Summary & Practice Sheets
Grade 9 - Integrated

Introduction to Chemistry
Analyzing Data

The Structure of the Atom
Electrons in Atoms

A Story of Two Substances: Introducing Chemistry

What is Chemistry?

Chemistry is the scientific study of the composition and properties of matter.

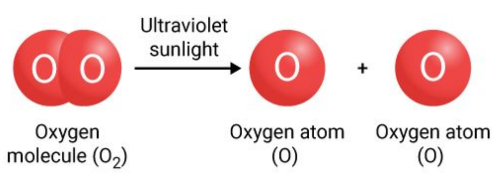
Types of Substances

A substance is a kind of matter with uniform composition and properties. It can be classified into natural and synthetic substances.

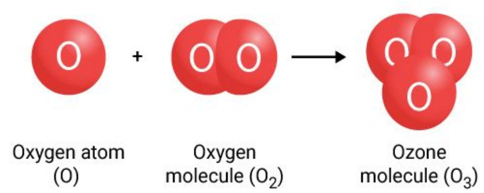
Type of Substance	Natural Substance	Synthetic Substance
Example of Substance	ozone (O_3)	chlorofluorocarbon (CFC)
Origin	produced in Earth's stratosphere	produced in laboratory
Uses	shields Earth from the Sun's harmful radiation	used in aerosol sprays, foam food packaging, coolant for air-conditioners and refrigerators

Formation of Ozone

Step 1

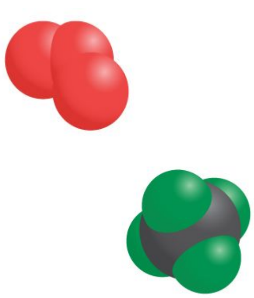


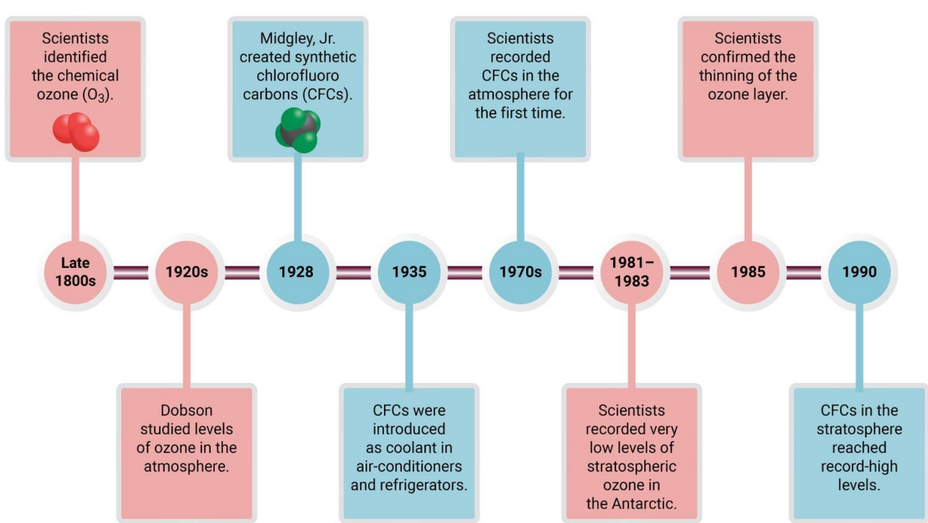
Step 2



Impact of chlorofluorocarbons (CFCs)

Chemistry helped us to understand the thinning of the ozone layer and linked it to increased levels of stratospheric CFCs.



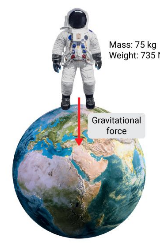


Chemistry and Matter

Measuring Matter

Scientists study matter and need to compare measurements around the world. Matter refers to any physical substance with mass and that takes up space.

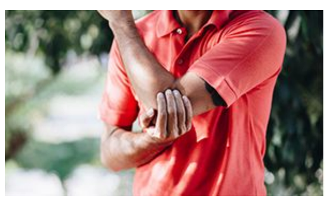
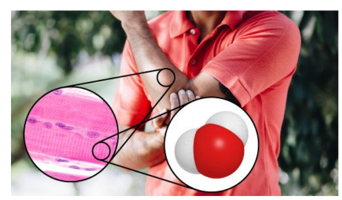
Physical Quantity	Mass	Weight
What Is Measured?	amount of matter in an object	gravitational force pulling on an object with mass
SI Unit of Measurement	kilograms (kg)	newtons (N)
Dependent on Gravity	no	yes



Scientists use mass to measure matter as it is not dependent on gravity.

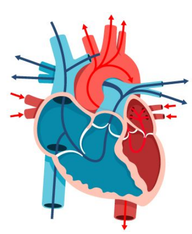
Observing Matter

Scientists use observations to describe matter at three levels.

Level of Observation	Macroscopic Level	Microscopic Level	Submicroscopic Level
Description	objects visible to the naked eye	objects too small to see with the naked eye	objects too small to see even with an optical microscope
Example	 elbow	 muscle tissue	 water molecule

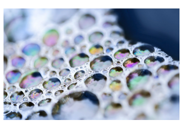
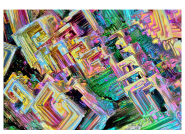
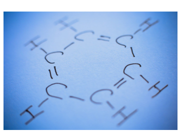
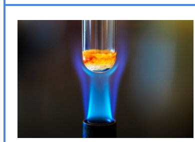
Explaining Observations of Matter Using Scientific Models

A model is a visual representation of something that is too difficult to see or understand.

Type of Model	Physical Model	Visual Model	Mathematical Model
Description	model that you can see and touch	diagram or illustration that explains an idea	model made up of data or equations
Example			$E = mc^2$

Studying Different Types of Matter

Chemistry is considered a central science. Scientists study the composition and properties of many different types of matter. Chemistry is divided into different branches based on the area of study.

Branch of Chemistry		Area of Study
	analytical chemistry	composition and structure of matter
	biochemistry	structure and chemical reactions of substances in living organisms
	environmental chemistry	presence, movement, and impact of chemicals in the environment
	industrial chemistry	chemical reactions used in industrial manufacturing processes
	inorganic chemistry	properties and behavior of inorganic compounds
	organic chemistry	structure, properties, and composition of carbon-containing compounds
	physical chemistry	chemical reactions and the physical properties of atoms and molecules
	polymer chemistry	composition of large, complex molecules (called polymers)
	thermochemistry	heat released or absorbed during chemical reactions

Scientific Methods

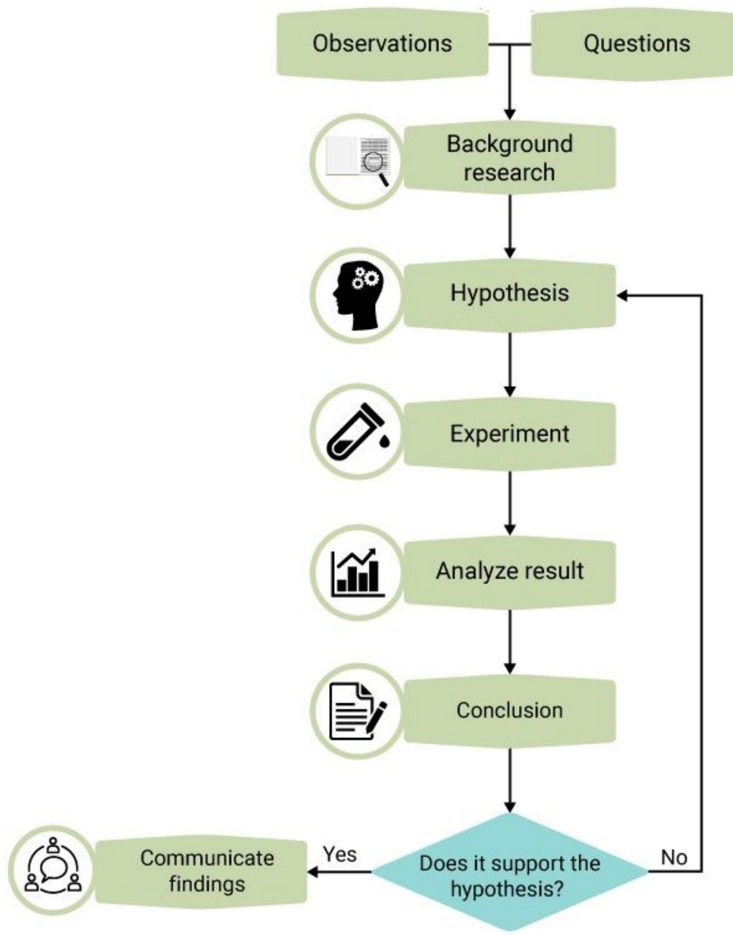
Scientific Method

The scientific method is an organized, systematic approach to solving a scientific question.

Independent Variable
factor that is changed or controlled during the experiment; does not depend on another variable

Dependent Variable
factor that is measured during the experiment;
depends on the independent variable

Control
sample that stays the same throughout the whole experiment;
standard used for comparison



Types of Observations

Different observations are made to gather data during an experiment.

Types of Data	Qualitative Data	Quantitative Data
Description	data based on observations using your senses	data that can be measured and presented numerically
Examples	color, smell, sound	mass, volume, length

Scientific Theory and Scientific Law

- A scientific theory is a hypothesis based on multiple investigations over time.
- A scientific law is a description of a phenomenon based on multiple investigations over time.

Scientific Research

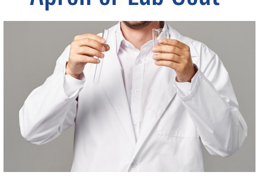
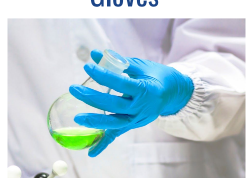
Types of Scientific Investigations

- Pure research is done to make discoveries and gain new knowledge.
- Applied research is done to solve a specific problem.

Laboratory Safety Symbols and Their Meanings

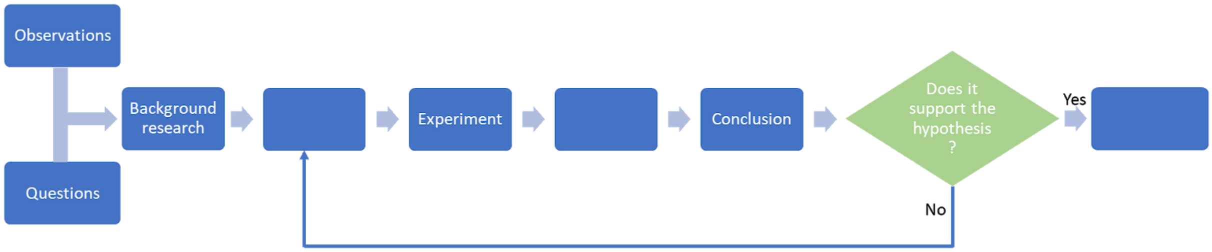
 biological organisms and tissue can be harmful to humans	 corrosive chemicals can burn and destroy human tissue	 electrical equipment can cause electrical shock or burns
 flammable substances can catch fire easily	 chemical fumes can harm the eyes and respiratory tract	 harmful chemicals can irritate the skin and/or respiratory tract
 radioactive materials are very dangerous	 sharp objects can cut and slice the skin	 toxic chemicals can be poisonous to plants and animals

Laboratory Safety Equipment

Apron or Lab Coat	Goggles	Gloves	Protective Gloves	Mask
 protects skin and clothing from chemicals and biological materials	 protects eyes from chemicals, fumes, and sharp objects	 protects hands from chemicals and biological materials	 protects hands from extreme heat and cold	 prevents the inhalation of fumes and fungal spores

PRACTICE: Introduction to Chemistry

1. Fill in the missing parts about the scientific method.



2. ________ objects are too small to see with the naked eye.

   a. Big
   b. Small
   c. Microscopic
   d. Physical

3. Group the following into natural or synthetic substances.
   ozone   water   chlorofluorocarbon   plastic

Synthetic Substances	Natural Substances

4. Explain why scientists use models to describe submicroscopic events.

____

____

____

5. Identify the meaning of the following safety symbol.

   a. Wear protective clothing.
   b. Use caution when handling hot objects.
   c. Do not wear a necklace.
   d. Do not eat in the lab.

6. Match each of the following physical quantities with what is measured.

mass	gravitational force pulling on an object with mass
weight	amount of space occupied by an object
	amount of matter in an object
	amount of mass per unit volume

7. Select two examples of qualitative observation.

a. color

b. volume

c. mass

d. sound

8. Choose the branch of chemistry that focuses on the composition and structure of matter?

a. industrial chemistry

b. organic chemistry

c. polymer chemistry

d. analytical chemistry

9. Differentiate between a scientific theory and a scientific law.

A scientific theory

____

____

A scientific law

____

____

10. _______________ is the scientific study of the composition and properties of matter.

11. Select the group of elements found in chlorofluorocarbon?

a. chlorine, carbon, nitrogen

b. carbon, chlorine, fluorine

c. hydrogen, oxygen, fluorine

d. chlorine, fluorine, sodium

12. Select where the ozone layer is located in the Earth's atmosphere.

   a. troposphere
   b. mesosphere
   c. stratosphere
   d. thermosphere

Choose from the following to match the descriptions below.

control   independent variable   dependent variable   suspended variable

13. ____________________ factor that is changed or controlled during the experiment; does not depend on another variable

14. ____________________ factor that is measured during the experiment; depends on the independent variable

15. ____________________ sample that stays the same throughout the whole experiment; standard used for comparison

Units and Measurement

SI Base Units

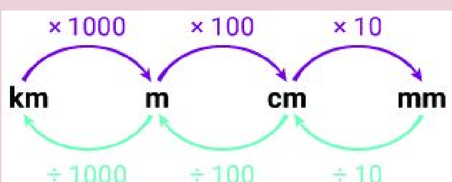
Scientists use the international system of units or **SI units** to communicate scientific data.

SI Base Unit	Symbol	Quantity Measured
meter	m	length
second	s	time
kelvin	K	temperature
candela	cd	luminous intensity
mole	mol	amount of a substance
ampere	A	electric current
kilogram	kg	mass

SI Prefixes

Change base units into larger or smaller units using **prefixes**.

EXAMPLE
Convert the base unit meter into:
- larger units using the prefix kilo-
- smaller units using the prefixes centi-, and milli-.



Converting Between Temperature Scales

The three common temperature scales used are Fahrenheit, Celsius, and Kelvin.

Kelvin-Celsius conversion equation:

$$K = °C + 273$$

Fahrenheit-Celsius conversion equation:

$$°F = 1.8(°C) + 32$$

Derived Units

Units of measurements that combine base units are called **derived units**.

Physical Quantity	Volume	Density
What Is Measured?	amount of space an object takes up	measure of mass per unit volume
Derived Unit of Measurement	cubic centimeters (cm^3)	grams per cubic centimeter (g/cm^3)
Calculating the Physical Quantity	Volume of regularly shaped object: volume = width × length × height Volume of irregularly shaped object: volume = volume of water displaced	Density equation: $\text{density} = \dfrac{\text{mass}}{\text{volume}}$

Scientific Notation and Dimensional Analysis

Scientific Notation

It is easier to express very big or very small numbers using scientific notation. In scientific notation, a number is expressed as a coefficient multiplied by 10 raised to an exponent.

$$C \times 10^{n}$$

KEY:
coefficient: any number between 1 and 10
base: always the number 10
exponent: positive or negative integer

Writing Numbers in Scientific Notation

Steps		Positive Exponent	Negative Exponent
Step 1	Move the decimal point of the number until the number is between 1 and 10.	514,000	0.00000082
Step 2	Count the number of places the decimal point moved to determine the exponent. If the decimal point moves to the: • left, the exponent is positive • right, the exponent is negative	514,000. n = (5) 4 3 2 1	0.00000082 n = 1 2 3 4 5 6 (7)
Step 3	Write the number in scientific notation.	5.14×10^{5}	8.2×10^{-7}

Addition and Subtraction of Numbers in Scientific Notation

If the exponents are the same:		Addition	Subtraction
Step 1	Check that the exponents are the same.	$(4.3 \times 10^{4}) + (2.1 \times 10^{4})$	$(5.8 \times 10^{2}) - (1.7 \times 10^{2})$
Step 2	Add or subtract the coefficients.	$4.3 + 2.1 = 6.3$	$5.8 - 1.7 = 4.1$
Step 3	Combine parts to write the answer.	6.3×10^{4}	4.1×10^{2}

If the exponents are NOT the same:		Addition	Subtraction
Step 1	Convert the numbers to the value of the biggest component.	$(3.3 \times 10^{4}) + (3.2 \times 10^{2})$ $(3.3 \times 10^{4}) + (0.032 \times 10^{4})$	$(7.8 \times 10^{5}) - (4.3 \times 10^{4})$ $(7.8 \times 10^{5}) - (0.43 \times 10^{5})$
Step 2	Add or subtract the coefficients.	$3.3 + 0.032 = 3.332$	$7.8 - 0.43 = 7.37$
Step 3	Combine parts to write the answer.	3.332×10^{4}	7.37×10^{5}

Multiplication and Division of Numbers in Scientific Notation

The exponents don't have to be the same.		Multiplication	Division
Step 1	Write down the problem.	$(1.7 \times 10^4) \times (2.2 \times 10^2)$	$(7.8 \times 10^5) \div (2 \times 10^{-3})$ Dividend: (7.8×10^5) Divisor: (2×10^{-3})
Step 2	Multiply or divide the coefficients.	1.7 × 3.2 = 3.74	7.8 ÷ 2 = 3.9
Step 3	Add or subtract the exponents.	4 + 2 = 6	Subtract exponent of the divisor from that of dividend: 5 − (−3) = 5 + 3 = 8
Step 4	Combine parts to write the answer.	3.74×10^6	3.9×10^8

Dimensional Analysis

- Use **dimensional analysis** to convert from one unit to another.
- A **conversion factor** is a ratio written to show the relationship between two different units. It is always equal to 1.

EXAMPLE

- The unit of time can be written in minutes or seconds.
- There are 60 seconds in 1 minute (60 seconds = 1 minute).
- The conversion factors are shown alongside.

Time can be converted from seconds into minutes by multiplying it with a conversion factor.

Use a conversion factor to write 192 seconds in minutes:

$$192 \text{ seconds} \times \frac{1 \text{ minute}}{60 \text{ seconds}} = 3.2 \text{ minutes}$$

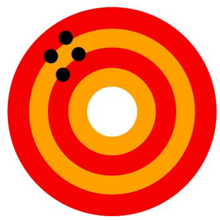
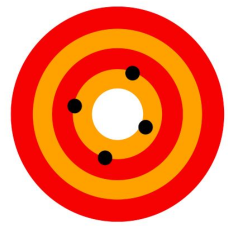
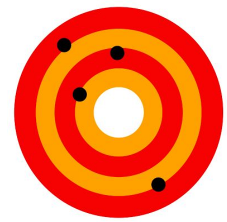
The unit of time changes, but not its value!

Conversion Factors	
$\frac{60 \text{ seconds}}{1 \text{ minute}}$	$\frac{1 \text{ minute}}{60 \text{ seconds}}$

Uncertainty in Data

Accuracy and Precision

- Accuracy is how close a measurement is to the known or accepted value.
- Precision is how close a set of measurements are to one another.

High Accuracy High Precision	Low Accuracy High Precision	High Accuracy Low Precision	Low Accuracy Low Precision
			

Error and Percent Error

Error Evaluate how accurate and reliable experimental data is.	**Percent Error** Evaluate how close a measurement is to the accepted value.
Error equation: error = experimental value − accepted value	Percent error equation: $\text{percent error} = \frac{\lvert\text{error}\rvert}{\text{accepted value}} \times 100$

Significant Figures

- Significant figures are the valid digits in a measurement. All nonzero digits are significant.
- Nonsignificant figures are any zero that acts as a placeholder.

Significant figures		Nonsignificant figures	
zeros between two nonzero digits	trailing zeros to RIGHT of decimal point	trailing zeros to LEFT of decimal point	leading zeros to RIGHT of decimal point
340.072	**340.0720**	**340**	**0.072**

The number of significant figures show the degree of precision of a measurement.

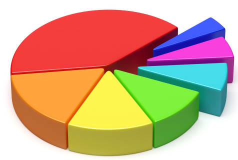
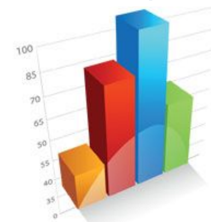
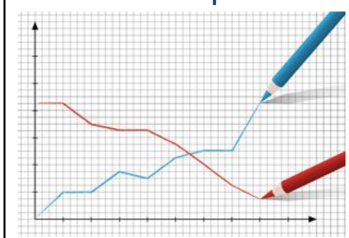
Rounding numbers

- Identify the measurement with the fewest significant figures.
- Add, subtract, multiply or divide measurements as required to calculate the answer.
- Round off the answer to have the same number of decimal places as the measurement with the fewest significant figures.

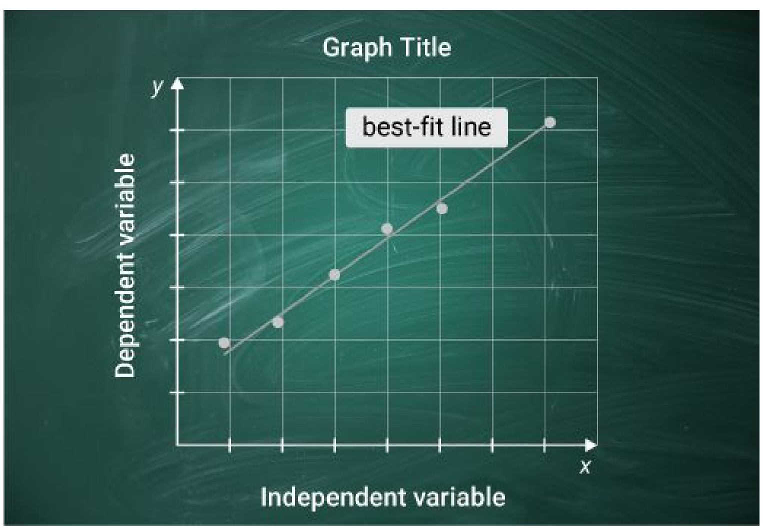
Representing Data

Types of Graphs

A graph is a diagram that represents data as a visual image or picture.

Type of Graph	Circle Graph	Bar Graph	Line Graph
			
Graph Shows ...	parts of a whole	how a factor varies over categories	how a variable changes over time
Type of Data	percentages of a distribution	discrete data	continuous data
Variable Plotted on *X*-Axis	–	categories	independent variable
Variable Plotted on *Y*-Axis	–	dependent variable	dependent variable

Structure of a Line Graph

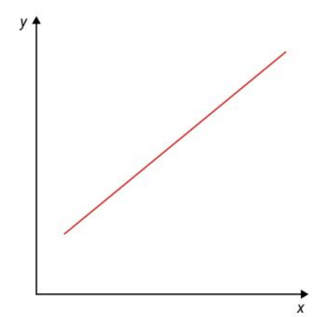


- The graph title summarizes the information represented in the graph.
- The dependent variable is plotted on the *y*-axis. It changes in response to changes in the independent variable.
- The independent variable is plotted on the *x*-axis. It is changed by the scientist during the experiment.
- The best-fit line is drawn through most of the data points. Half of the data points should be above the best-fit line and half below.

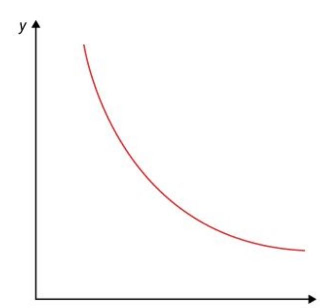
Relationship between variables

The shape of the best-fit line shows the relationship between variables.

straight-line → linear relationship

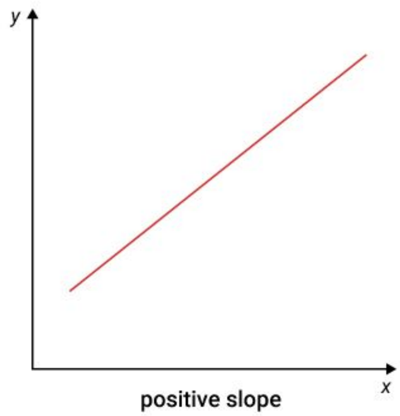
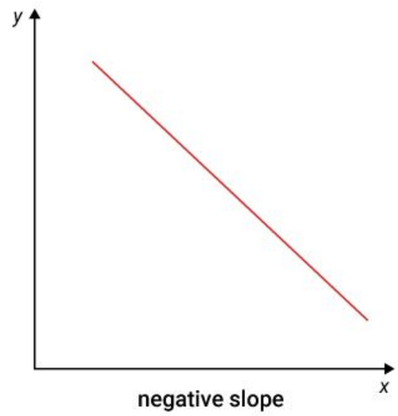


curved line → nonlinear relationship



Slope of a Straight-Line Graph

The slope of a straight-line graph is the steepness of the best-fit line.

Positive Slope	Negative Slope
independent variable *increase* dependent variable *increase*	independent variable *increase* dependent variable *decrease*
	

Calculating Slope
Slope is the ratio of the vertical change (rise) over the horizontal change (run).

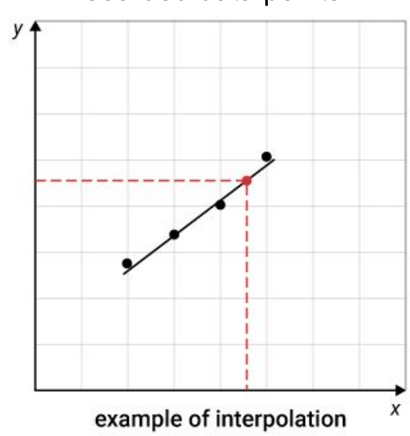
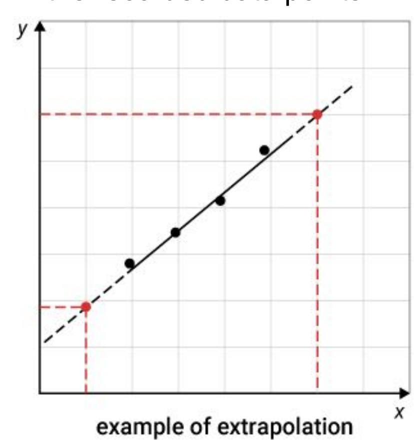
Slope equation:

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

The slope of a straight-line graph is always constant.

Interpolation and Extrapolation of Data

Line graphs show continuous data. You can estimate any point that falls between or outside the recorded data points.

Interpolation	Extrapolation
estimate the value of any point that falls BETWEEN two recorded data points	estimate the value of any point that falls BEFORE or AFTER the recorded data points
	

PRACTICE: Analyzing Data

1. Write 8.348×10^6 km in ordinary notation.

____

2. Using the conversion equation °F = 1.8(°C) + 32, the value of 48°C in °F is ______.

   a. 118.4

   b. 112

   c. 101.4

   d. 218.4

3. Select the SI base units from the list.

   a. meter (m)

   b. kelvin (K)

   c. square meter (m^2)

   d. kilogram (kg)

4. Use a conversion factor to write 255 seconds in minutes:

Conversion Factors	
$\frac{60 \text{ seconds}}{1 \text{ minute}}$	$\frac{1 \text{ minute}}{60 \text{ seconds}}$

5. There are _____ meters (m) in 0.5 km.

   a. 500 m

   b. 5,000 m

   c. 50 m

   d. 5 m

6. Identify the derived unit in the options given below.

   a. volume

   b. mass

   c. meter

   d. second

7. The table shows the data sets collected by three students during a practical class.

	Concentrations of an Unknown Solution		
	Hamad	**Sultan**	**Omar**
Trial 1	2.65 mol/dm^3	2.55 mol/dm^3	2.80 mol/dm^3
Trial 2	2.72 mol/dm^3	2.78 mol/dm^3	2.79 mol/dm^3
Trial 3	2.67 mol/dm^3	2.62 mol/dm^3	2.81 mol/dm^3
Average	**2.68 mol/dm^3**	**2.65 mol/dm^3**	**2.80 mol/dm^3**

Accepted value = 2.68 mol/dm^3

Identify which student's measurements were most precise.

   a. Omar

   b. Hamad

   c. Sultan

   d. Hamad and Sultan

8. Calculate the mass of aluminum that displaces 5.0 mL of water from a 25-mL graduated cylinder.

density of aluminum = 2.7 g/mL

volume of aluminum = 5.0 mL

mass = volume x _______

mass = ______ x 2.7 g/mL

mass = ______

9. Solve the following problem and write your answer in scientific notation.

$(4 \times 10^3) \times (3 \times 10^5)$

a. 12×10^8

b. 120×10^8

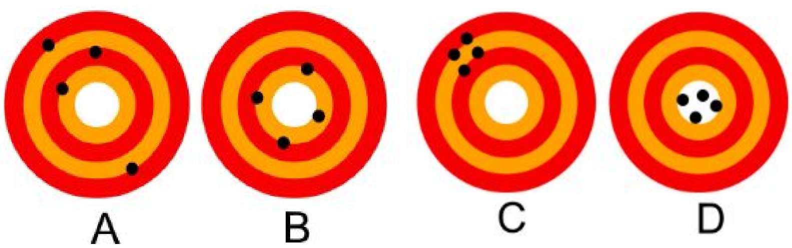
c. 1.2×10^9

d. 1.2×10^8

10. Complete the Kelvin-Celsius conversion equation:

_____ = °C + _____

11. Select the image that presents precision but no accuracy.



a. image A

b. image B

c. image C

d. image D

12. Express 1,547,000 in scientific notation.

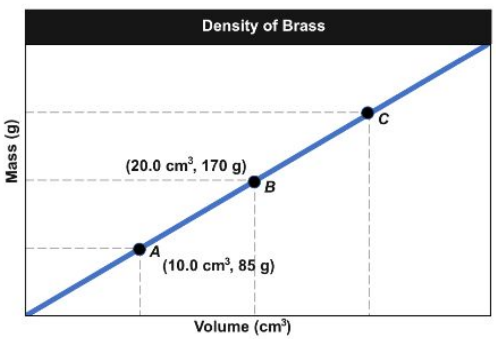
____

13. The average mass of a cup of date fruits is 5.66 g. Use dimension analysis to calculate how many cups of date fruits are there in 3.0 pounds of date fruits.

1 pound = 16 ounces
1 ounce = 28.3 g

14. Omar measured the length of his pencil and got 1,200 mm. Determine the number of significant figures in the measurement.

15. The slope of the line in the graph shows the density of brass. Determine the brass density.



a. 8.5 g/cm³

b. 85 g/cm³

c. 95 g/cm³

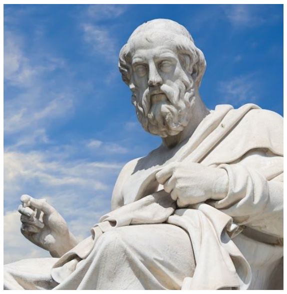
d. 9.5 g/cm³

16. Solve the following problem and write your answer in scientific notation.

$(8.4 \times 10^4) + (3.3 \times 10^2)$

Early Ideas About Matter

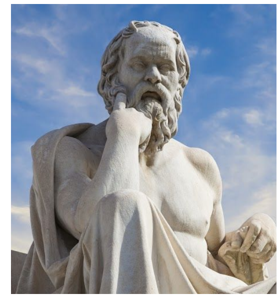
Ancient Philosophers



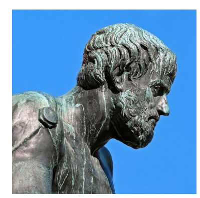
Early philosophers concluded that matter was made up of four elements:

- fire
- air
- earth
- water

Democritus was the first person to propose that matter could not be divided infinitely.



Greek Philosophers Democritus and Aristotle

Democritus (460–370 B.C.)	Aristotle (384–322 B.C.)
Democritus proposed the following ideas: • Matter is made of atoms. • Atoms move through empty space. • Atoms are solid. • Atoms cannot be destroyed or divided. • Atoms have the same composition and properties. • Different types of atoms have different shapes and sizes. • The properties of matter depend on the size, shape, and movement of atoms.	Aristotle maintained the following ideas: • Matter is made of the four elements (fire, air, earth, and water). • Empty space does not exist. Aristotle was one of the most prominent philosophers of the time and rejected Democritus' ideas. 

Dalton's Atomic Theory

John Dalton (1766–1844) conducted scientific experiments and proposed Dalton's atomic theory.

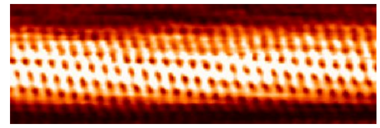
- All elements are made of extremely small particles called atoms.
- Atoms of an element have the same size, mass, and chemical properties.
- Atoms of different elements have different sizes, masses, and properties.
- Atoms cannot be divided, created or destroyed.
- Atoms combine in whole-number ratios to form compounds.
- During chemical reactions, atoms may be rearranged, combined, or separated.

Unlike Democritus, Dalton performed experiments to understand how atoms behave during a chemical reaction.

Law of Conservation of Mass
The law of conservation of mass states that matter cannot be created or destroyed in a chemical reaction. By using closed systems for his experiments, Dalton measured the mass of both the reactants and the products. Dalton's atomic theory explains the conservation of mass during a chemical reaction.

Defining the Atom: Discovery of the Electron

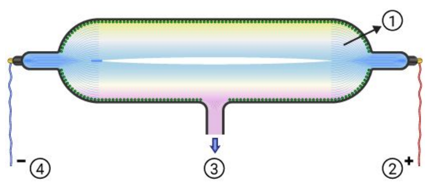
Studying Atoms



Scientists study atoms using a scanning tunneling microscope (STM).

The Cathode-Ray Tube

Cathode-ray tubes are used to study the behavior of electricity in a vacuum.



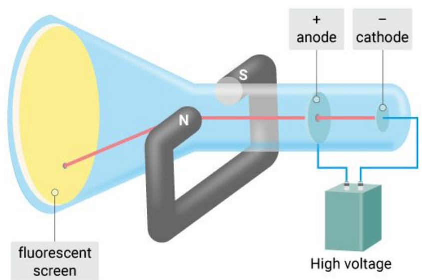
KEY:
1: glass tube
2: opening for the vacuum pump to remove air
3: negative electrode (cathode)
4: positive electrode (anode)

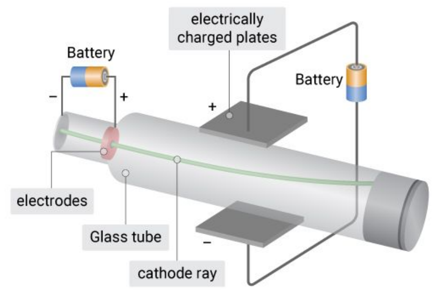
Discovering the Electron

Sir William Cookes accidentally discovered the cathode ray. This ray travels from the cathode to the anode in a cathode-ray tube.

Cathode rays deflect in a magnetic field. They are streams of charged particles.

Cathode rays deflect towards a positively charged plate in an electric field. The particles are negatively charged.





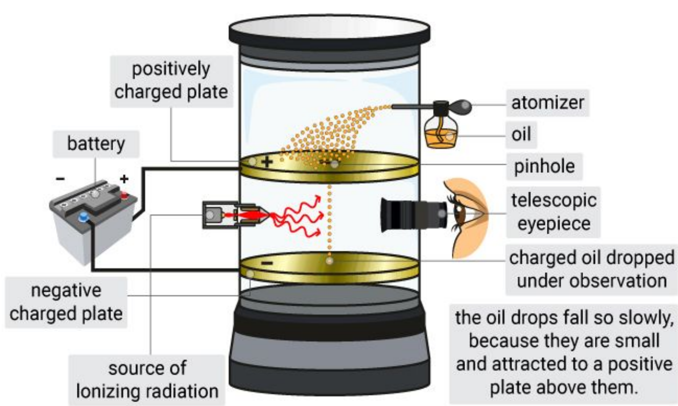
Scientists concluded that negatively charged particles, called electrons, from part of all matter.

Mass of an Electron

J.J. Thompson determined that the mass of the charged particle was much less than that of a hydrogen atom.

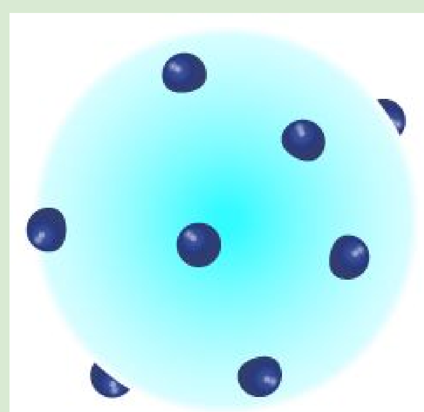
Charge of an Electron

Robert Millikan used the oil-drop experiment to determine the charge of an electron.



Thompson's Plum Pudding Model

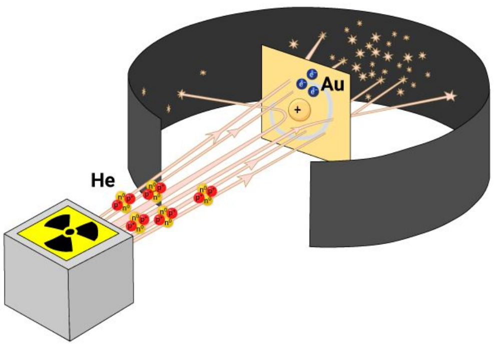
J.J. Thompson proposed the plum pudding model of the atom. He proposed that the atom is a positively charged sphere with negatively charged electrons evenly distributed through it.



Defining the Atom: Structure of the Atom

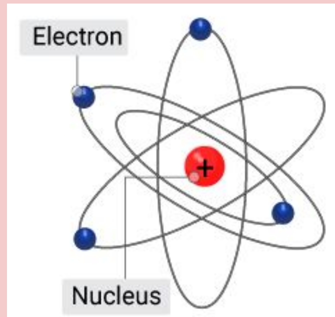
Rutherford's Gold Foil Experiment

Ernest Rutherford (1871–1937) aimed a beam of alpha particles at gold foil. He expected the alpha particles to move straight through, but they were deflected.



Rutherford's Model of the Atom

Rutherford concluded that most of the positive charge and the mass is found in the center of the atom. He called this the **nucleus**.



The model did not explain all the mass of the atom.

Protons

Rutherford concluded that the nucleus is made of charged subatomic particles called **protons**.

- Protons have a positive charge (1+).
- The charge is equal but opposite to that of an electron (1−).

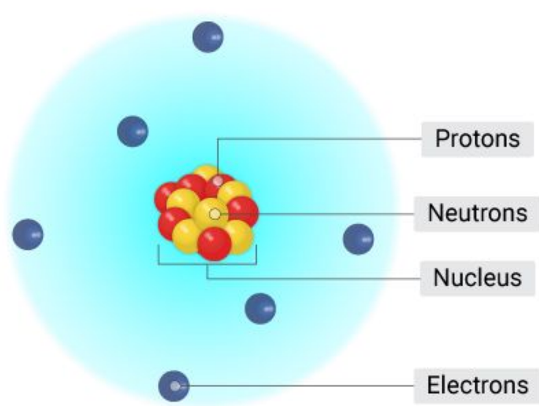
Neutrons

James Chadwick (1891–1974) showed that the nucleus also contained **neutrons**. Neutrons are subatomic particles with:

- no electrical charge
- a mass similar to that of protons

Structure of the Atom

All atoms have a spherical structure and are made of electrons, protons, and neutrons.



Subatomic particle	Electron	Proton	Neutron
Symbol	e^-	p	n
Electric charge	1−	1+	0
Relative mass	$\frac{1}{1840}$	1	1

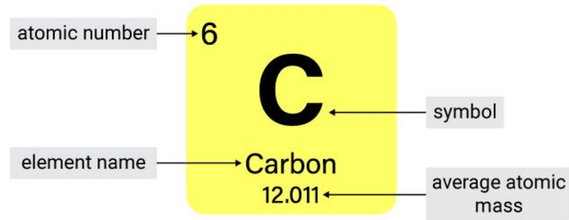
Quarks

Modern scientists discovered that protons and neutrons are made up of smaller subatomic particles called **quarks**.

How Atoms Differ: Isotopes

Atomic Number

Atomic number is the number of protons in the nucleus of an atom. It increases from left-to-right on the periodic table, and from top-to-bottom.



Mass Number

Mass number is the sum of the number of protons and neutrons in the nucleus of an atom.

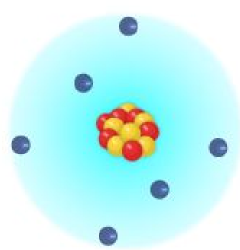
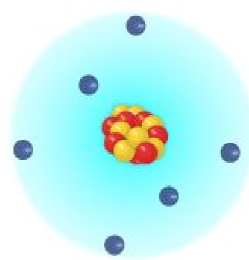
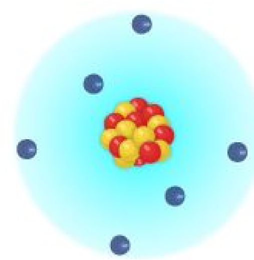
Calculating Mass Number

Calculating the mass number of carbon (C):

mass number = atomic number + number of protons
= 6 + 6
= 12

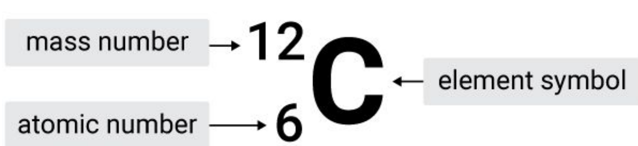
Isotopes

Isotopes are atoms with the same number of protons, but different numbers of neutrons.

Carbon Isotope	Carbon-12	Carbon-13	Carbon-14
Diagram			
Number of Subatomic Particles	6 electrons 6 protons 6 neutrons	6 electrons 6 protons 7 neutrons	6 electrons 6 protons 8 neutrons

Representing Isotopes

Chemists use a visual system to represent isotopes.



Atomic Mass

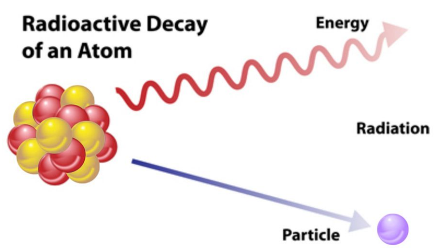
The atomic mass of an element is the weighted average mass of the element's isotopes.

The atomic mass represents the mass of an atom using atomic mass units (amu). It is a unit of measure precisely equal to $\frac{1}{12}$ the mass of carbon-12.

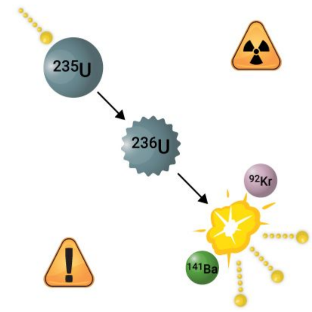
Unstable Nuclei and Radioactive Decay

Radioactivity

- Radioactivity is the spontaneous emission of particles or energy by an unstable atomic nucleus.
- Radiation is the particles and rays emitted by radioactive materials.

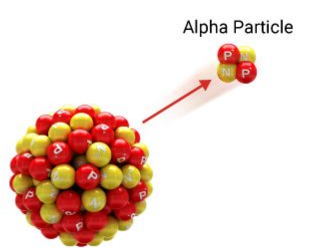
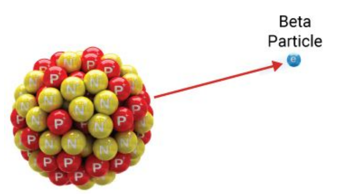
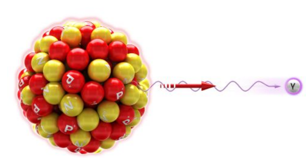


A nuclear reaction involves a change in the:
- structure of an atomic nucleus
- mass of an atomic nucleus



Types of Radiation

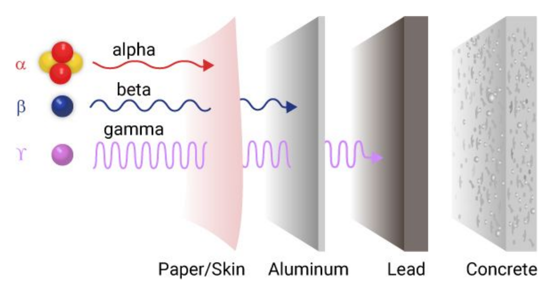
Scientists identified 3 types of radiation based on their electric charge.

Type of Radiation	Alpha	Beta	Gamma
Symbol	α or $^{4}_{2}He$	β or e^-	γ
Identity	helium nucleus	electron	energy
Charge	2+	2−	0
Mass number	4	0	0
Diagram			

Penetrating ability of radiation

Gamma radiation has the highest penetrating ability.

Alpha particles can do more damage as they are larger and have more mass.



PRACTICE: The Structure of the Atom

1. Select an idea of Dalton's atomic theory from the list.
    a. Solid particles are lighter than gaseous particles
    b. Atoms are divisible into many pieces.
    c. Matter is composed of extremely small particles called atoms.
    d. Action and reaction are equal and opposite

2. Identify the law that states "matter cannot be created or destroyed in a chemical reaction."
    a. Law of conservation of mass
    b. Law of definite proportion
    c. Law of constant composition
    d. Law of diffusion

3. Select the statement that correctly defines an atom.
    a. An atom a mixture of four substances.
    b. An atom is two or more substances chemically combined.
    c. An atom is a negatively charged particle.
    d. An atom is the smallest part of an element that still has the properties of that element.

4. Identify the particle that has a charge of 1+.
    a. atom
    b. electron
    c. proton
    d. neutron

5. Circle the example of a physical change from the list.

Water boils. A match burns. Food rots. Iron rusts.

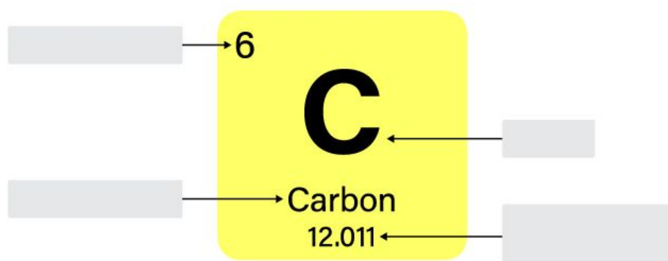
6. Complete the following sentence about the cathode ray tube.

Cathode rays travel from the ____________ cathode to the ____________ anode.

7. From the table below, select the two atoms that are isotopes.

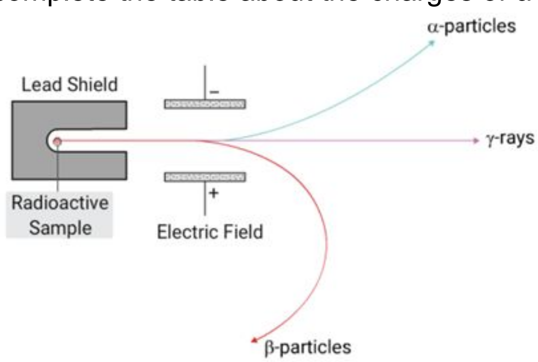
Atom	Protons	Neutrons	Electrons
1	6	6	6
2	8	10	8
3	9	9	9
4	6	8	6

8. Label the image to describe a carbon atom.



9. _______ is the spontaneous emission of particles or energy by an unstable atomic nucleus.

10. An electric field deflects the radiations according to their charges. Use the diagram to complete the table about the charges of α- and β-particles.



	α-particle	β-particle
charge		

11. Complete the following nuclear equations.

$$^{242}_{94}\text{Pu} \longrightarrow ^{238}_{92}\text{U} + \square$$

$$^{14}_{6}\text{C} \longrightarrow ^{14}_{7}\text{N} + \square$$

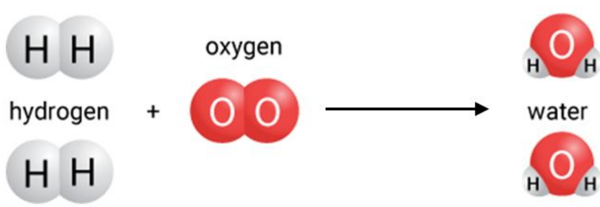
12. The ______ is the sum of the number of neutrons and protons in the nucleus of an atom.

    a. isotopic number
    b. proton number
    c. mass number
    d. atomic number

13. Select a reason why atoms in the periodic table are electrically neutral.

    a. They have equal numbers of neutrons and electrons.
    b. They have different numbers of protons neutrons.
    c. They have equal numbers of protons and neutrons.
    d. They have equal numbers of protons and electrons.

14. Deduce the type of reaction described by the equation below.



    a. nuclear reaction
    b. chemical reaction
    c. physical reaction
    d. electronic reaction

15. Calculate the number of neutrons in neon-22, $^{22}_{10}Ne$.

a. 22

b. 10

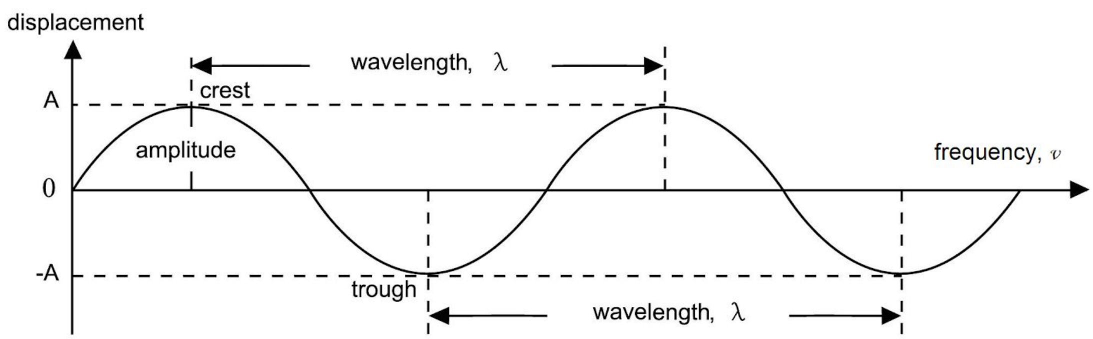
c. 11

d. 12

Light and Quantized Energy: Wave Nature of Light

Properties of waves

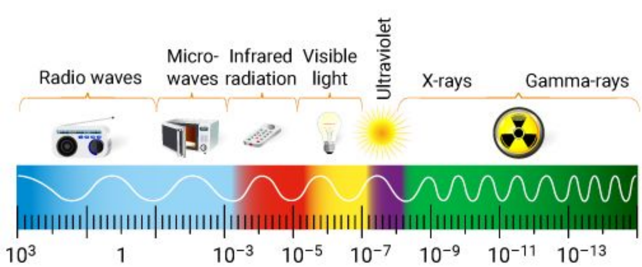
Light behaves as waves. All waves have the same properties.



- amplitude: the maximum height of a wave from its crest or trough to its origin
- wavelength: the distance between two identical points on a wave, for example, two adjacent crests or two adjacent troughs
- frequency: the number of waves that pass a certain point per second
- crest: highest point above the origin on a wave
- trough: lowest point below the origin on a wave

Electromagnetic spectrum

- Electromagnetic radiation is a form of energy that can travel through empty space or through matter as waves.
- The electromagnetic spectrum is the range of different wavelengths and frequencies over which electromagnetic waves extend.
- Visible light forms part of the electromagnetic spectrum.



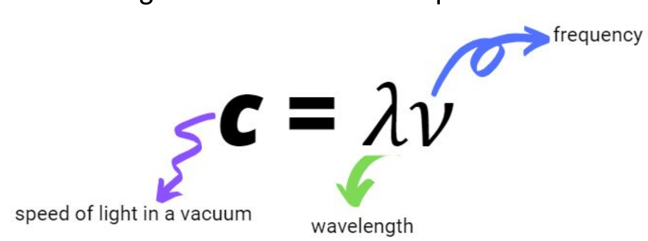
Electromagnetic Wave Relationship

All electromagnetic waves:

- are transverse waves
- transfer energy
- travel through space at a speed of 3.00×10^8 m/s

The frequency and wavelength of an electromagnetic wave are related to its speed.

Electromagnetic wave relationship:



All electromagnetic, or EM waves, travel at the same speed in a vacuum.

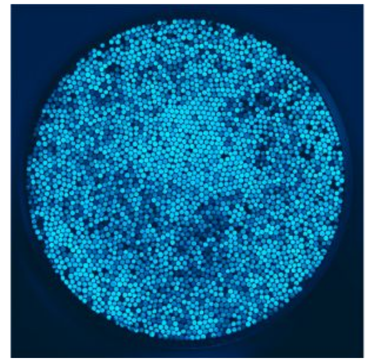
Light and Quantized Energy: Particle Nature of Light

Light quanta

Sometimes matter behaves in a way that could not be explained by the wave model.

- On a large scale, the electromagnetic spectrum appears as a continuous spectrum.
- At very small scales, electromagnetic waves emit energy in tiny packets called light quanta.

Light quanta are not continuous.



Max Planck proposed that:

- electromagnetic radiation could only be emitted in discrete units of energy or quanta
- the amount of energy emitted is the product of the light's frequency and a constant value, h, is now known as Planck's constant.

Planck's Constant

The symbol for Planck's constant is h. Its value is approximately 6.63×10^{-34} joule-seconds.

Energy of a Quantum

The energy of a quantum of light is equal to the product of Planck's constant and the frequency of the light.

Equation for Energy of a Quantum:

$$E = h\nu$$

E = energy; measured in joules, J
h = Planck's constant; measured in joule-second, J·s
ν = frequency; measured in hertz, Hz

EXAMPLE

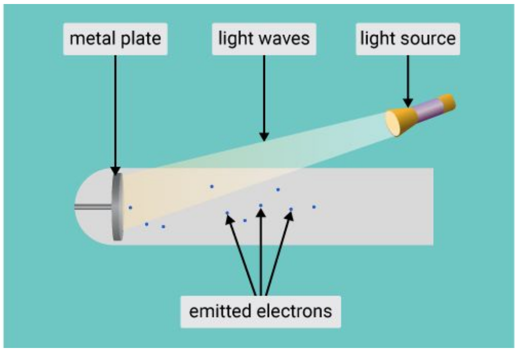
To calculate the energy of a quantum of a microwave:

Microwave frequency = 2.88×10^{10} s^{-1}

$$E = h\nu$$
$$E = (6.63 \times 10^{-34})(2.88 \times 10^{10})$$
$$= 1.91 \times 10^{-23}\ J$$

Light and Quantized Energy: Continuous and Emission Spectra

Photoelectric effect



When light is directed at metal, it ejects some of the electrons on the metal surface. This is known as the photoelectric effect.

The emitted electrons are called photoelectrons.

Only light of a certain frequency causes the electrons to leave a metal. Below the minimum frequency, no electrons are emitted. This minimum frequency is called threshold frequency.

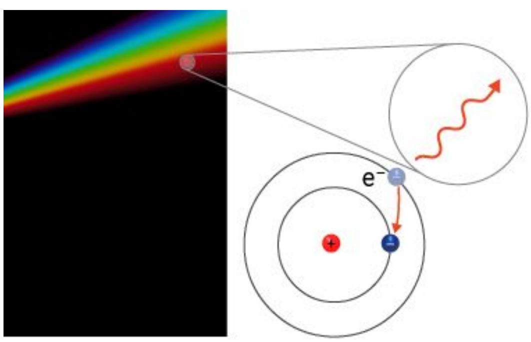
Dual Nature of Light

Einstein proposed that light behaves as both particles and waves. The dual nature of light.

A photon is a particle of light that contains one quantum of energy, but no mass.

Calculate the Energy of a Photon:

$$E = h\nu$$

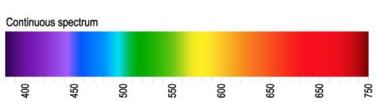
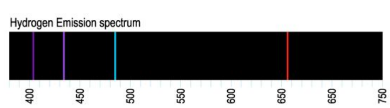
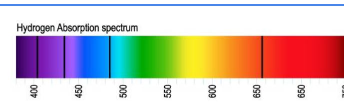


Each metal atom or ion emits a distinct color when given energy in the form of heat (flame test), electric energy and electromagnetic radiation.

- An atom absorbs energy and gets excited.
- The excited atom returns to a stable state by releasing the same amount of energy as it absorbed.
- The photons of energy released correspond to a specific frequency of visible light.

Atomic Emission Spectra

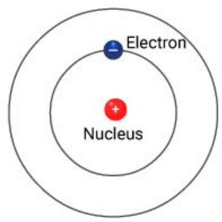
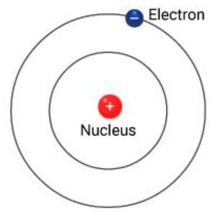
An atomic emission spectrum is a set of frequencies that are emitted by the atoms of a particular element.

Spectrum	Continuous	Emission	Absorption
Example			
Description	shows all wavelengths over a wide range; continuous	wavelengths appear as separate lines; discontinuous	wavelengths appear as separate black lines on a continuous spectrum

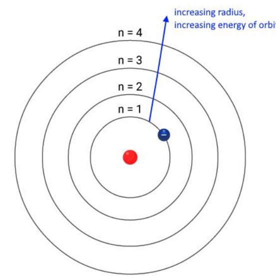
Quantum Theory and the Atom: Bohr's Model of the Atom

Energy States of the Hydrogen Atom

Niels Bohr proposed that the hydrogen atom may occupy different energy states.

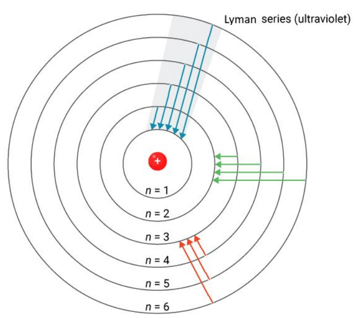
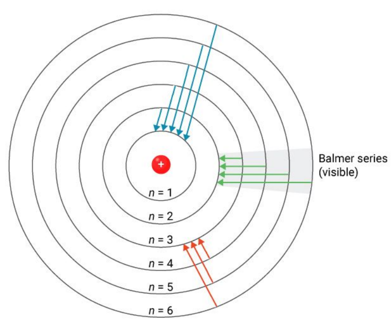
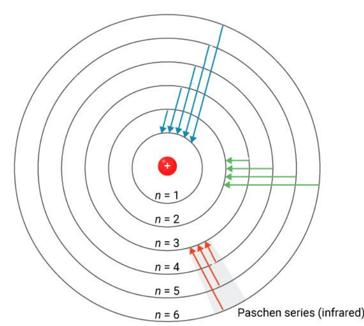
Energy State of Atom	Ground State	Excited State
Diagram		
Description	electron occupies lowest circular orbit	electron absorbs a discrete amount of energy and moves to a larger orbit

Each orbit is represented by a **quantum number**, *n*. The closest orbit to the nucleus (*n* = 1) is the lowest energy level.



Line Spectra of the Hydrogen Atom

When an electron falls between different energy orbits, it emits a photon. Only certain frequencies of electromagnetic radiation are emitted.

Lyman Series	Balmer Series	Paschen Series
		
• emissions fit into the **ultraviolet range** • occur when electron drops from a larger orbit back down to the *n* = 1 level	• emissions fit into the **visible range** • occur when electron drops from a larger orbit back to the *n* = 2 level	• emissions fit into the **infrared range** • occur when electron drop from a larger orbit back down to the *n* = 3 level

Limitations to Bohr's Atomic Model

Bohr's model could not explain:

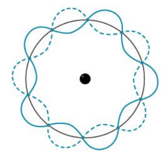
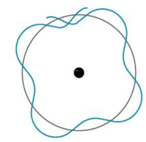
- the emission spectra of other atoms, which looked different from hydrogen's spectrum
- why there were energy orbitals in an atom
- the behavior of atoms

Quantum Theory and the Atom: Quantum Mechanical Model of the Atom

Electrons as Waves

Louis de Broglie (1892–1987) said that all moving particles, including electrons, could be treated as standing waves with specific wavelengths.

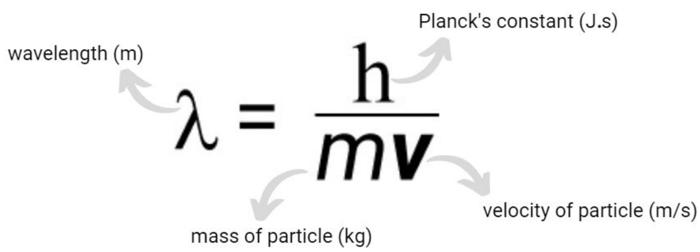
Only a certain number of wavelengths, *n*, are allowed around the nucleus.

n = whole number	*n* ≠ whole number
	
If the standing wave matches up perfectly, the number of wavelengths, *n*, will always be a whole number or integer.	If the orbit path around the nucleus is too long or too short, the standing wave does not match up and it will collapse.

Electrons can only exist at specific distances from the nucleus, i.e. the orbits have fixed radii.

De Broglie Equation

De Broglie rearranged existing equations to relate the wavelength of a particle to its mass.



Limitations of the de Broglie Equation

De Broglie predicted that all moving particles have wave-like properties.

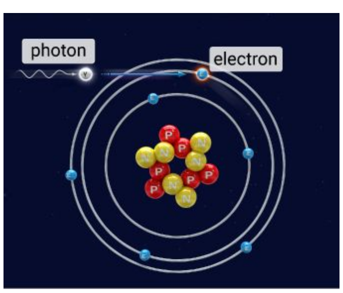
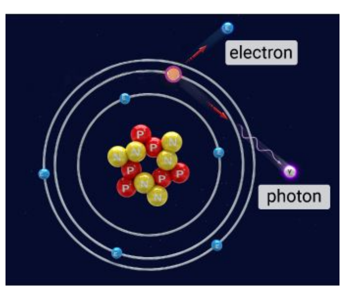
The de Broglie equation assumes that the electrons are:

- restricted to circular orbits around the nucleus
- always the same distance from the nucleus

Heisenberg Uncertainty Principle

The Heisenberg uncertainty principle states that it is impossible to know a particle's position and its velocity at the same time.

The interaction between a photon and an electron illustrates this principle.

Before Interaction	After Interaction
	

Schrödinger's Wave Equation

Schrödinger (1887–1961) built on de Broglie's work and derived the Schrödinger wave equation.

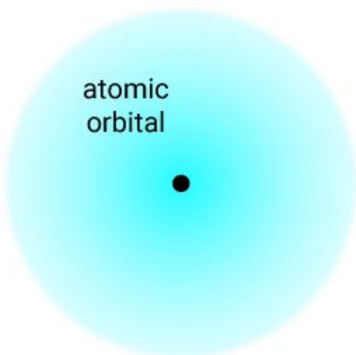
The solutions to this equation are called wave functions. They give the probability of finding an electron at any given point. Where the wave function is higher, there is a high probability of finding an electron.

Treating moving particles as waves have become the basis of our modern understanding of the atom. The modern quantum mechanical model of the atom describes the electrons in an atom as waves.

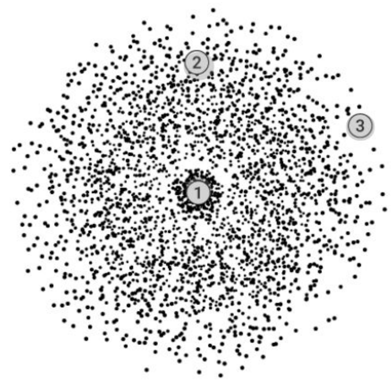
Quantum Theory and the Atom: Shapes of Orbitals

Atomic Orbitals

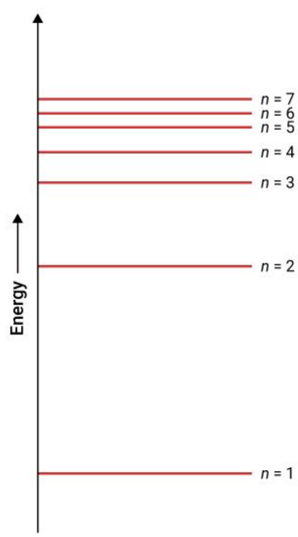
An atomic orbital is a three-dimensional area around a nucleus where there is a 90% probability of finding an electron.



Density Maps

Density maps represent the probability of finding an electron. Every dot on a density map represents the position of an electron in the orbital at a moment in time. 	KEY 1: high density of dots; most probable location of electrons inside the orbital 2: low density of dots, least probable location of electrons inside the orbital. 3: orbital boundary; no definite boundary

Quantum Numbers



The quantum mechanical model of the atom also uses four quantum numbers to describe orbitals.

The first quantum number is called the principal quantum number. It describes the relative size and energy of the orbitals.The principal quantum number is represented by n. The value of n is always a positive integer.

The main energy levels around the nucleus of an atom are represented by the principal quantum number, *n*. Every main energy level of the atom is called a principal energy level.

The principal energy levels can accommodate more than one electron.

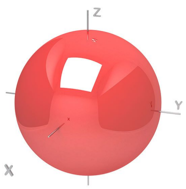
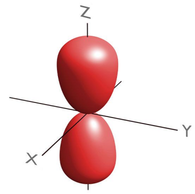
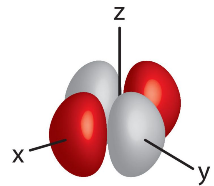
Energy Sublevels

The sublevels within principal energy levels are called energy sublevels.The different sublevels are called s, p, d and f. These sublevels indicate the shapes of the orbitals.

The sublevels are assigned a number and a letter, for example, 1s and 2p.

Shapes of Orbitals

The labels s, p, d, and f indicate the shape of the orbitals.

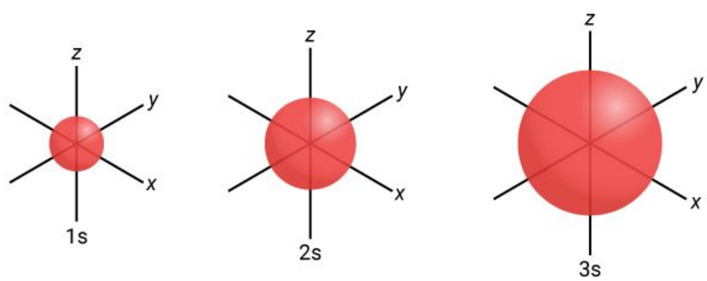
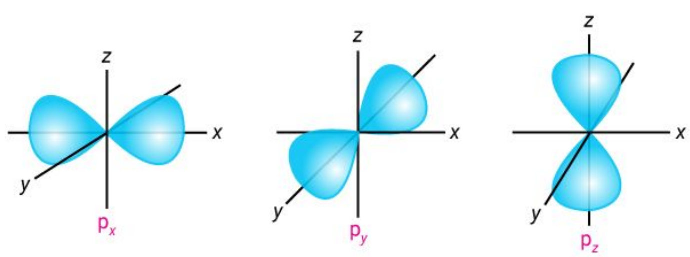
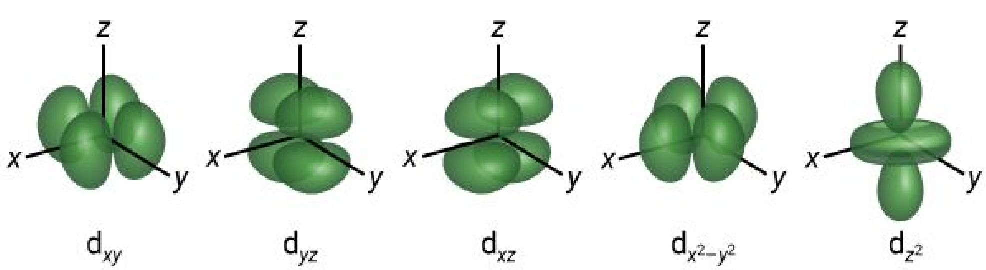
s orbital	p orbital	d orbital
		

Note: the f orbitals are too complicated to learn now

Orientations of Orbitals

The three-dimensional orientation of an orbital can be described in terms of three axes: x, y, and z.

- The subscript x, y, and z is used to show the orientation of each orbital.
- The intersection of the three axes show the location of the center of the nucleus.

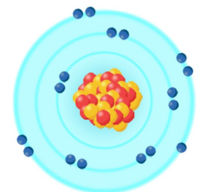
s orbital	
p orbital	
d orbital	

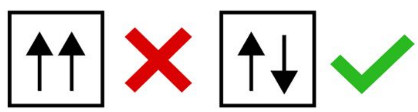
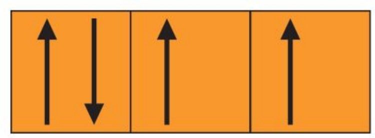
Electron Configuration: Writing Electron Configurations

Electron Configuration

Electron configuration is the specific arrangement of electrons in the atomic orbitals around the nucleus of an atom.

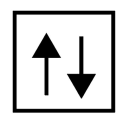
There are three rules or principles that determine how electrons are arranged around the nucleus of an atom.



Aufbau Principle	Pauli Exclusion Principle	Hund's Rule
The **aufbau principle** states that an electron occupies orbitals with lower energies first before those with higher energies. The order in which electrons fill sublevels are: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, and 6d.	The **Pauli exclusion principle** states that two electrons can only occupy an orbital if they spin in opposite directions. 	**Hund's rule** states that single electrons will fill up the orbitals of a sublevel first, before pairing up with electrons spinning in the opposite direction. 

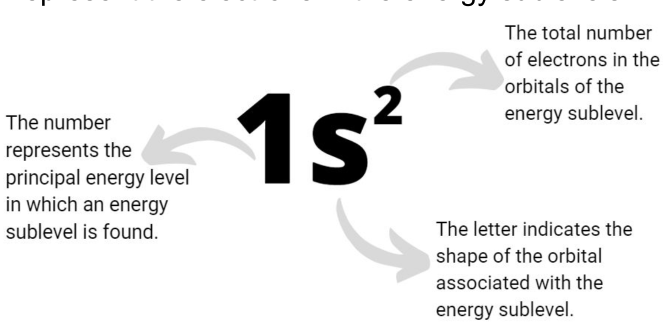
Orbital Diagrams

This method of representing the electron configuration of an atom is called an orbital diagram. This diagram represents an orbital with two paired electrons.



Electron Configuration Notation

Electron configuration notation uses numbers and letters to represent the electrons in the energy sublevels.



Exceptions to the Rules for Electron Configuration

There are exceptions to the electron configuration of some elements. These elements are more stable when their electrons fill or half-fill the outer s and d orbitals.

EXAMPLE

The atomic number of chromium (Cr) is 24.

Expected Electron Configuration	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^4$
Actual Electron Configuration	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$

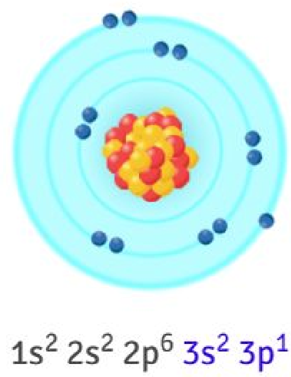
Electron Configuration: Representing Valence Electrons

Valence Electrons

Valence electrons are the electrons in the outermost energy level of an atom.

EXAMPLE

Aluminium has 3 valence electrons in the 3s and 3p orbitals.



NOTE

Electrons in the highest principal energy level form part of the valence electrons.

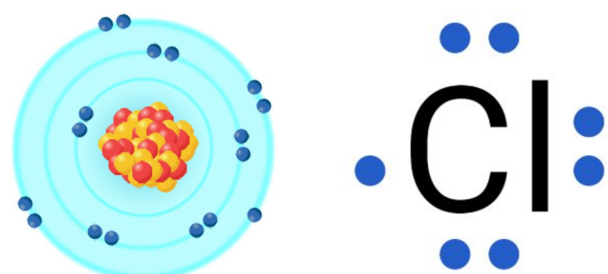
Starting from scandium in period 4, d orbitals of *n* = 1 also make up part of the valence electrons.

So the valence electrons in scandium would be: $4s^2 3d^1$

Electron-Dot Structures

Electron-dot structures represent the valence electrons of an atom.

In an electron-dot structure, the element's symbol represents the nucleus and inner electrons of an atom. The outer electrons are drawn around the chemical symbol.

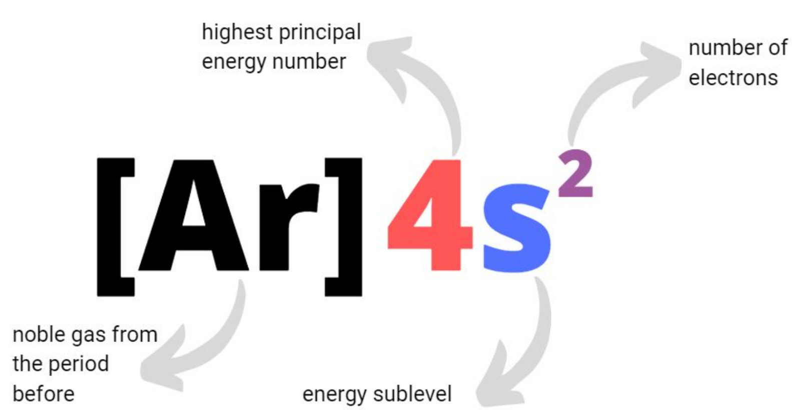


Noble-Gas Notation

Noble-gas notations can be used to shorten writing electron configuration notations.

The noble-gas notation of an atom consists of the elemental symbol of the noble gas that comes before that atom in the periodic table.

It is followed by the configuration of the remaining electrons.



PRACTICE: Electrons in Atoms

1. Match the following terms about waves with their correct definitions

Term	Definition
wavelength	number of waves that pass a certain point per second
frequency	distance between adjacent crests on a wave
amplitude	maximum height of a wave from its trough to its origin

2. Electromagnetic waves travel through space or vacuum at a speed of ___________.

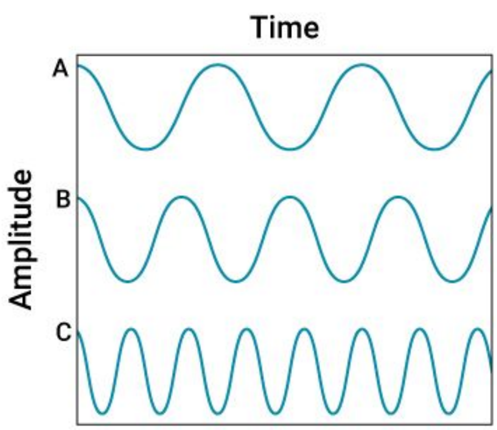
   a. 3.00×10^8 m/s

   b. 30.0×10^8 m/s

   c. 3.00×10^9 m/s

   d. 5.00×10^8 m/s

3. Select which of the following waves has the shortest wavelength.



   a. A

   b. B

   c. C

   d. B and C

4. As described by the electromagnetic wave equation, the speed of light (*c*) is the ______ of its wavelength (λ) and its frequency (*v*).

   a. multiple

   b. product

   c. addition

   d. square root

5. Calculate the energy of a quantum of yellow light that has a frequency of 5.2×10^{14} hertz. Remember that the value of Planck's constant is: $6.63 \times 10^{-34}\ J \cdot s$

   a. $3.8 \times 10^{-18}\ J$

   b. $8.6 \times 10^{-14}\ J$

   c. $2.9 \times 10^{-19}\ J$

   d. $1.1 \times 10^{-8}\ J$

6. A phenomenon observed when light is shined on the surface of a metal and eject electrons is referred to as the __________.

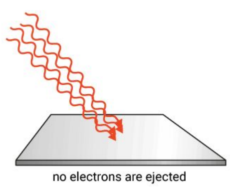
   a. electromagnetism

   b. photoelectric effect

   c. electronic configuration

   d. law of inertia

7. Select the reason why red light could not eject electrons from the metal surface.



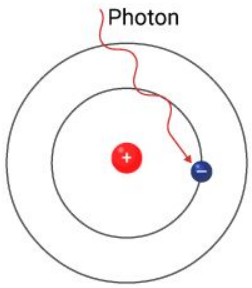
   a. The frequency of the red light is less than the threshold frequency.

   b. The wavelength of the red light is greater than the threshold frequency.

   c. The speed of the red light is less than the speed of the electrons.

   d. The frequency of the metal plate is less than the threshold frequency.

8. When a hydrogen atom absorbs a photon, it is said to be in a(n) ________.



a. general state

b. lone state

c. ground state

d. excited state

9. Arrange the following types of electromagnetic radiation in order of increasing frequency.

- ultraviolet light
- radio waves
- microwaves
- gamma-rays

10. The electron of a hydrogen atom emits a photon when it drops to the energy level n = 1. Select a series that refers to this emission.

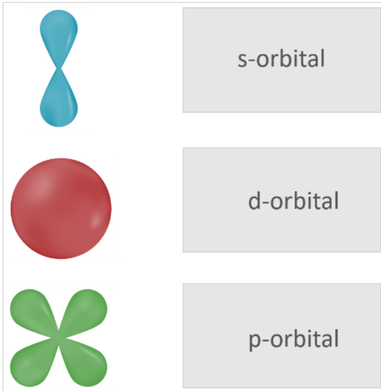
a. Paschen series

b. Balmer series

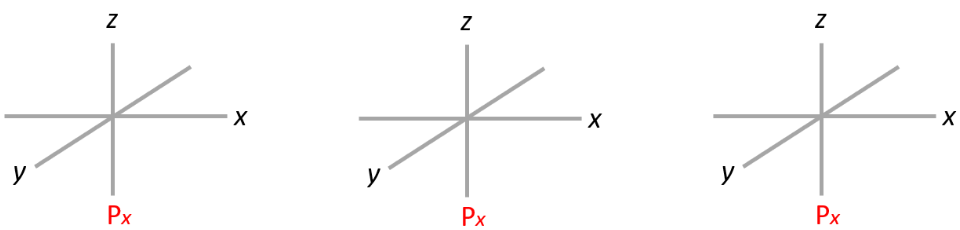
c. Lyman series

d. Bracket series

11. The diagram shows the shapes of three atomic orbitals. Match each shape to its name.



12. Complete the following diagram about the orientations of p-orbital.



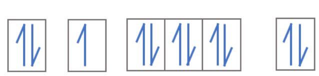
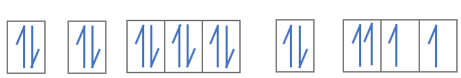
13. Fill in the blank to complete the electron configuration notation for chlorine atom.

$1s^{□}\ 2s^{2}\ 2p^{6}\ 3s^{□}\ 3p^{□}$

14. Maryam was trying to draw the orbital diagram for the electrons' arrangement around a carbon, sodium, and sulfur atom. State which principle/rule is being violated in each case.

Principles/rule:

- Aufbau's principle
- Pauli's exclusion principle
- Hund's rule

Atom	Orbital Diagram	Rule Violated
carbon		
sodium		
sulfur		

15. Select the limitations of Bohr's model of the atom.

Select 2 options.

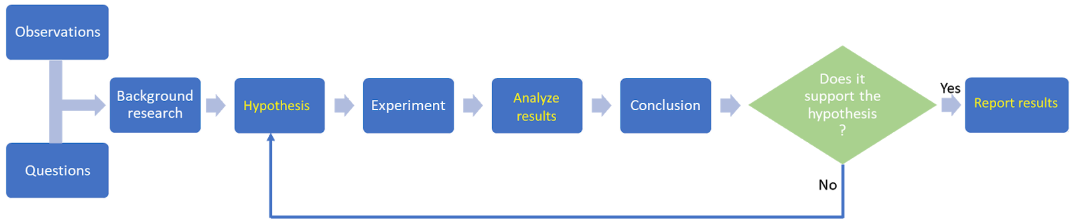
a. It could only explain the emission spectra of hydrogen atoms.

b. It could only explain the emission spectra of the first 7 atoms.

c. It could not explain the chemical behavior of atoms.

d. It could only explain the magnetic properties of atoms.

PRACTICE: Introduction to Chemistry – Model Answers

1. 

2. c. Microscopic

3.

synthetic substances	natural substances
chlorofluorocarbon (CFC)	ozone
plastic	water

4. Scientists use models to describe submicroscopic events because they are hard to visualize and explain.

5. b. Use caution when handling hot objects.

6. mass: amount of matter in an object

   weight: gravitational force pulling on an object with mass

7. a. color
   d. sound

8. d. analytical chemistry

9. A scientific theory explains a natural phenomenon based on many observations and investigations over time.

   A scientific law is a relationship in nature that is supported by many experiments

10. **Chemistry** is the scientific study of the composition and properties of matter.

11. b. carbon, chlorine, fluorine

12. c. stratosphere

13. independent variable

14. dependent variable

15. control

PRACTICE: Analyzing Data – Model Answers

1. 8,348,000 km
2. 118.4
3. meter (m)
   kelvin (K)
   kilogram (kg)
4. 4.25 minutes
5. 500 m
6. volume
7. Omar
8. density
   5.0 mL
   8.1 g
9. 1.2×10^{9}
10. **K** = ^{o}C + **273**
11. Image C
12. 1.547×10^{6}
13. $3\ pounds \times \frac{16\ ounces}{1\ pound} \times \frac{28.3\ g}{1\ ounce} \times \frac{1\ cup}{5.66\ g}$
    240 cups
14. 2
15. 8.5 g/cm^3
16. 8.433×10^{4}

PRACTICE: The Structure of the Atom – Model Answers

1. c. Matter is composed of extremely small particles called atoms.

2. a. Law of conservation of mass

3. d. An atom is the smallest part of an element that still has the properties of that element.

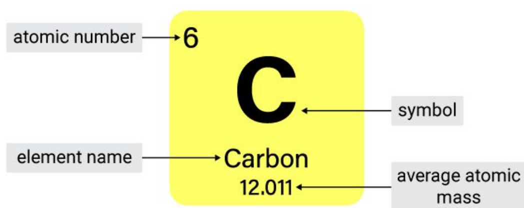
4. c. proton

5. Water boils.

6. Cathode rays travel from the **negative** cathode to the **positive** anode.

7. Atoms 1 and 4

8.



9. **Radioactivity** is the spontaneous emission of particles or energy by an unstable atomic nucleus.

10. α-particle: positively charged

    β-particle: negatively charged

11.

$$^{242}_{94}Pu \longrightarrow ^{238}_{92}U + ^{4}_{2}He$$

$$^{14}_{6}C \longrightarrow ^{14}_{7}N + ^{0}_{-1}e$$

12. c. mass number

13. d. They have equal numbers of protons and electrons.

14. b. chemical reaction

15. d. 12 neutron

PRACTICE: Electrons in Atoms – Model Answers

1.

Term	Definition
wavelength	distance between adjacent crests on a wave
frequency	number of waves that pass a certain point per second
amplitude	maximum height of a wave from its trough to its origin

2. a. 3.00×10^8 m/s

3. c. C

4. b. product

5. c. $2.9 \times 10^{-19}\ J$

$$E = h$$
$$E = 6.63 \times 10^{-34}\ J \cdot s \times 4.3 \times 10^{14}\ s^{-1}$$
$$E = 2.9 \times 10^{-19}\ J$$

6. b. photoelectric effect

7. a. The frequency of the red light is less than the threshold frequency.

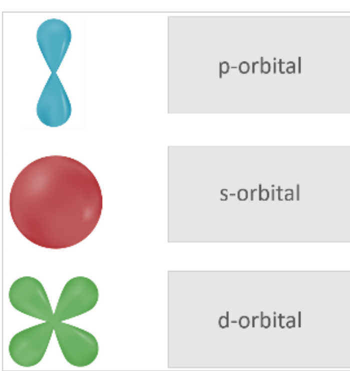
8. d. excited state

9.

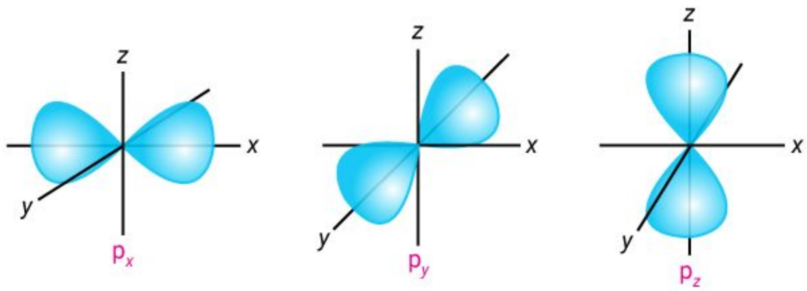
radio waves	microwaves	ultraviolet light	gamma rays

10. c. Lyman series

11.



12.



13.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

14.

Atom	Orbital Diagram	Rule Violated
carbon	[↑↓] [↑↓] [↑↓][ ][ ]	Hund's rule
sodium	[↑↓] [↑] [↑↓][↑↓][↑↓] [↑↓]	Aufbau's principle
sulfur	[↑↓] [↑↓] [↑↓][↑↓][↑↓] [↑↓] [↑↑][↑][↑]	Pauli's exclusion principle

15. a. It could only explain the emission spectra of hydrogen atoms.
c. It could not explain the chemical behavior of atoms.