Warm-Up | The Structure of the Atom

Lesson Objectives

By the end of this lesson, you should be able to:

- Describe the structure of atoms, and discriminate between the relative sizes and electrical charges of protons, neutrons, and electrons.
- Explain that protons and neutrons have substructures and consist of particles called quarks.
- Identify an element based on the number of protons in an atom.
- Explain the relationship between the number of neutrons in an atom of an element, its mass number, and its isotopes.

Science Practice: Use math to calculate the average atomic mass of an element from its isotopic composition.

Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

atom	the smallest particle of an element that has the same properties as the element
atomic mass	the mass of a single atom, which is approximately equal to the total mass of the protons and neutrons in an atom
atomic mass unit	A measurement equal to one-twelfth the mass of a C-12 atom; corresponds to $1.660538921 \times 10^{-24}$ g
atomic number	the number of protons in the nucleus of an atom
electron	a negatively charged particle in the orbitals surrounding the nucleus of the atom
average atomic mass	the weighted average mass of all isotopes of an element

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W2K

Words to Know

isotope	an atom of the same element that has a different mass number
mass number	the number of protons and neutrons in the nucleus of an atom
neutron	a neutral particle in the nucleus of an atom
nucleus	the center of the atom, which holds the protons and neutrons
orbitals	the regions that surround the nucleus and in which the electrons are located
proton	a positively charged particle in the nucleus of an atom
quark	a small particle that makes up protons and neutrons

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Lesson Question

What is the structure of the atom?

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The Atom

An **atom** is the smallest [particle] of an element that has the same properties as the element.

The atom can be divided into two parts:

- [Nucleus]: The center of the atom that holds the protons and neutrons.
- [Orbitals]: Regions surrounding the nucleus in which the electrons are located.

Charged Particles in the Atom

The atom is made of three particles: protons, electrons, and neutrons.

[Protons] are a positively charged particle in the nucleus of an atom	[Electrons] are a negatively charged particle in the orbitals surrounding the nucleus of the atom	[Neutrons] are the neutral particle in the nucleus of an atom

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Location is Everything

Nucleus

- [Protons]
- Neutrons

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Location is Everything

Orbitals

- Electrons

Different [elements] = different particle counts and arrangements

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Atomic Mass Unit

The **atomic mass unit** is the unit used to express the [mass] of an atom.

- [One-twelfth] the mass of a C-12 atom
- Corresponds to $1.660538921 \times 10^{-24}$ g

The Size of Subatomic Particles

Proton

- Mass: 1.673×10^{-24} g
- Mass: 1 amu

[Neutron]

- Mass: 1.675×10^{-24} g
- Mass: 1 amu

Electron

- Mass: 9.109×10^{-28} g
- Mass: [0.0006] amu

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Particles That Make Up the Proton and Neutron

Quarks are small [particles] that make up protons and [neutrons].

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What is the structure of the atom?

Atomic number (Z)

- Number of [protons] in an atom
- Differs for each [element]
- Increases across a row in the [periodic] table
  - Periodic table shows atomic number

13	14
Al	Si
Aluminum	Silicon
26.98	28.09

Every atom of a given element has the same atomic number, and atomic number can be used to identify an element.

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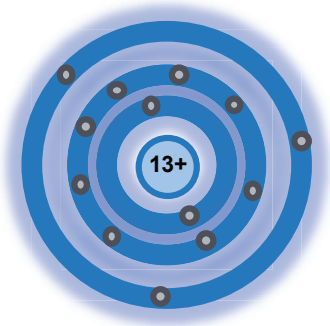
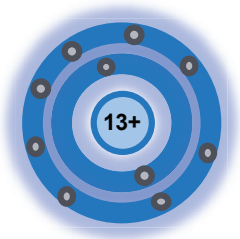
Number of Electrons

The number of electrons in an [atom] can vary.



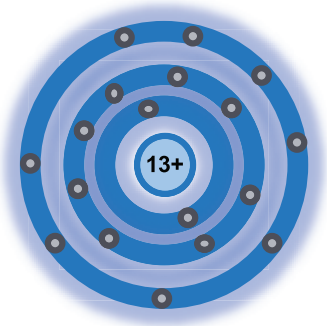
$+13 + (-13) = 0$

[Neutral]



$+13 + (-10) = +3$

[Positively charged]



$+13 + (-18) = -5$

[Negatively charged]

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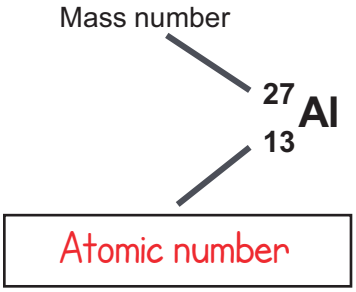
Mass Number

Mass number (*A*)

- The number of [protons] and neutrons in the nucleus of an atom
- Can vary from atom to atom



$N = A - Z$

$N = 27 - 13 = 14$ neutrons

Ways to represent an [atom]:

- aluminum-27
- [Al-27]
- ^{27}Al

All atoms of an element have the same atomic number, but atoms of the same element can have different mass numbers.

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Isotopes

Isotopes

- Atoms of the same element with different mass numbers.
  - Number of protons are the [same]
  - Number of electrons are the [same]
  - Number of neutrons are [different]

Isotope	*N*	*Z*	*A*
Al-24	11	13	24
Al-25	12	13	25
Al-26	13	13	26
Al-27	14	13	27
Al-28	15	13	28
Al-29	16	13	29
Al-30	17	13	30

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Atomic Mass

Atomic mass: The mass of a single atom; approximately equal to the total mass of the protons and [neutrons] in an atom.

- Mass of a single atom
- Mass of [electron] is negligible

Mass of atom ≈ mass of [protons] + mass of neutrons

Average Atomic Mass

The **average atomic mass** is the weighted [average] mass of all [isotopes] of an element.

Abundance of aluminum isotopes:

- 100% is from Al-27

Abundance of silicon isotopes:

- 92.2297% is from Si-28
- 4.6832% is from [Si-29]
- 3.0872% is from Si-30

13	14
Al	Si
[Aluminum]	Silicon
26.98	28.09

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How to Calculate Average Atomic Mass

$$M_A = (M_1)(P_1) + (M_2)(P_2) + \ldots + (M_n)(P_n)$$

- M_A = average atomic [mass]
- M_1, M_2, etc. = atomic mass of isotope 1, isotope 2, etc.
- P_1, P_2, etc. = fractional abundance of isotope 1, isotope 2, etc.

[Chlorine] isotopes:

- Cl-35, 34.96885 amu: 75.78%
- Cl-37, 36.96590 amu: 24.22%

$$M_A = (M_1)(P_1) + (M_2)(P_2) = (34.96885)(0.7578) + (36.96590)(0.2422) = \text{35.45 amu}$$

Summary | The Structure of the Atom

Lesson Question

What is the structure of the atom?

Answer

(Sample answer) Atoms are made up of protons, neutrons, and electrons. The protons and neutrons sit in the center of the atom and the electrons orbit around this central mass.

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Properties of Subatomic Particles

Subatomic Particle	Charge	Location	Mass	Made of quarks?
Proton	+1	Nucleus	~ 1 amu	Yes
Neutron	0	Nucleus	~ 1 amu	Yes
Electron	–1	Orbitals	~0.0006 amu	No

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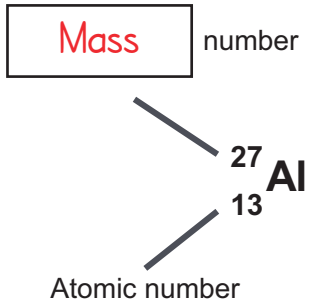
How to Identify Elements

The atomic number:

- is the number of protons.
- is unique to a given [element].
- is represented by *Z*.



The mass number:

- is the number of protons + number of [neutrons].
- can vary within an element.
- is represented by *A*.

Isotopes

Isotopes of the same element have:

- the same [atomic] number.
- different mass numbers.

[Average] atomic mass of an element is calculated using:

- the mass of each naturally occurring isotope.
- the relative abundance of each naturally occurring [isotope].

Summary | The Structure of the Atom

Use this space to write any questions or thoughts about this lesson.