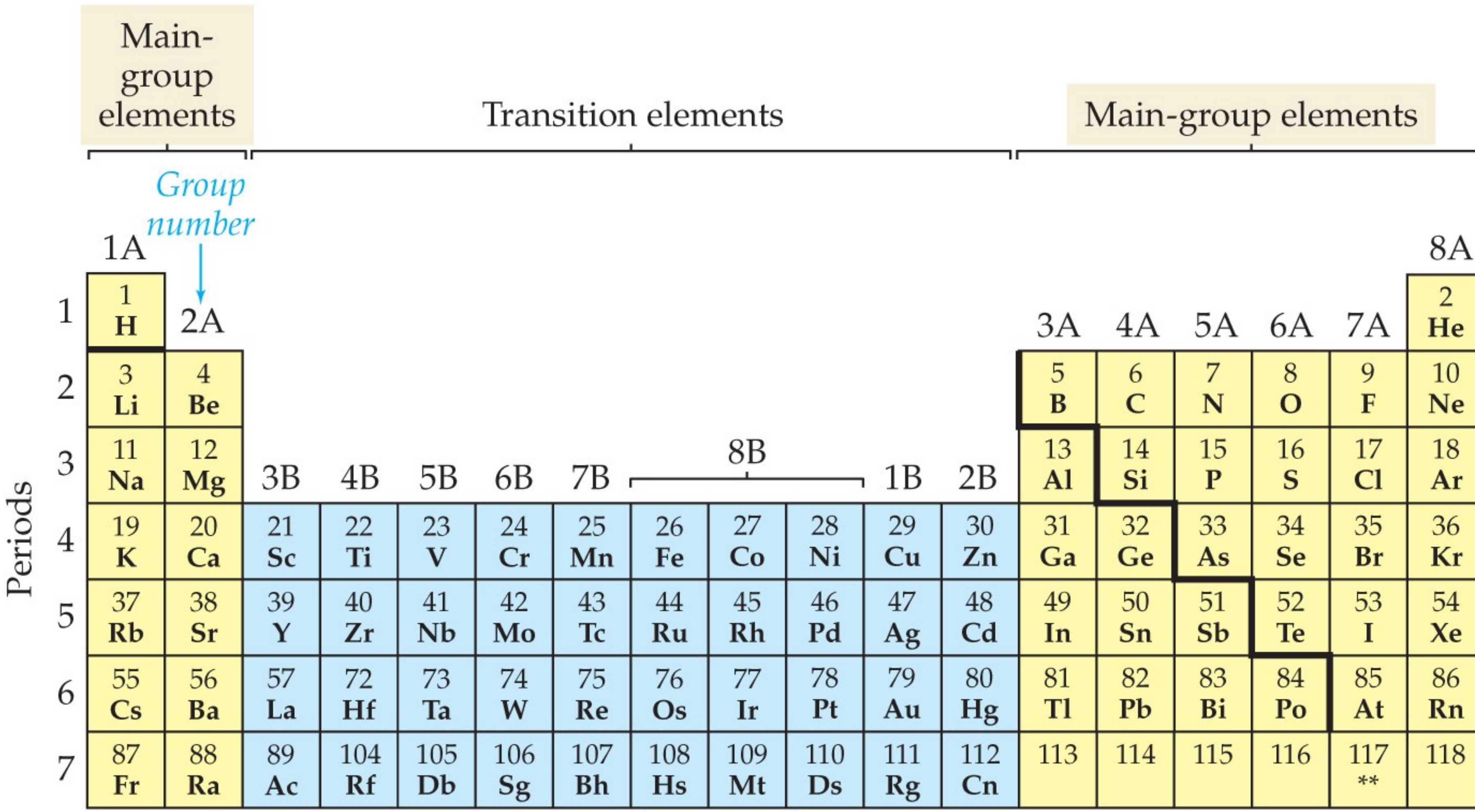
4.6 Looking for Patterns: Nonmetals

- Nonmetals occupy the upper right side of the periodic table.
- The dividing line between metals and nonmetals is the zigzag diagonal line running from boron to astatine.
- Nonmetals have more varied properties; some are solids at room temperature, while others are gases.
- As a whole, nonmetals tend to be poor conductors of heat and electricity.
- Nonmetals tend to gain electrons when they undergo chemical changes.
- Good examples of nonmetals are oxygen, nitrogen, chlorine, and iodine.

4.6 Looking for Patterns: Metalloids

- **Metalloids** lie along the zigzag diagonal line dividing metals and nonmetals.
- **Metalloids**, also called semimetals, display **mixed properties**.
- **Metalloids** are also called **semiconductors** because of their **intermediate electrical conductivity**, which **can be changed and controlled**.
- This property makes semiconductors useful in the manufacture of electronic devices that are central to computers, cell phones, and other modern gadgets.
- **Silicon, arsenic, and germanium are good examples of metalloids.**

4.6 Looking for patterns in main group elements, whose properties can generally be predicted based on their position, and transition elements, whose properties tend to be less predictable based on their position.



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The periodic table with groups highlighted: 1A, alkali metals; 2A, alkaline earth metals; 7A, halogens; and 8A, noble gases.

Alkali metals

Alkaline earth metals

Halogens

Noble gases

Group numbers

Transition metals

1A	2A											3A	4A	5A	6A	7A	8A
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											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 Cn	113	114	115	116	117 **	118

Lanthanides	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
Actinides	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

Periodic Table of videos

http://www.periodicvideos.com/

Recommended OPTIONAL videos:

Potassium (K) video:

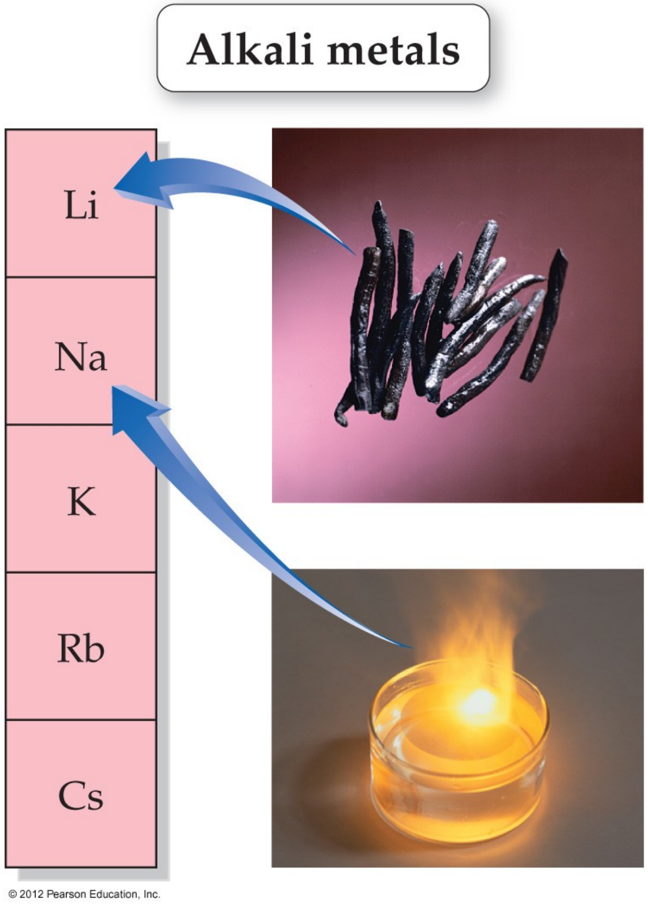
- http://www.periodicvideos.com/videos/019.htm

- Fluorine gas video:
- http://www.periodicvideos.com/videos/009.htm

- Neon gas video:
- http://www.periodicvideos.com/videos/010.htm

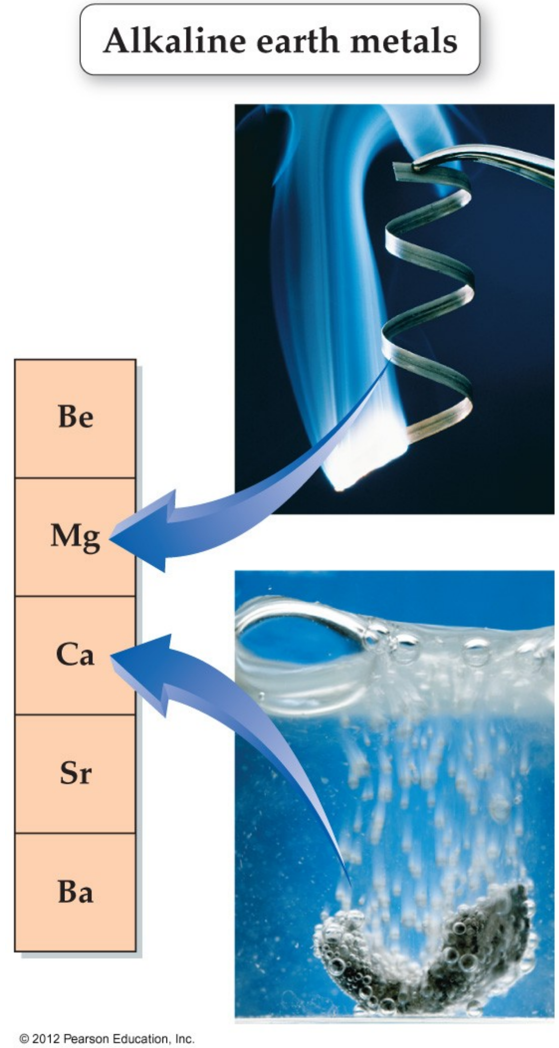
4.6 Looking for Patterns: Alkali Metals

- The alkali metals include **lithium** (shown in the first photo), **sodium** (shown in the second photo reacting with water), **potassium**, **rubidium**, and **cesium**.



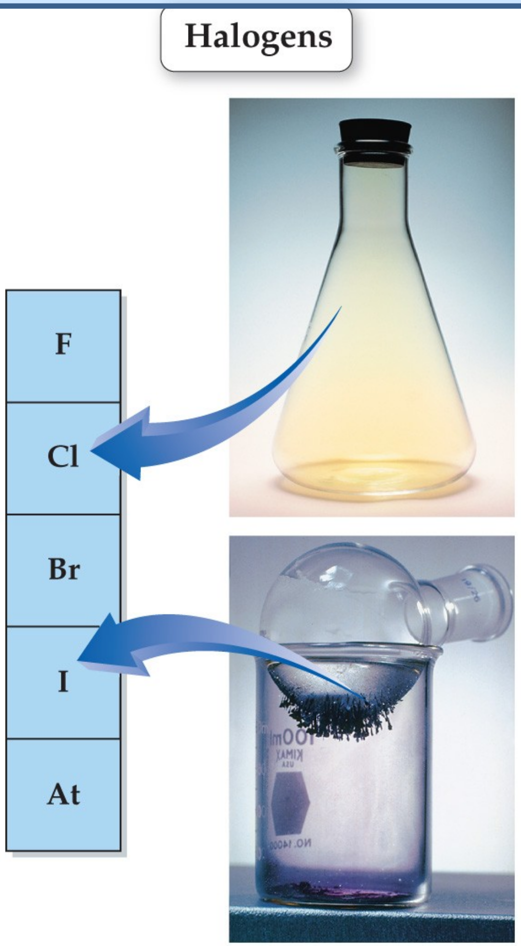
4.6 Looking for Patterns: Alkaline Earth Metals

- The **alkaline earth metals** include beryllium, magnesium (shown burning in the first photo), calcium (shown reacting with water in the second photo), strontium, and barium.



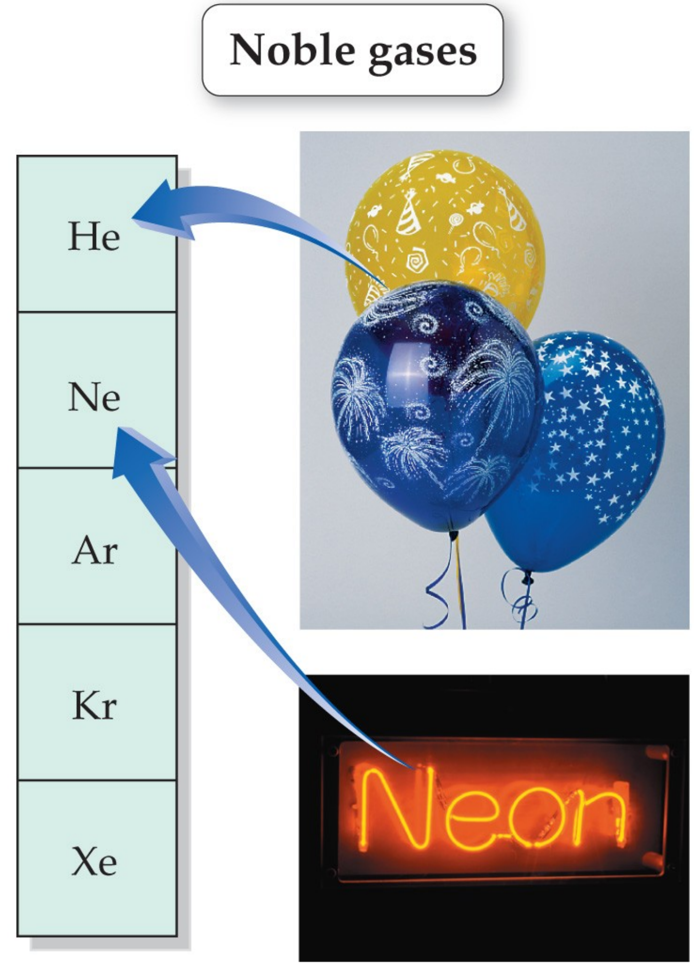
4.6 Looking for Patterns: Halogens

- The halogens include fluorine, chlorine (shown in the first photo), bromine, iodine (shown in the second photo), and astatine.



4.6 Looking for Patterns: Noble Gases

- The noble gases include helium (used in balloons), neon (used in neon signs), argon, krypton, and xenon.



Recommended you tube tutorials:

- **Atomic number, mass number, atomic charge**
- **(by Tyler DeWitt)**
- https://www.youtube.com/watch?v=dRfrvpVdKGM&list=PLIU3qkfGWJjA-rrnnFVVb2flP2WGgqK6O&index=14

- **What are isotopes?**
- https://www.youtube.com/watch?v=EboWeWmh5Pg&list=PLIU3qkfGWJjA-rrnnFVVb2flP2WGgqK6O&index=13

- https://www.khanacademy.org/science/chemistry/atomic-structure-and-properties/introduction-to-the-atom/v/atomic-number-mass-number-and-isotopes

4.7 Ions: Losing and Gaining Electrons

- In chemical reactions, atoms often lose or gain electrons to form charged particles called ions.
- Positive ions are called cations.
- Negative ions are called anions.
- The charge of an ion is shown in the upper right corner of the symbol.
- Ion charges are usually written with the magnitude of the charge first followed by the sign of the charge.

4.7 Ions: Losing Electrons

In reactions, lithium atoms lose one electron (e^-) to form Li^+ ions.

$$Li \longrightarrow Li^+ + e^-$$

The charge of an ion depends on how many electrons were gained or lost and is given by the formula

$$\text{Ion charge} = \text{number of protons} - \text{number of electrons}$$

$$= \#p^+ - \#e^-$$

where p^+ stands for *proton* and e^- stands for *electron.*

For the Li^+ ion with 3 protons and 2 electrons, the charge is

Ion charge = 3 − 2 = 1+

4.7 Ions: Gaining Electrons

In reactions, fluorine atoms gain 1 electron to form F^- ions:

$$F + e^- \longrightarrow F^-$$

The charge of an ion depends on how many electrons were gained or lost and is given by the formula

$$\text{Ion charge} = \text{number of protons} - \text{number of electrons}$$
$$= \#p^+ - \#e^-$$

where p^+ stands for *proton* and e^- stands for *electron.*

For the F^- ion with 9 protons and 10 electrons, the **charge is**

Ion charge = 9 − 10 = 1-

Recommended tutorials:

- IONS (tutorial):
- https://www.khanacademy.org/science/chemistry/atomic-structure-and-properties/introduction-to-compounds/v/introduction-to-ions

- What's an ION?:
- https://www.youtube.com/watch?v=WWc3k2723IM

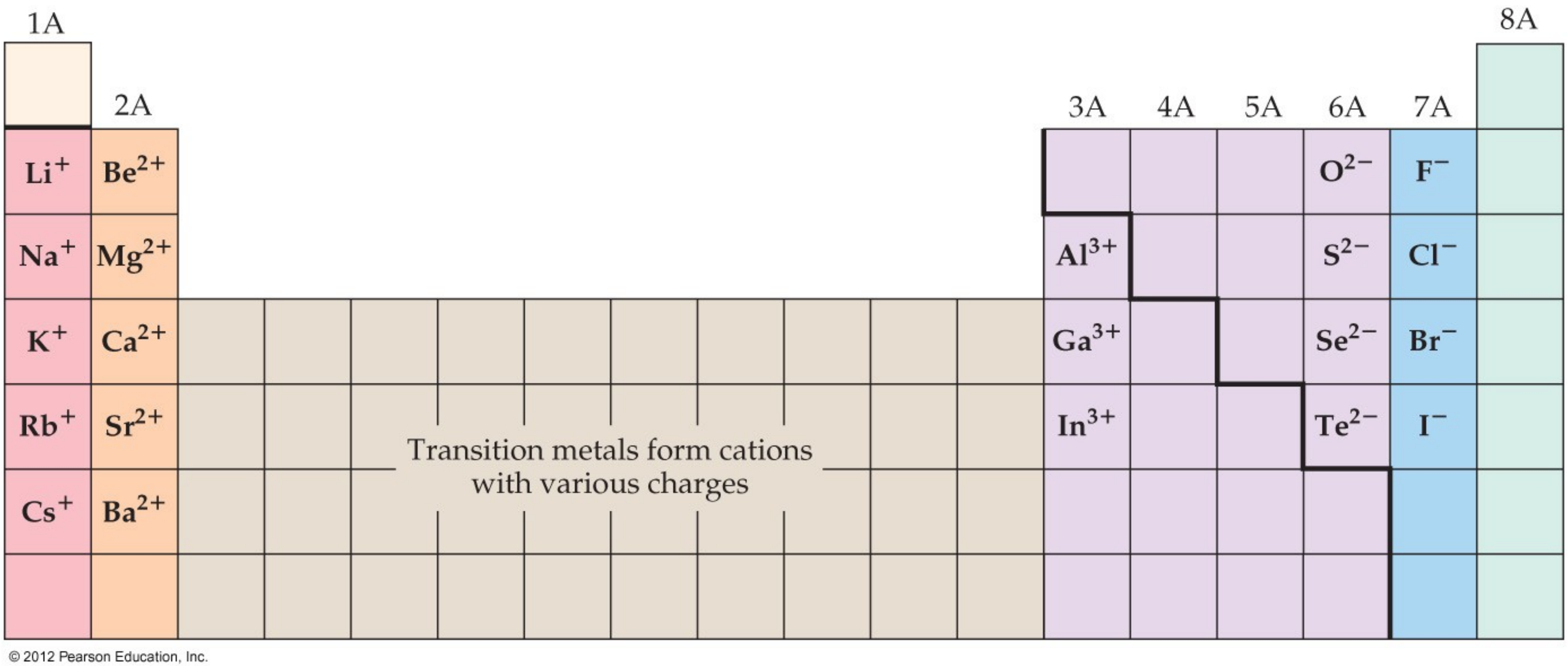
Self-Check

- Write down the ionic charge of a Chromium ion that has 21 electrons?
- Write down the ionic charge of a Tellurium ion that has 54 electrons?
- If the ionic charge of a Bromine ion is -1 ,
- What's the number of electrons in this ion ?

4.7 Ions: Ions and the Periodic Table

- The number associated with the letter A above each *main-group* column in the periodic table—1 through 8—gives the number of *valence electrons* for the elements in that column.
- The key to predicting the charge acquired by an element is its position in the periodic table relative to the noble gases.
- Main-group elements tend to form ions that have the same number of valence electrons as the nearest noble gas.

Elements that form predictable ions



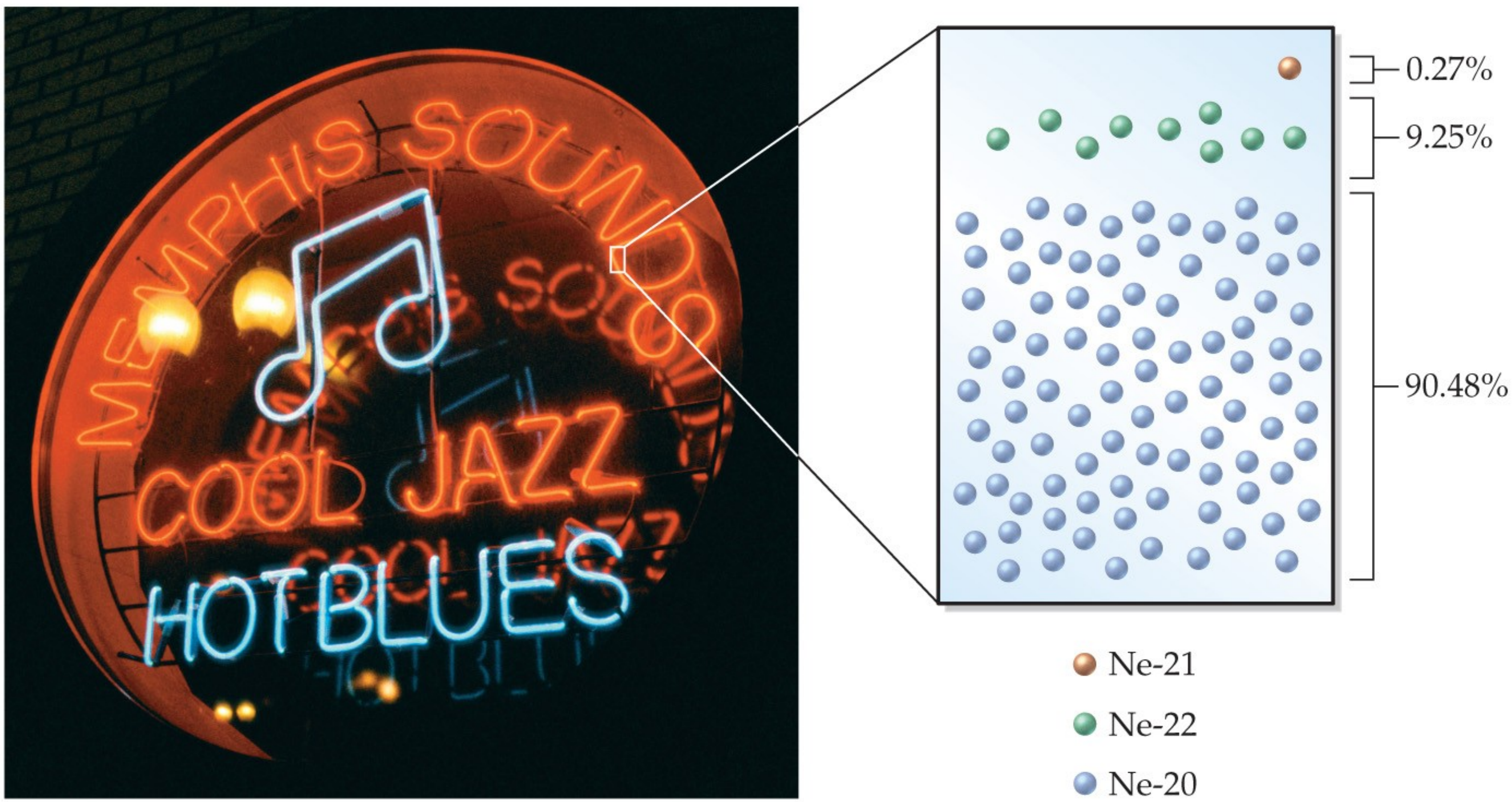
4.8 Isotopes:
When the Number of Neutrons Varies

- All atoms of a given element have the same number of protons.
- They do not necessarily have the same number of neutrons.
- Atoms with the same number of protons but different numbers of neutrons are called isotopes.
- All elements have their own unique percent natural abundance of isotopes.

4.8 Isotopes: Natural Abundance

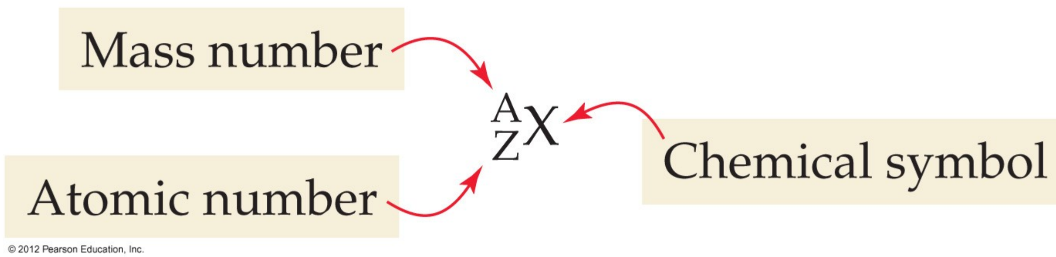
Isotopes of neon

Naturally occurring neon contains three different isotopes: Ne-20 (with 10 protons and 10 neutrons), Ne-21 (with 10 protons and 11 neutrons), and Ne-22 (with 10 protons and 12 neutrons).



4.8 Isotopes: Isotope Symbols

Isotopes are often symbolized in the following way:



For example, the symbols for the isotopes of neon are:

Ne-20	neon-20
Ne-21	neon-21
Ne-22	neon-22

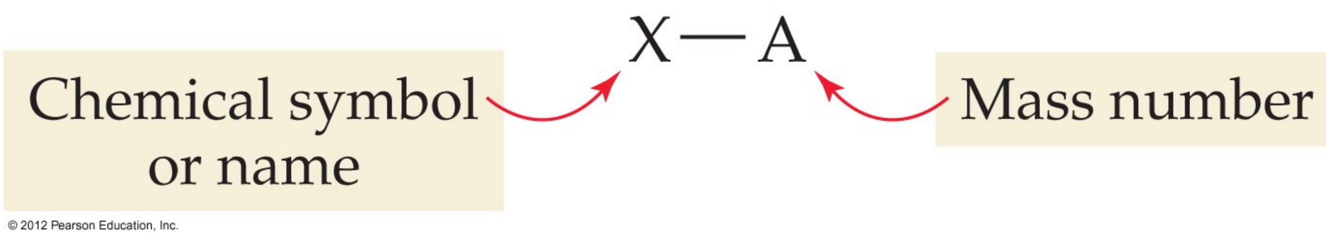
4.8 Isotopes: Isotope Symbols

- **The mass number (*A*) is the *sum* of the number of protons and the number of neutrons.**

- The **number of neutrons in an isotope is the difference between the mass number and the atomic number.**

4.8 Isotopes: Isotope Symbols

- A second notation for isotopes is the chemical symbol (or chemical name) followed by a hyphen and the mass number of the isotope.



In this notation, the neon isotopes are:

Ne-20 neon-20
Ne-21 neon-21
Ne-22 neon-22

4.9 Atomic Mass: The Average Mass of an Element's Atoms

- The **atomic mass of each element listed in the periodic table represents the average mass of the atoms** that compose that element.
- Naturally occurring chlorine consists of **75.77% chlorine-35 (mass 34.97 amu) and 24.23% chlorine-37 (mass 36.97 amu).**
- **Its atomic mass is:**

$$\begin{aligned}\text{Atomic mass} &= (0.7577 \times 34.97\ \text{amu}) + (0.2423 \times 36.97\ \text{amu}) \\ &= 35.45\ \text{amu}\end{aligned}$$

4.9 Atomic Mass: The Average Mass of an Element's Atoms

In general, atomic mass is calculated according to the following equation:

Atomic mass =

(Fraction of isotope 1 × Mass of isotope 1) +
(Fraction of isotope 2 × Mass of isotope 2) +
(Fraction of isotope 3 × Mass of isotope 3) +
…

where the fractions of each isotope are the percent natural abundances converted to their decimal values.

EXAMPLE 4.9 Calculating Atomic Mass

- Gallium has two naturally occurring isotopes: **Ga-69, with mass 68.9256 amu** and a natural abundance of **60.11%,** and **Ga-71, with mass 70.9247 amu** and a natural abundance of **39.89%.**

- Calculate **the atomic mass of gallium**.

EXAMPLE 4.9 Calculating Atomic Mass

- Convert the percent natural abundances **into decimal form by dividing by 100.**
  - **Solution:**
  - **Fraction Ga-69** $= \frac{60.11}{100} = 0.6011$
  - **Fraction Ga-71** $= \frac{39.89}{100} = 0.3989$

EXAMPLE 4.9 Calculating Atomic Mass

- Use the fractional abundances and the atomic masses of the isotopes to compute the atomic mass according to the atomic mass definition given earlier.

$$\text{Atomic mass} = (0.6011 \times 68.9256\ \text{amu}) + (0.3989 \times 70.9247\ \text{amu}) =$$

$$= 41.4321\ \text{amu} + 28.2919\ \text{amu}$$

$$= 69.7231 = 69.72\ \text{amu}$$

Recommended you tube tutorial:

- **How to calculate atomic mass practice problems**
- (by Tyler DeWitt)

- https://www.youtube.com/watch?v=ULRsJYhQmlo

Isotopes in the Environment

- The nuclei of some isotopes of a given element are not stable.
- These atoms emit a few energetic subatomic particles from their nuclei and change into different isotopes of different elements.
- The emitted subatomic particles are called nuclear radiation.
- The isotopes that emit them are termed radioactive.

Isotopes in the Environment

- **Nuclear radiation** can be harmful to humans and other living organisms because the energetic particles interact with and damage biological molecules.
- Some isotopes, such as **Pb-185,** emit significant amounts of radiation only for a <u>very short time</u>.
- Other isotopes, such as **Pu-239**, remain radioactive <u>for a long time</u>—thousands, millions, or even billions of years.

Isotopes in the Environment

- Radioactive isotopes are not always harmful.
- Many have beneficial uses.
- For example, technetium-99 (Tc-99) is often given to patients to diagnose disease.
- The radiation emitted by Tc-99 helps doctors image internal organs or detect infection.

Chapter 4 in Review

- The atomic theory:
  Ancient Greeks: Matter is composed of small, indestructible particles. Dalton: Matter is composed of atoms.
- **Atoms of a given element have unique properties that distinguish them from atoms of other elements.**
- **Atoms combine in simple, whole-number ratios to form compounds.**

Chapter 4 in Review

In the nuclear model of the atom:

- **The atom is composed of protons and neutrons, which compose most of the atom's mass and are grouped together in a dense nucleus.**
- **Electrons comprise most of the atom's volume.**
- **Protons and neutrons have similar masses (1 amu), while electrons have a much smaller mass.**

Chapter 4 in Review

The periodic table:

- **Tabulates all known elements in order of increasing atomic number.**
- **Columns of elements have similar properties and are called groups or families.**
- **Elements on the left side are metals. They tend to lose electrons in their chemical changes.**
- **Elements on the upper right side are nonmetals. They tend to gain electrons in their chemical changes.**
- **Elements between the two are called metalloids.**

Atomic number:

- **The characteristic that defines an element is the number of protons in the nuclei of its atoms; this number is called the atomic number (Z).**

Chapter 4 in Review

Ions:

- **When an atom gains or loses electrons, it becomes an ion.**
- **Positively charged ions are called cations.**
- **Negatively charged ions are called anions.**
- **Cations and anions occur together so that matter is charge-neutral.**

Isotopes:

- **Atoms of the same element with different numbers of neutrons are called isotopes.**
- **Isotopes are characterized by their mass number (A), the sum of the protons and the neutrons in the nucleus.**
- **Each naturally occurring sample of most elements has the same percent natural abundance of each isotope.**
- **The atomic mass of an element is a weighted average of the masses of the individual isotopes.**

Chemical Skills

- Determining ion charge from numbers of protons and electrons
- Determining the number of protons and electrons in an ion
- Determining atomic numbers, mass numbers, and isotope symbols for an isotope
- Determining the number of protons and neutrons from isotope symbols
- Calculating atomic mass from percent natural abundances and isotopic masses