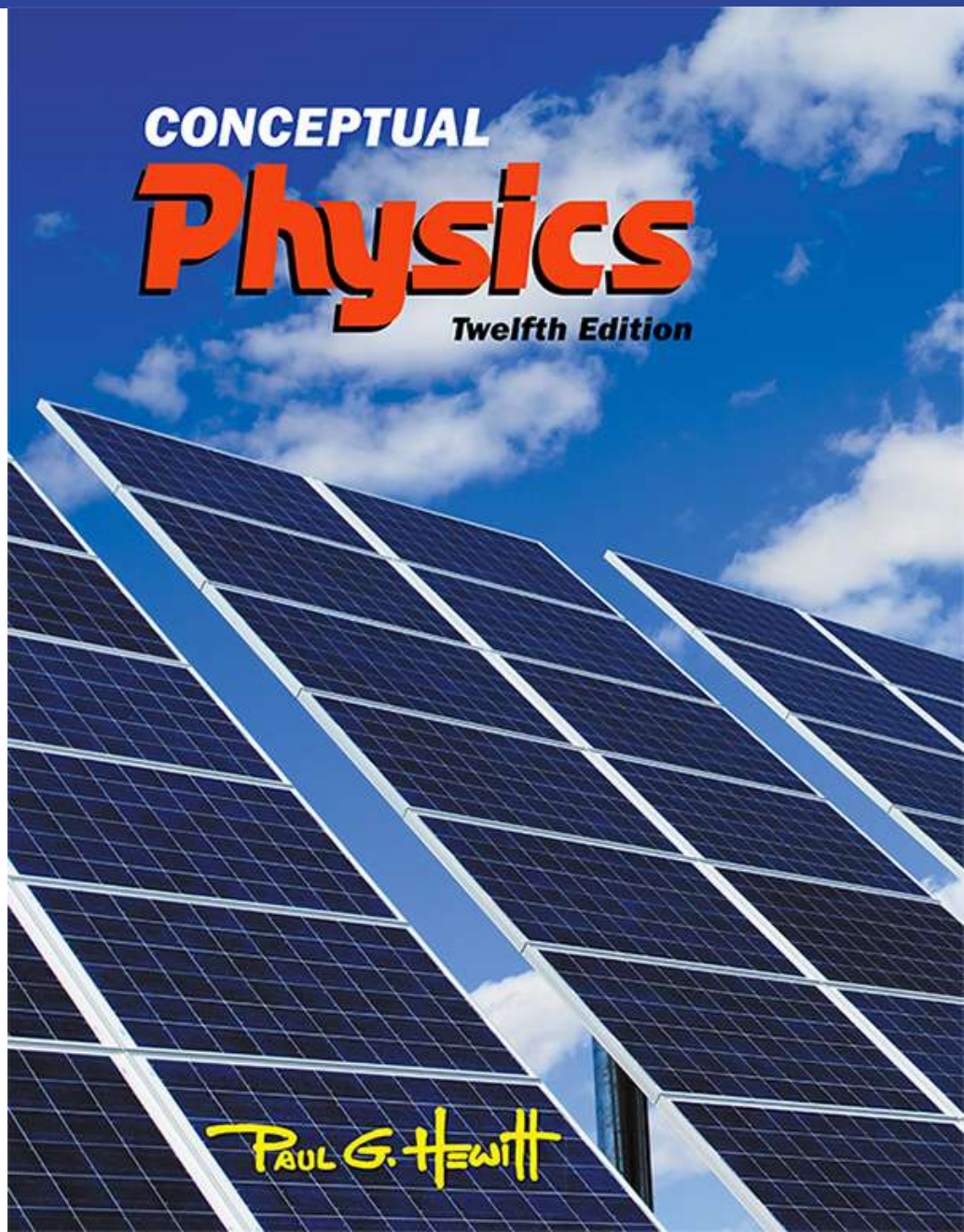
Lecture Outline

Chapter 11: The Atomic Nature Of Matter



This lecture will help you understand:

- The Atomic Hypothesis
- Characteristics of Atoms
- Atomic Imagery
- Atomic Structure
- The Elements
- The Periodic Table of Elements
- Relative Sizes of Atoms
- Isotopes
- Compounds and Mixtures
- Molecules
- Antimatter
- Dark Matter

Atoms

- "All things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another."

—Richard Feynman

The Atomic Hypothesis

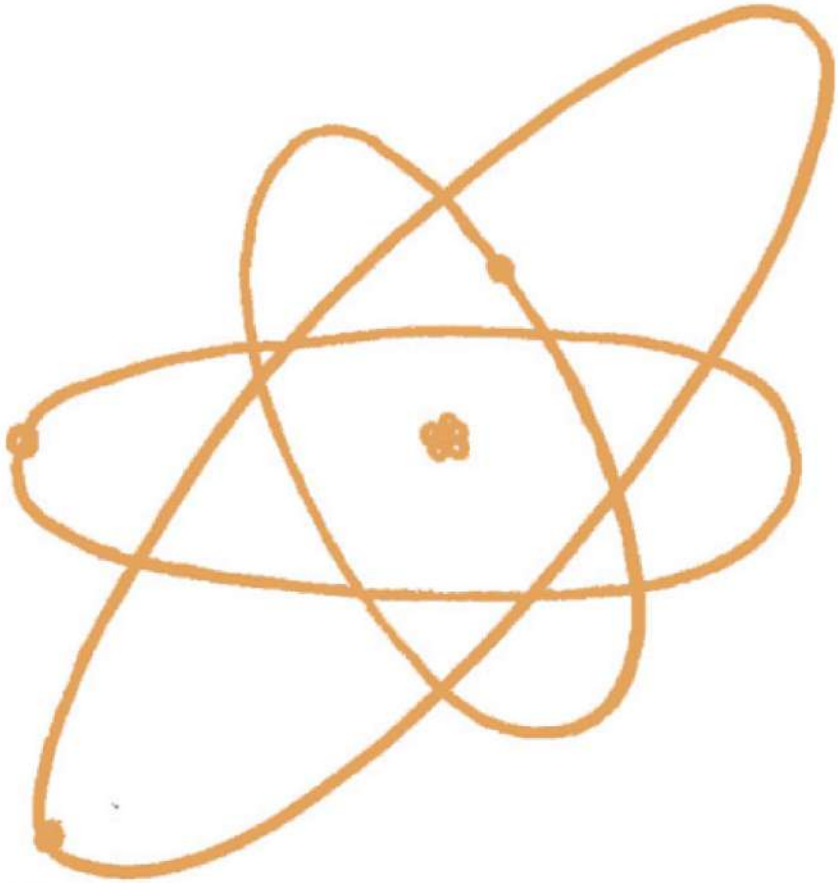
- The idea of matter:
  - First thought by Aristotle to be a combination of four elements—earth, air, fire, and water
  - Thought to be composed of atoms by Greeks from the fifth century BC
  - Further proposed as atoms in 1800s by meteorologists and schoolteacher John Dalton

The Atomic Hypothesis, Continued

- In 1827, Robert Brown, a botanist, observed collisions between visible particles and invisible atoms (Brownian motion)—later confirmed by Einstein as evidence for the existence of atoms.

Characteristics of Atoms

- Characteristics of atoms:
  - Incredibly tiny
  - Numerous
  - Perpetually in motion
  - Ageless



Characteristics of Atoms
CHECK YOUR NEIGHBOR

Which of the following are incorrect statements about the atom?

A. Atoms are smaller than the wavelength of visible light.
B. Atoms are mostly empty space, just as the solar system is mostly empty space.
C. Atoms are perpetually moving.
D. Atoms are manufactured in plants, and in humans during pregnancy.
E. All are correct.

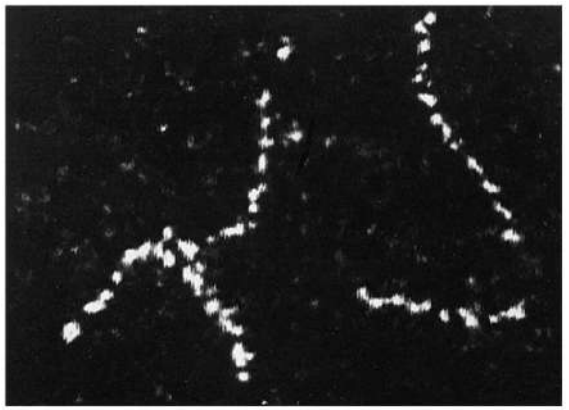
Characteristics of Atoms
CHECK YOUR ANSWER

Which of the following are incorrect statements about the atom?

D. Atoms are manufactured in plants, and in humans during pregnancy.

Atomic Imagery

- View of atoms
  - Too small to be seen with visible light
  - As chains of individual thorium atoms in a 1970 electron micrograph image
  - Revealed as ripples in rings by scanning tunneling microscope in mid-1980s
  - Classical model has a nucleus at the center, surrounded by electrons



Atomic Structure

- Atomic structure composed of
  - atomic nucleus
    - concentration of nearly all the mass
  - nucleons
    - building block of nucleus
    - all are identical
      - in a neutral state—a neutron
      - in a positively charged state—a proton
        - positive charges repel positive charges and attract negative charges
  - quarks—particles that make up a nucleon

The Elements

- Atoms
  - Refer to particles that make up a substance
- Elemental substance
  - Composed of only one kind of atom
    - Lightest and most abundant is hydrogen.
  - To date, about 115 are known.
    - 90 occur in nature.
    - Others produced in laboratory are unstable.
  - Words *atom* and *element* can be used interchangeably.

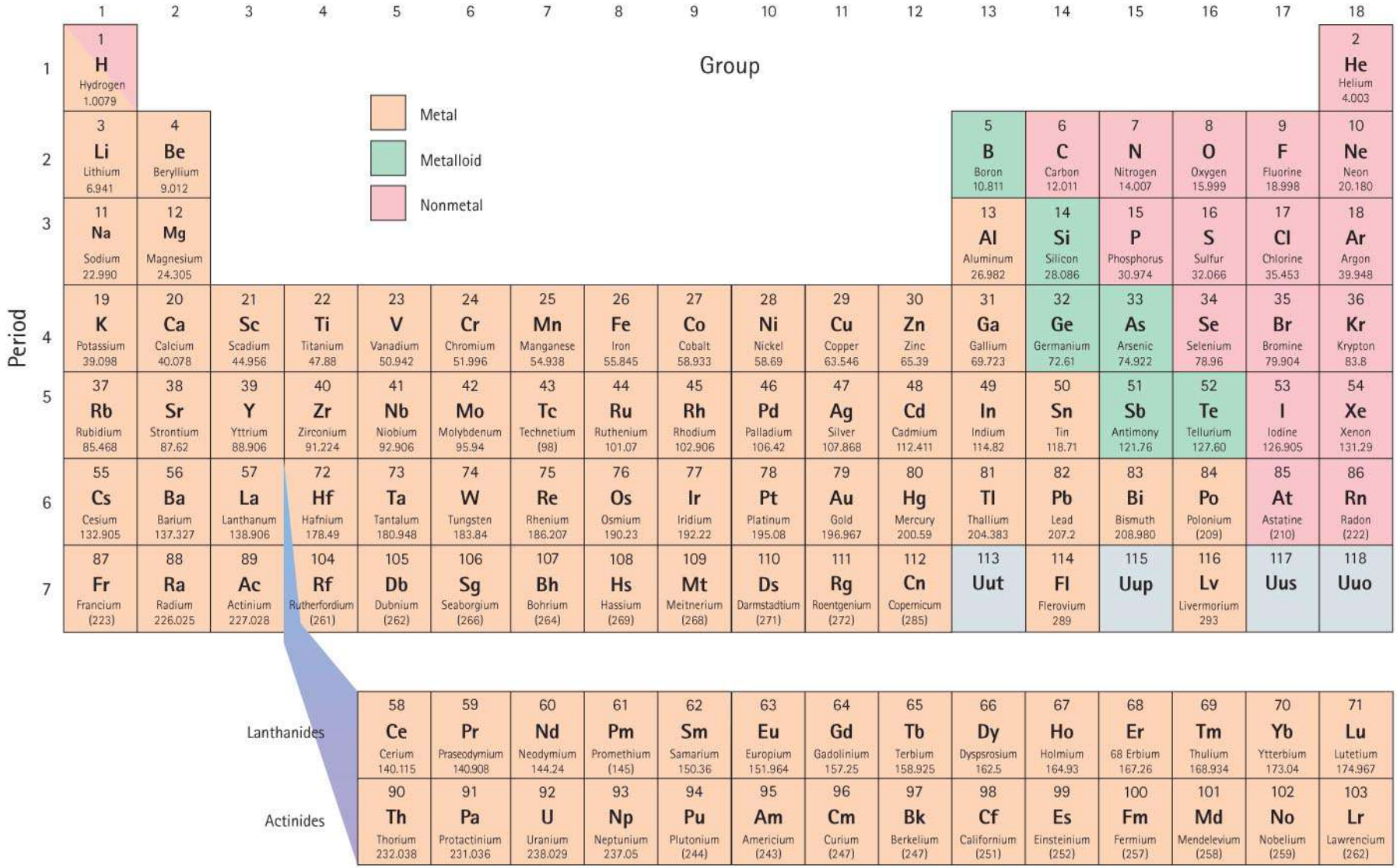
The Elements, Continued

- Composition of living things include these 5 elements:
  - Oxygen
  - Carbon
  - Hydrogen
  - Nitrogen
  - Calcium

Periodic Table of the Elements

- Periodic table:
  - A chart (chemist's road map) of elements arranged by atomic number
    - Classified by the number of protons in the nucleus
  - Arranged from left to right
    - Each having one more proton and electron than the preceding element
    - On the far right, outer shells are filled to capacity, known as noble gases

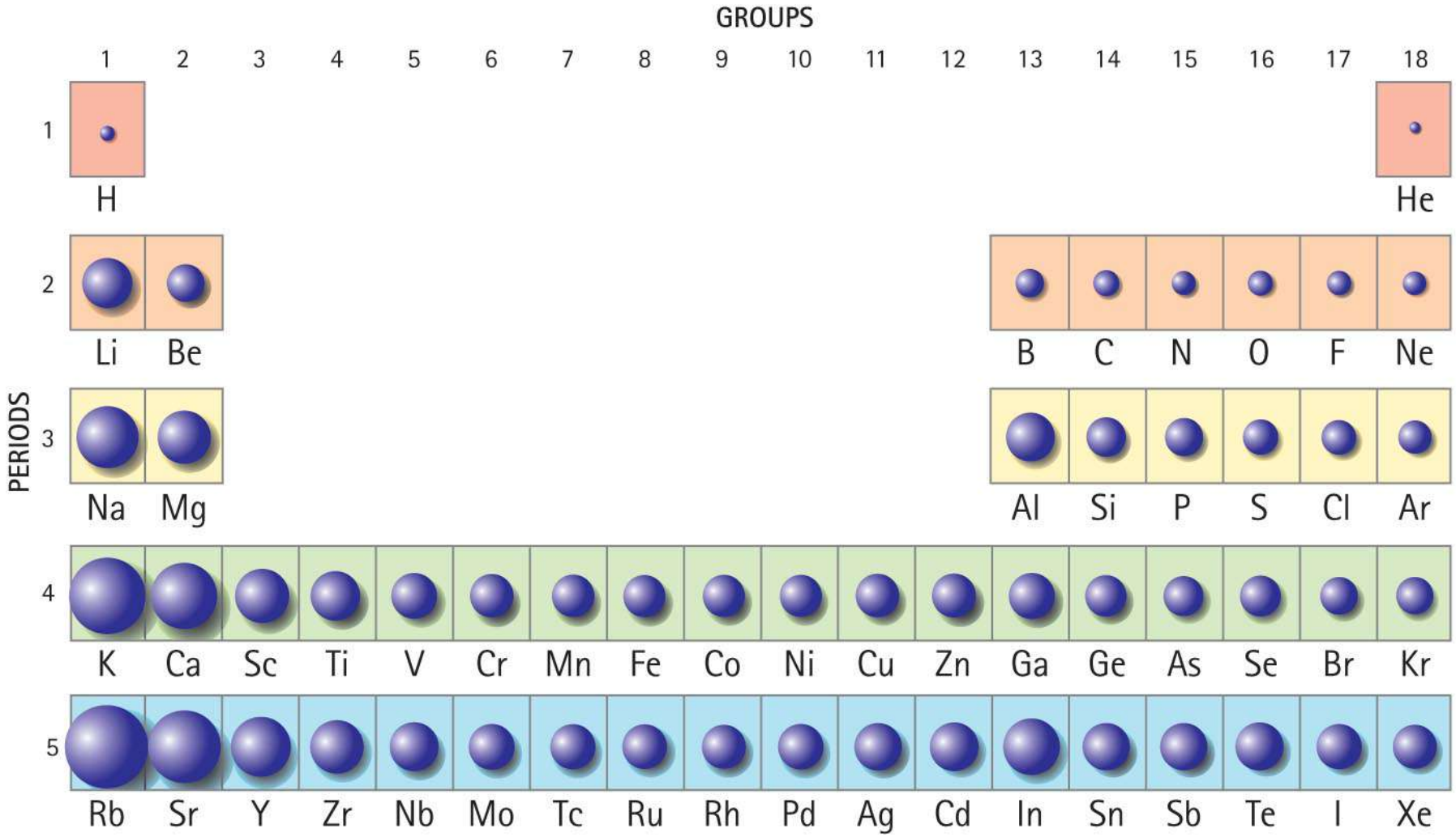
Periodic Table of the Elements, Continued



Relative Sizes of Atoms

- Diameters of the outer electron shells:
  - are determined by the amount of electrical charge in nucleus.
  - gradually decrease from left to right across the periodic table.
- As nuclear charge increases and electrons are added to outer orbits, the inner orbit shrinks.

Relative Sizes of Atoms, Continued



Ions and Isotopes

- An ion is a charged atom.
  - Positive ion has deficiency of electrons.
  - Negative ion has an excess of electrons.
- Isotopes:
  - Atoms of the same element with different numbers of neutrons
  - Identical behavior

Isotopes

- Protons in nucleus matches electrons around nucleus, but not necessarily neutrons.
- Isotopes:
  - Atoms of the same element with different numbers of neutrons
  - Identical behavior
  - Identified by their mass number (total number of protons and neutrons in the nucleus or number of nucleons)
    - Example: Iron isotope with 26 protons contain 30 neutrons. Mass number is number 56, referred to as iron-56.

Isotopes
CHECK YOUR NEIGHBOR

The atomic number of an element matches the number of

A. protons in the nucleus of an atom.
B. electrons in a neutral atom.
C. Both of the above.
D. None of the above.

Isotopes
CHECK YOUR ANSWER

The atomic number of an element matches the number of

C. Both of the above.

Comment:

When the atomic number doesn't match the number of electrons, the atom is an ion.

Isotopes
CHECK YOUR NEIGHBOR, Continued

A nucleus with an atomic number of 44 and a mass number of 100 must have

A. 44 neutrons.
B. 56 neutrons.
C. 100 neutrons.
D. All of the above.

Isotopes
CHECK YOUR ANSWER, Continued

A nucleus with an atomic number of 44 and a mass number of 100 must have

B. 56 neutrons.

Comment:

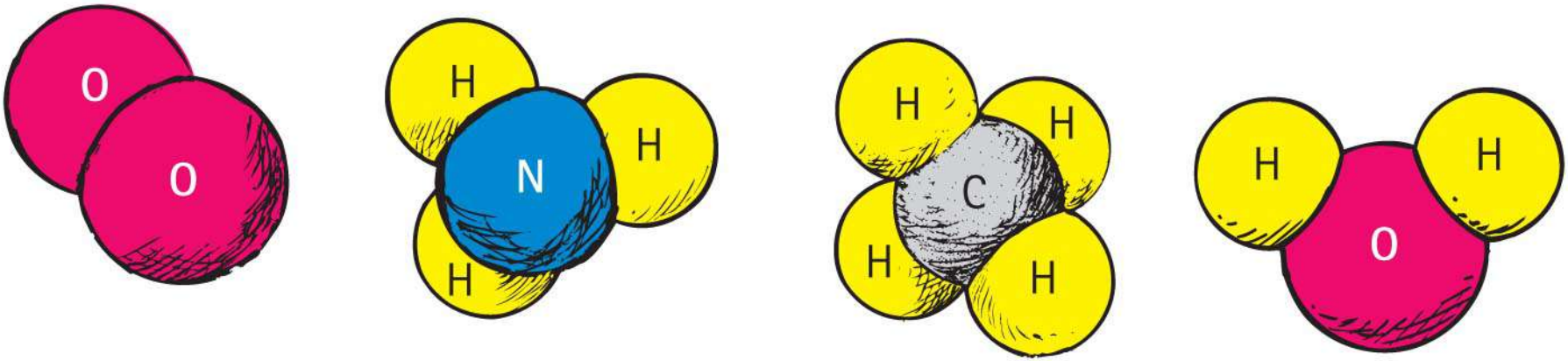
Be sure to distinguish between *neutron* and *nucleon*. Of the 100 nucleons in the nucleus, 56 are neutrons. A neutron *is* a nucleon, as is a proton.

Compounds and Mixtures

- When atoms of different elements bond to one another, they make a **compound.**
  - A compound is different from the elements from which it is made.
  - It can only be separated into its constituent elements by chemical means.
  - Example: Salt (a compound of sodium and chlorine)
- A substance that is mixed together without chemically bonding is called a **mixture.**
  - Example: Air (a mixture of several gases)

Molecules

- Molecules
  - Two or more atoms bonded together
  - Example:
    - NH_3 (ammonia)
    - 3 atoms of hydrogen and 1 atom of nitrogen

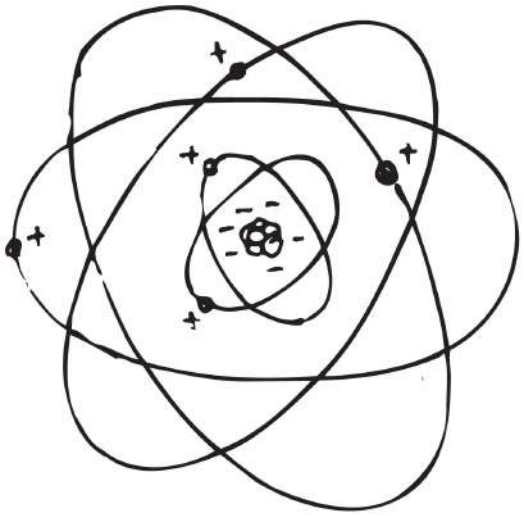


Molecules, Continued

- Chemical reaction:
  - A process in which atoms rearrange to form different molecules
  - Example:
    - Pulling molecules apart requires energy.
      - During photosynthesis, sunlight's energy breaks bonds of CO_2 to produce O_2 and C.
    - Combining atoms releases energy.
      - Oxygen atoms combine with iron atoms to form rust.

Antimatter

- Matter:
  - Composed of atoms with positive nuclei and negative electrons
- Antimatter:
  - Composed of atoms with negative nuclei and positive electrons (positrons)
- Both matter and antimatter cannot exist in our environment.



Antimatter, Continued

- Positrons
  - have the same mass as an electron but are positively charged.
- Antiprotons
  - have the same mass as protons but are negatively charged.

Dark Matter

- Dark matter
  - is unseen and unidentified matter very different from the elements that comprises about 23% of matter in the universe.
- Dark energy
  - is an antigravity energy comprising 73% of the universe.

Dark Matter, Continued

- Finding the nature of the dark matter and the nature of the energy of empty space are high-priority quests in these times.
- What we will have learned by 2050 will likely dwarf all that we have ever known.