The Beginnings of Atomic Theory

- Who came up with the first theory of atoms?
- In the fourth century BCE, the Greek philosopher Democritus suggested that the universe was made of indivisible units called atoms.

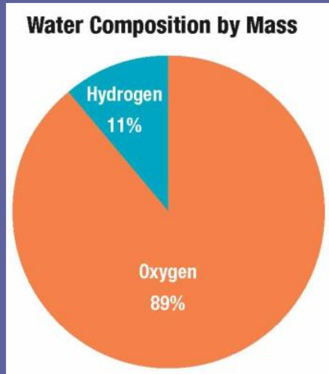
- Democritus did not have evidence for his atomic theory.

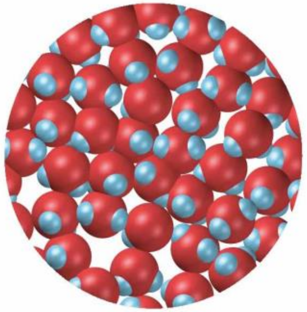
Dalton's Atomic Theory

- What did Dalton add to the atomic theory?
- According to Dalton, all atoms of a given element were exactly alike, and atoms of different elements could join to form compounds.

Dalton's Atomic Theory, *continued*

- Dalton used experimental evidence.
  - *Law of definite proportions:* A chemical compound always contains the same elements in exactly the same proportions by weight or mass.





For any given water sample, the proportions of hydrogen and oxygen by mass are constant.

This fact suggests that water molecules are made up of atoms that combine in simple whole-number ratios to form compounds.

- Dalton's theory did not fit all observations

Thomson's Model of the Atom

- How did Thomson discover the electron?
- Thomson's cathode-ray tube experiment suggested that cathode rays were made of negatively charged particles that came from inside atoms.

Thomson's Model of the Atom, *continued*

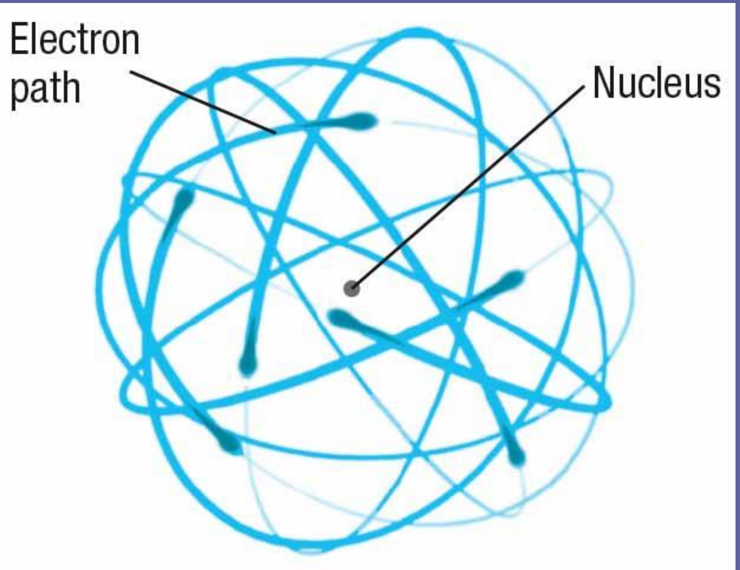
- Thomson developed the plum-pudding model.
  - In his cathode-ray tube experiment, Thomson had discovered electrons.
    - **electron:** a subatomic particle that has a negative charge
  - Thomson's *plum-pudding model:* electrons are spread throughout the atom, like blueberries in a muffin

Rutherford's Model of the Atom

- What is Rutherford's atomic model?
- Rutherford proposed that most of the mass of the atom was concentrated at the atom's center.

Rutherford's Model of the Atom, *continued*

- Rutherford conducted the gold-foil experiment.
- Rutherford discovered the nucleus.
  - **nucleus:** an atom's central region, which is made up of protons and neutrons



The Rutherford model of the atom

What Is in an Atom?

- What is the difference between protons, neutrons, and electrons?

- The three main subatomic particles are distinguished by mass, charge, and location in the atom.

Particle	Charge	Mass (kg)	Location in the atom
Proton	+1	1.67×10^{-27}	in the nucleus
Neutron	0	1.67×10^{-27}	in the nucleus
Electron	–1	9.11×10^{-31}	outside the nucleus

What Is in an Atom?, *continued*

- Each element has a unique number of protons.
- Unreacted atoms have no overall charge.
  - Because there is an equal number of protons and electrons, the charges cancel out.
- The electric force holds the atom together.
  - Positive protons are attracted to negative electrons by the *electric force.*
  - This force holds the atom together.

Atomic Number and Mass Number

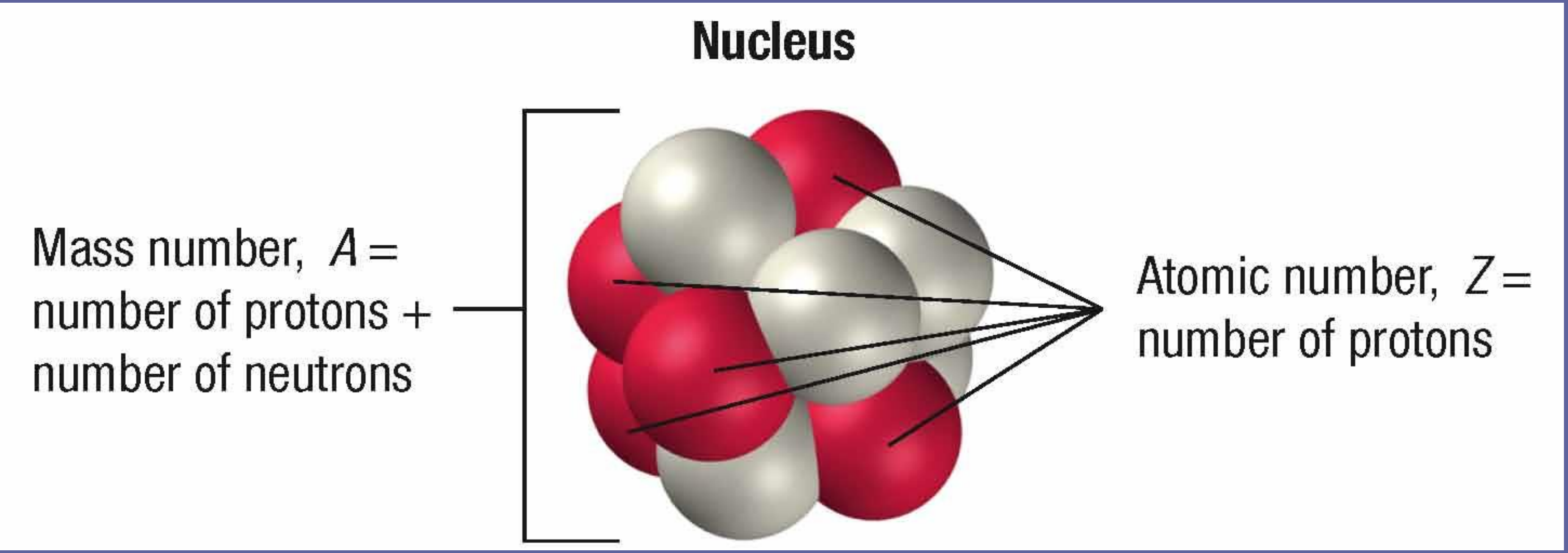
- What do atoms of an element have in common with other atoms of the same element?

- Atoms of each element have the same number of protons, but they can have different numbers of neutrons.

Atomic Number and Mass Number, *continued*

- The atomic number equals the number of protons.
  - **atomic number:** the number of protons in the nucleus of an atom
- The mass number equals the total number of subatomic particles in the nucleus.
  - **mass number:** the sum of the numbers of protons and neutrons in the nucleus of an atom

Atomic Number and Mass Number, *continued*

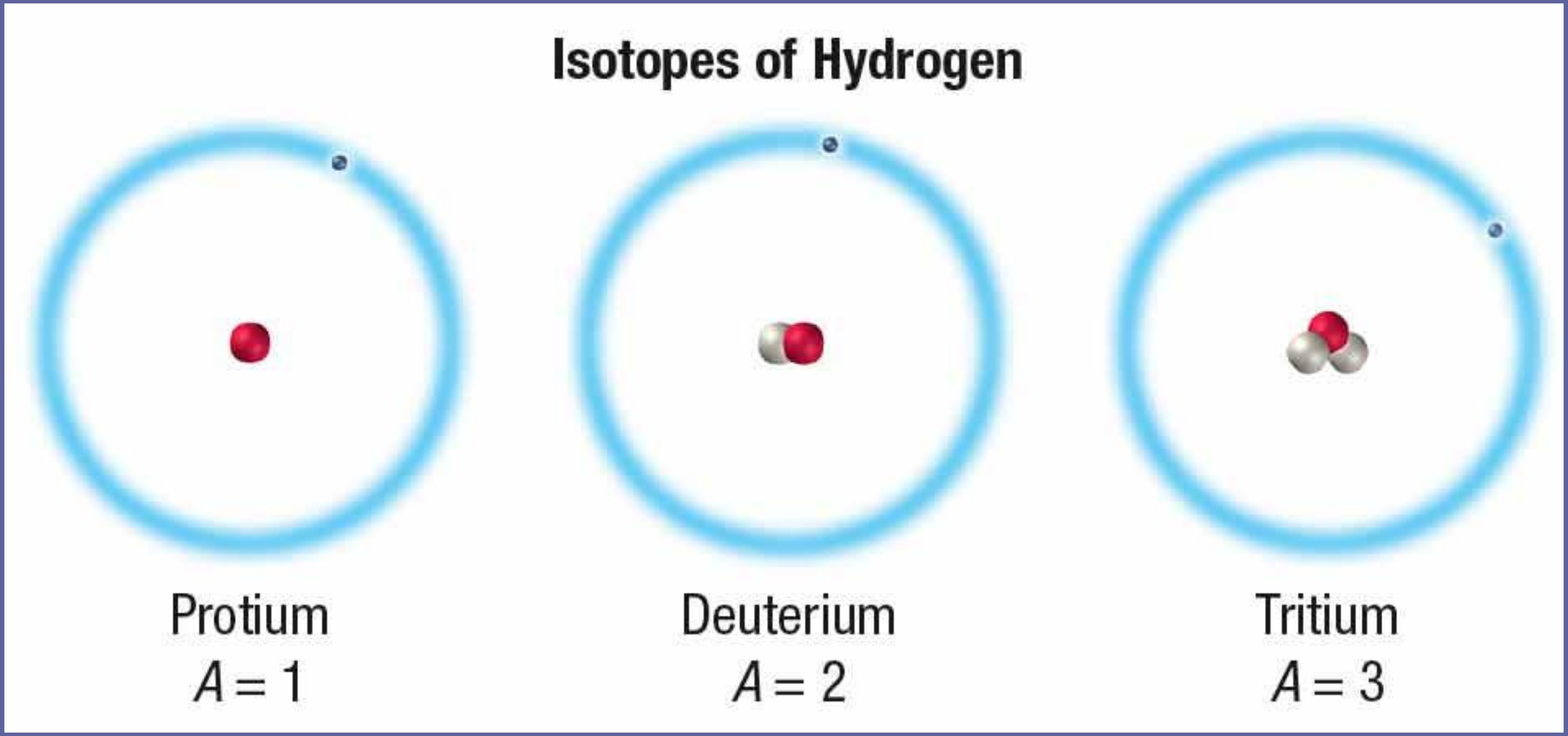


Isotopes

- Why do isotopes of the same element have different atomic masses?

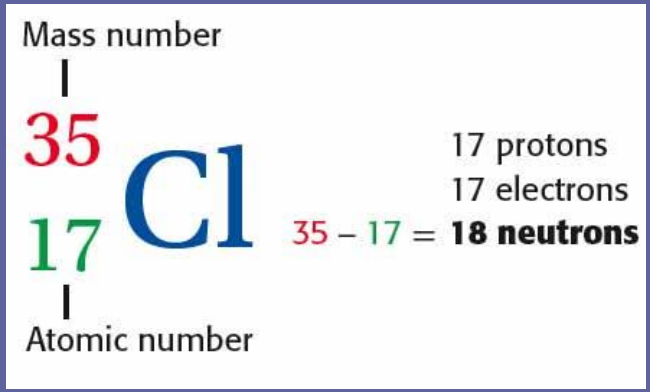
- Isotopes of an element vary in mass because their numbers of neutrons differ.

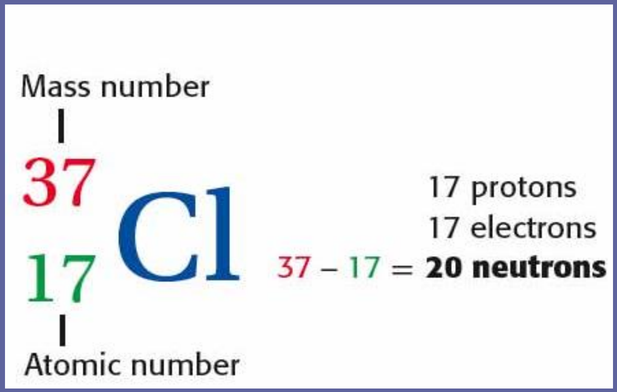
Isotopes, *continued*



Isotopes, *continued*

- Some isotopes are more common than others.
  - *radioisotopes:* unstable isotopes that emit radiation and decay into other isotopes
- The number of neutrons can be calculated.
  - number of neutrons = mass number – atomic number





Atomic Masses

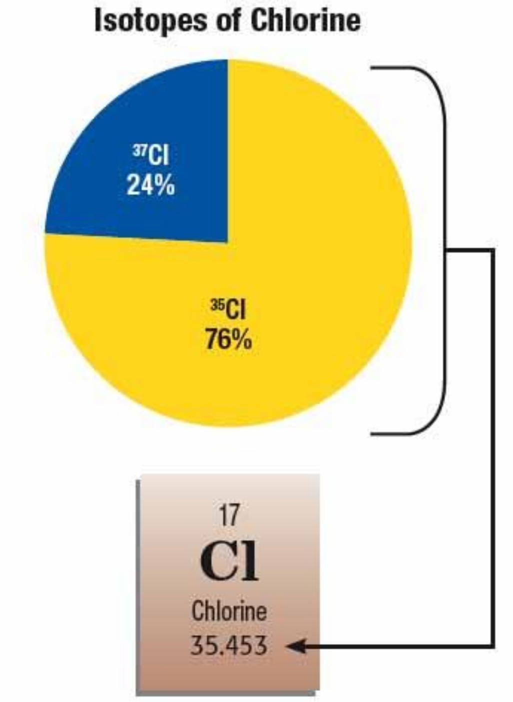
- What unit is used to express atomic mass?

- Because working with such tiny masses is difficult, atomic masses are usually expressed in unified atomic mass units.

- **unified atomic mass unit:** a unit of mass that describes the mass of an atom or molecule; it is exactly 1/12 the mass of a carbon atom with mass number 12 (symbol, u)

Atomic Masses, *continued*

- Average atomic mass is a weighted average.
  - Isotope abundance determines the average atomic mass.
  - Example: Chlorine-35 is more abundant than chlorine-37, so chlorine's average atomic mass (35.453 u) is closer to 35 than to 37.



Note: Calculations using the values from the pie graph do not give a result of exactly 35.453 u because of rounding.

Atomic Masses, *continued*

- The mole is useful for counting small particles.

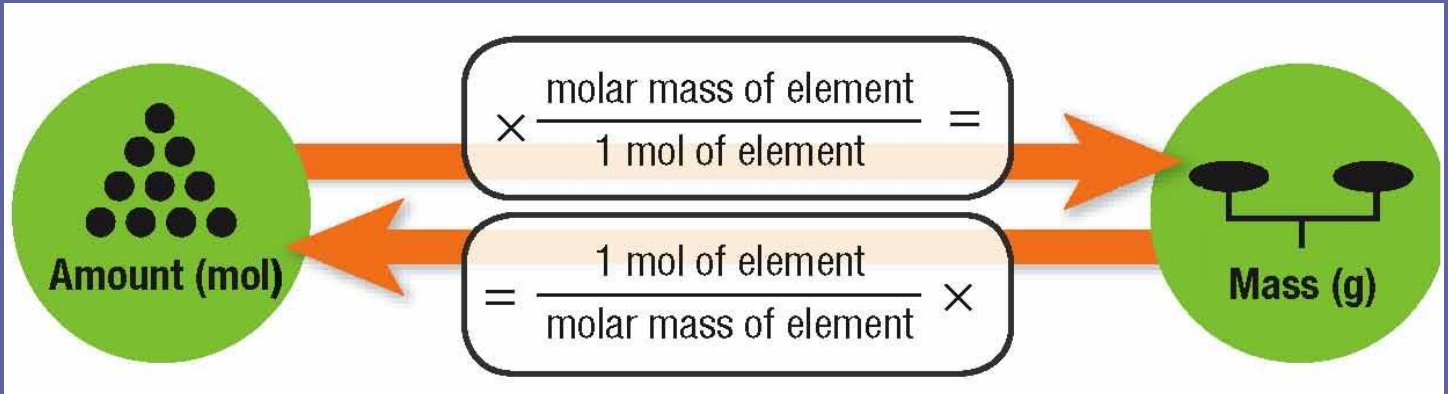
- **mole:** the SI base unit used to measure the amount of a substance whose number of particles is the same as the number of atoms of carbon in exactly 12 g of carbon-12 (abbreviation, mol)

  - 1 mol = 602, 213, 670, 000, 000, 000, 000, 000 particles

  - This number, usually written as 6.022×10^{23}, is called *Avogadro's number.*

Atomic Masses, *continued*

- Moles and grams are related.
  - *molar mass* = the mass in grams of one mole of a substance
  - Example: 1 mol of carbon-12 atoms has a mass of 12.00 g, so the molar mass of carbon-12 is 12.00 g/mol
- You can convert between moles and grams.



Math Skills

Converting Moles to Grams

Determine the mass in grams of 5.50 mol of iron.

1. List the given and unknown values.

Given: amount of iron = 5.50 mol Fe
molar mass of iron = 55.84 g/mol Fe*

Unknown: mass of iron = ? g Fe

*Use the periodic table to find molar masses. The average atomic mass of an element is equal to the molar mass of the element. This book rounds values to the hundredths place.

Math Skills, *continued*

2. Write down the conversion factor that converts moles to grams.

The conversion factor you choose should have what you are trying to find (grams of Fe) in the numerator and what you want to cancel (moles of Fe) in the denominator.

$$\frac{55.84 \text{ g Fe}}{1 \text{ mol Fe}}$$

3. Multiply the amount of iron by this conversion factor, and solve.

$$5.50 \text{ mol Fe} \times \frac{55.84 \text{ g Fe}}{1 \text{ mol Fe}} = \boxed{307 \text{ g Fe}}$$

Atomic Masses, *continued*

- Compounds also have molar masses.

  – To find the molar mass of a compound, add up the molar masses of all of the atoms in a molecule of the compound.

  – Example: finding the molar mass of water, H_2O
    - molar mass of O = 16.00 g/mol
    - molar mass of H = 1.01 g/mol
    - molar mass of H_2O = (2 × 1.01 g/mol) + 16.00 g/mol = 18.02 g/mol

Modern Models of the Atom

- What is the modern model of the atom?
- In the modern atomic model, electrons can be found only in certain energy levels, not between levels. Furthermore, the location of electrons cannot be predicted precisely.

Modern Models of the Atom, *continued*

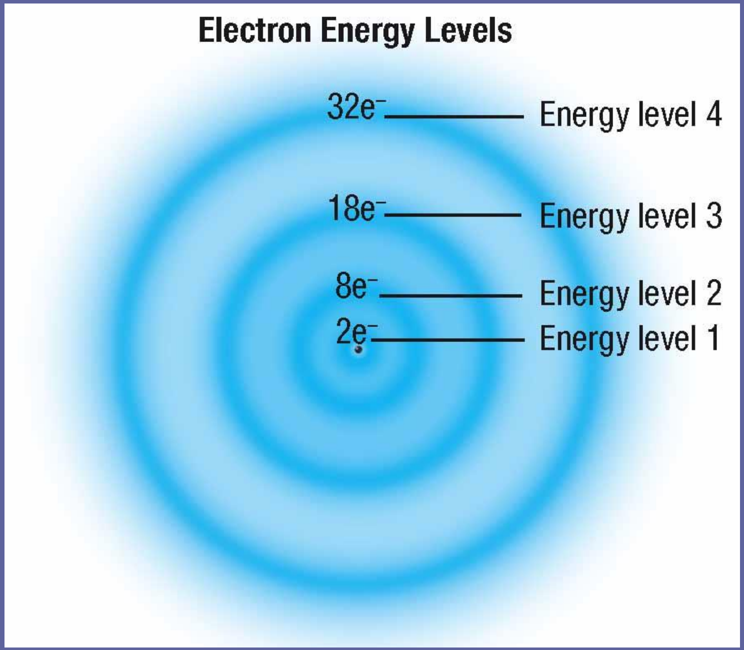
- Electron location is limited to energy levels.
  - In Bohr's model, electrons can be in only certain energy levels.
  - They gain energy to move to a higher energy level or lose energy to move to a lower energy level.

Modern Models of the Atom, *continued*

- Electrons act like waves.
- The exact location of an electron cannot be determined.
- **orbital:** a region in an atom where there is a high probability of finding electrons

Electron Energy Levels

- How are the energy levels of an atom filled?
- The number of energy levels that are filled in an atom depends on the number of electrons.



- **valence electron:** an electron that is found in the outermost shell of an atom and that determines the atom's chemical properties

Electron Energy Levels, *continued*

- There are four types of orbitals.
  - Orbital types are s, p, d, and f.
  - Each orbital can hold 2 electrons.

- Orbitals determine the number of electrons that each level can hold.

Energy level	Number of orbitals by type				Total number of orbitals		Number of electrons
	s	p	d	f			
1	1				1 = 1	× **2** =	2
2	1	3			1 + 3 = 4		8
3	1	3	5		1 + 3 + 5 = 9		18
4	1	3	5	7	1 + 3 + 5 + 7 = 16		32

Electron Transitions

- What makes an electron jump to a new energy level?
- Electrons jump between energy levels when an atom gains or loses energy.

Electron Transitions, *continued*

- The lowest state of energy of an electron is called the *ground state.*
- If an electron gains energy by absorbing a photon, it moves to an *excited state.*
  - **photon:** a unit or quantum of light
- The electron releases a photon when it falls back to a lower level.
- Photons have different energies. The energy of a photon corresponds to the size of the electron jump.

Electron Transitions, *continued*

- Atoms absorb or emit light at certain wavelengths.
  - Because each element has a unique atomic structure, the wavelengths emitted depend on the particular element.
  - So, the wavelengths are a type of “atomic fingerprint” that can be used to identify the substance.