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One Concept at a Time

A *Guided Study* and Workbook for High School Chemistry

2012 Revision: Digital Preview

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Guided Study Book – 2012 Revision

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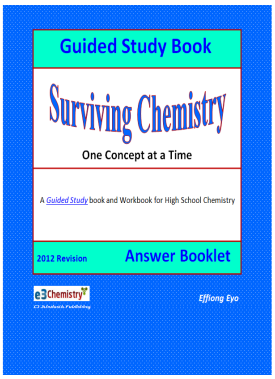

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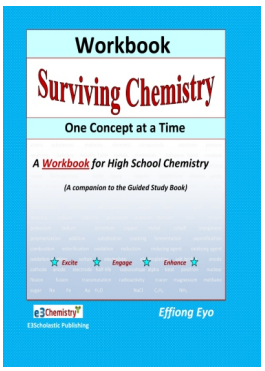
A great companion to this study book is the workbook, which is sold separately. The workbook contains almost 5000 problems in four sections: Worksheets, multiple choices, constructed responses, and reference tables. Questions in the workbook are also separated into concept sets. This allows students to work on a group of questions of one or related concepts. By working on groups of questions related to the same concept, students will test their understanding of that concept.
Each concept covered in the study book has at least one set of questions in the workbook.



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Topic 1 - Matter and Energy

Topic outline

In this topic, you will learn the following concepts:

. Types of matter and their characteristics
. Phases of matter and their characteristics
. Phase changes and relationship to energy
. Phase change diagram
. Temperature
. Heat energy and heat calculations
. Properties of gases and the gas laws
. Physical and chemical properties and changes

Lesson 1: Types of matter

Introduction

Chemistry is the study of matter; its composition, structure, properties, changes it undergoes, and the energy accompanying these changes.

Matter is anything that has mass and takes up space. Matter, in another word, is "stuff." Matter can be grouped and classified as pure substances or mixtures.

In this lesson you will learn about the different types of matter and their characteristics. You will also learn to recognize different types of matter by chemical symbols and diagrams.

1. Pure substances

A **pure substance** is a type of matter in which every sample has:
. Definite and fixed composition
. Same unique sets of properties

Elements and *Compounds* are classified as chemical pure substances.

Examples of pure substances

Elements	***Compounds***
Na (sodium)	H_2O (water)
Al (aluminum)	CO_2 (carbon dioxide)
H_2 (hydrogen)	NH_3 (ammonia)
He (helium)	$C_6H_{12}O_6$ (sugar)

Practice 1
Carbon dioxide, CO_2, is classified as a pure substance because
1) Its composition can vary
2) Its composition is fixed
3) It cannot be separated
4) It can be separated

Practice 2
Which list consists only of chemical pure substances?
1) Soil and salt water
2) Air and water
3) Iron and sodium chloride
4) Sugar and concrete

2. Elements

An **element** is a pure substance that:
. Is composed (made up) of identical atoms with the same atomic number
. C*annot* be decomposed (or broken down) into simpler substances by physical or chemical methods

Examples of elements

Mg (Magnesium) Br_2 (Bromine) Au (gold)

There are more than 100 known elements. Names, symbols, and other important information for all the elements can be found on the Periodic Table.

LOOKING Ahead ⇨ Topic 2 - Periodic Table , you will learn more about the elements.

Practice 3
Which cannot be decomposed by physical or chemical methods?
1) HBr 3) K_2O
2) Ni 4) CO

Practice 4
Lithium is classified as an element because it is composed of atoms that
1) have the same mass
2) have different masses
3) have the same atomic number
4) have different atomic numbers

3. Compounds

A **compound** is a pure substance that:
. Is composed of two or more different elements chemically combined
. Has a definite composition (fixed ratio) of atoms in all samples
. C*an be* decomposed into simpler substances by chemical methods
. Has the same unique set of properties in all of its samples
Note: Properties of a compound are different from those of the elements which it is composed.

Law of definite composition states that compounds contain two or more different atoms that are combined in a fixed ratio by mass. For example: The mass ratio in water, H_2O, is 8g of oxygen for every 1g of hydrogen. This ratio will be found in any sample of water.

Examples of compounds

H_2O (l) (Water)	CO_2 (g) (Carbon dioxide)
NH_3 (g) (Ammonia)	NaCl (s) (Sodium chloride)

Similarities and differences between compounds and elements are noted below.

Compounds are similar to elements in that:
. Both are pure substances
. Both always have homogeneous properties
. Both have fixed and definite composition in all samples

Compounds are different from elements in that :
. Compounds can be broken down (decomposed) by chemical means
. Elements cannot be decomposed

Practice 5
Which list consists only of substances that can be chemically decomposed?
1) K(s) and KCl(aq)
3) CO(aq) and CO_2(g)
4) Co(s) and $CaCl_2$(s)
4) LiBr(s) and CCl_4(l)

Practice 6
Which must occur for HF to form from its elements?
1) A physical change
2) A chemical change
3) A phase change
4) A nuclear change

Practice 7
MgO is different from Mg in that MgO
1) is a pure substance
2) has the same unique properties
3) can be chemically separated
4) can be physically separated

4. Mixtures

A **mixture** is a type of matter that:
. Is composed of two or more substances that are *physically* combined
. Has composition that can change (vary) from one sample to another
. Can be physically separated into its components
. Retains properties of its components

Examples of mixtures

NaCl (aq) (salt water)
$C_6H_{12}O_6$(aq) (sugar solution)
HCl (aq) (hydrochloric acid solution)
Soil , concrete, and air are also mixtures

Similarities and differences between mixtures and compounds:

Mixtures are similar to compounds in that:
. Both are composed (made up) of two or more different substances
. Both can be separated into their components

Mixtures are different from compounds in that:
. Components of mixtures are *physically* combined , and the composition can change (vary)
In compounds, they are *chemically* combined, and the composition is definite (fixed)
. Components of mixtures can be separated by *physical methods*
In compounds, they can be separated by *chemical methods*
. Mixtures can be classified as homogenous or heterogeneous
Compounds can only be homogenous.

Practice 8
Which is a mixture of substances?
1) Cl_2(g) 3) $MgCl_2$(s)
2) H_2O(l) 4) KNO_3 (aq)

Practice 9
Which is true of a KCl solution ?
1) It is composed of substances that are chemically combined
2) It is composed of substances that are physically combined
3) It is composed of substances with the same atomic number
4) It is a pure substance

5. Homogeneous and Heterogeneous Mixtures

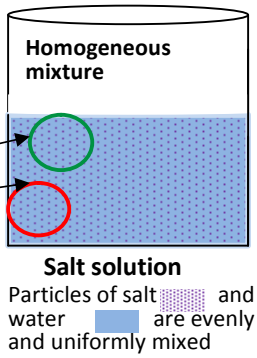
Homogeneous mixtures

A mixture is classified as homogeneous if it has the following properties:

. The components of the mixture are uniformly and evenly mixed throughout

. Samples taken within the same mixture have the same composition

Aqueous solutions are homogeneous mixtures made with water. For example, a scoop of salt that is completely dissolved in a cup of water makes an aqueous solution. (aq) next to a chemical symbol indicates an aqueous mixture of that substance. Ex. NaCl(aq) and CO_2(aq)



LOOKING Ahead ⇨ Topic 7 - Solutions. You will learn more about aqueous solutions.

Heterogeneous mixtures

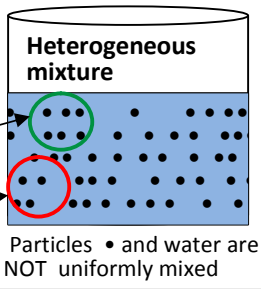
A mixture is classified as heterogeneous if:

. The components of the mixture are not uniformly mixed throughout

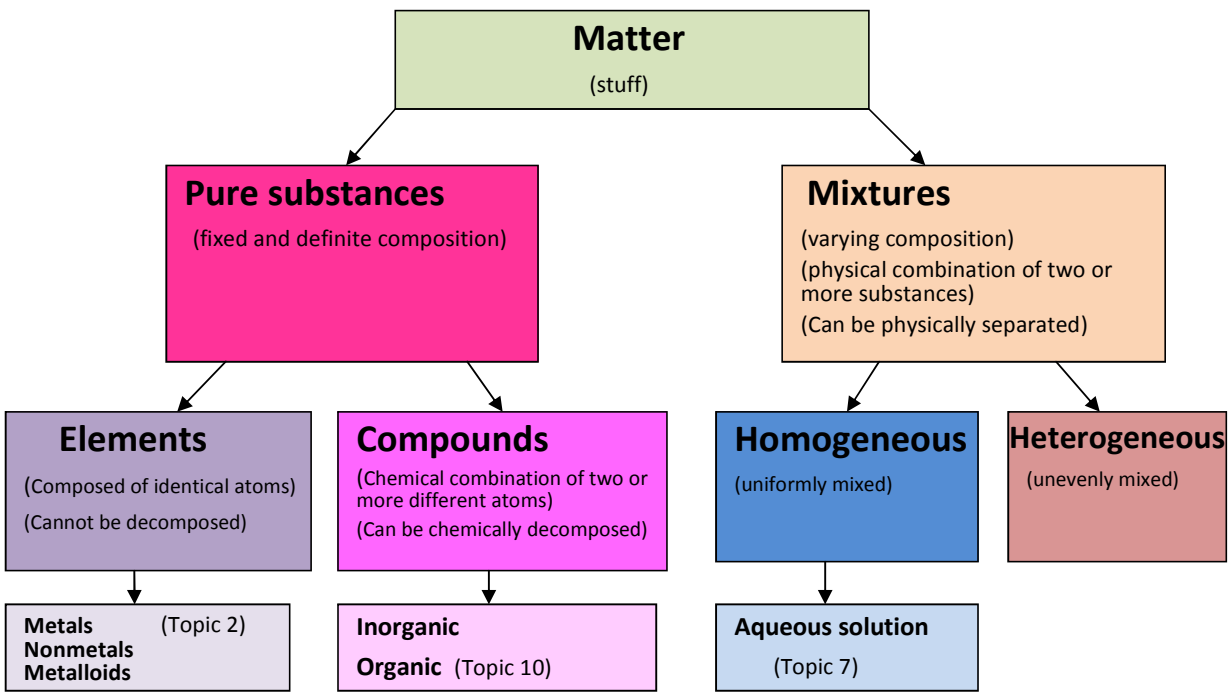
. Samples taken within the same mixture have different compositions

Examples of heterogeneous mixtures:

Concrete, soil, and sand-salt mixture.



6 Classification of Matter: Summary diagram



7. Separation of mixtures

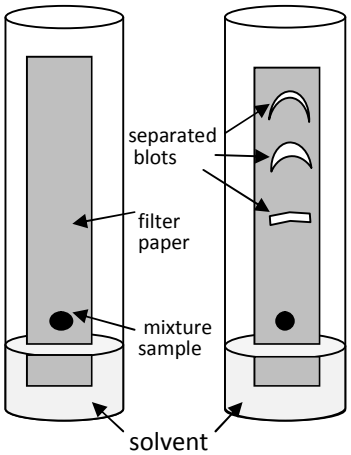
Substances that make up a mixture can be separated by various physical methods because the substances are physically combined, and each retains its physical properties. Methods of separation depend on physical characteristics of each substance in the mixture, as well as if the mixture is homogeneous or heterogeneous.

Separation of homogeneous mixtures

Distillation is a process of separating components of a homogeneous mixture (solution) by using differences in their boiling points. In a distillation process, a sample of a mixture is placed and heated in a distillation apparatus. As the *boiling point* of a substance in the mixture is reached, the substance will boil and evaporate out of the mixture. The substance with the lowest boiling point will boil and evaporate out first, and the substance with the highest boiling point will boil and evaporate out last. As each substance boils and evaporates out, it can be condensed back to liquid and collected in separate containers. Examples of mixtures that can be separated by distillation include: Water and alcohol mixture. A mixture of different hydrocarbon gases (methane, ethane, propane..etc). Salt and water mixture can be separated by boiling off the water and leaving the salt behind.

Chromatography is a process of separating substances of a homogeneous mixture by first dissolving the mixture in a solvent (mobile phase) , and then allowing the substances in the mixture to move through some sort of a stationary phase. In ***gas chromatography,*** a sample of a mixture is placed in equipment that vaporizes the components of the mixture and allows them to move through a series of columns packed with stationary phase chemicals. Components of the mixture will move through the columns at different speeds (rates), and can be detected and analyzed as they exit the columns. Gas chromatography is often used to analyze purity of a mixture. In ***paper chromatography***, a sample of a mixture is dissolved in a solvent (moving phase), and each component of the mixture will move up the chromatograph paper (stationary phase) at different rates. The height and other characteristics of each mark (blot) on the paper can be analyzed and be used to identify the different components of the mixture. Pigment separation is often done by paper chromatography.

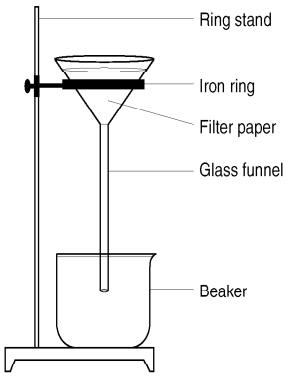
Paper chromatography set up



Separation of heterogeneous mixtures.

Decantation (pouring) is a simple process of separating a heterogeneous mixture in which the components have separated into layers. Each layer of the mixture can be poured out and collected one by one. Immiscible liquids (liquids that do not mixed well or evenly) are often separated by decantation. Oil and water are examples of immiscible liquids.

A filtration set up



Filtration

Filtration is a process that can be used to separate a liquid mixture that is composed of substances with different particle sizes. A filter is equipment with holes that allows particles of a mixture that are smaller than the holes to pass through, while particles that are bigger than the holes are kept on the filter. A mixture of salt water and sand can be separated through using a filtration process. During filtration, the aqueous components (salt and water) will go through the filter paper because molecules of water and particles of salt are smaller than holes of a filter. The sand component of the mixture will stay on the filter because sand particles are larger than holes of a filter paper.

8. Types of Matter: Practice Questions

Practice 10
Which type of matter can be separated only by physical methods?
1) A mixture 2) An element 3) A pure substance 4) A compound

Practice 11
Which two types of matter are considered chemical pure substances?
1) Elements and compounds
2) Solutions and compounds
3) Elements and mixtures
4) Solutions and mixtures

Practice 12
Which type of matter is composed of two or more different elements chemically combined in a definite ratio?
1) A homogeneous mixture 2) A heterogeneous mixture 3) A compound 4) An element

Practice 13
The formula $N_2(g)$ is best classified as
1) A compound 2) A mixture 3) An element 4) A solution

Practice 14
When $NaNO_3$ salt is dissolved in water, the resulting solution is classifies as a
1) Heterogeneous compound
2) Homogeneous compound
3) Heterogeneous mixture
4) Homogeneous mixture

Practice 15
One similarity between all mixtures and compounds is that both
1) Are heterogeneous
2) Are homogeneous
3) Combine in definite ratio
4) Consist of two or more substances

Practice 16
Two substances, X and Y, are to be identified. Substance X cannot be broken down by a chemical change. Substance Y can be broken down by a chemical change. What can be concluded about these substances?
1) X and Y are both elements
2) X and Y are both compound
3) X is an element and Y is a compounds
4) X is a compound and Y is an element

Practice 17
Bronze contains 90 to 95 percent copper and 5 to 10 percent tin. Because these percentages can vary, bronze is classified as
1) A compound 2) A substance 3) An element 4) A mixture

Practice 18
When sample X is passed through a filter a white residue, Y, remains on the filter paper and a clear liquid, Z, passes through. When liquid Z is vaporized, another white residue remains. Sample X is best classified as
1) A heterogeneous mixture
2) A homogeneous mixture
3) An element
4) A compound

Practice 19
A mixture of crystals of salt and sugar is added to water and stirred until all solids have dissolved. Which statement best describes the resulting mixture.
1) The mixture is homogeneous and can be separated by filtration
2) The mixture is homogeneous and cannot be separated by filtration
3) The mixture is heterogeneous and can be separated by filtration
4) The mixture is heterogeneous and cannot be separated by filtration

9. Diagram representation of matter

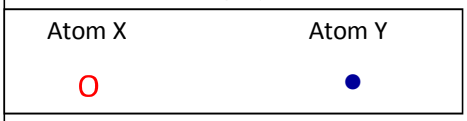
Diagrams can also be used to show compositions of elements, compounds and mixtures

Examples are given below.

Concept Task: Be able to recognize a diagram that shows an element, a compound or a mixture.

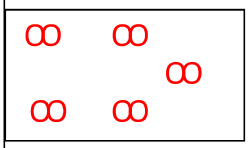
Examples

Given the following symbols:

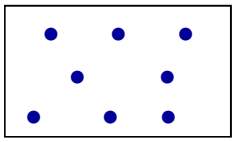


Elements

The diagrams below represent elements because units in each diagram consist of identical atoms.



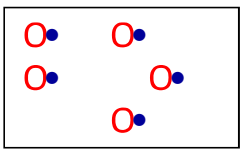
Diatomic element X



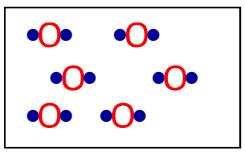
Monatomic element Y

Compounds

The diagrams below represent compounds because each consists of identical units, and each unit is composed of different atoms that are touching to show chemical bonding between the atoms.



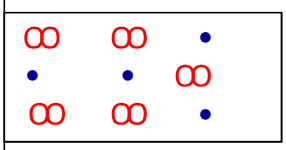
Compound composed of one atom X and one atom Y
(Five identical units of)



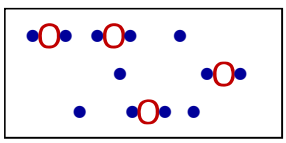
Compound composed of two atoms Y and one atom X
(Six identical units of)

Mixtures

The diagrams below represent mixtures because each consists of a mix of two or more different units . One unit is not touching the other to show physical combination between the different units)

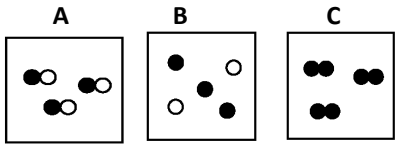


A mixture of diatomic element X and monatomic element Y



A mixture of compound XY and atom Y

Given diagrams A, B, and C below: Answer practice questions 13 - 15 based on the diagrams.



● = particle X
○ = particle Y

Practice 20

Which diagram or diagrams represents a compound of X and Y

1) A and B
2) A and C
3) A only
4) B only

Practice 21

Which diagrams represent chemical pure substances?

1) A and B
2) B and C
3) A and C
4) A, B and C

Practice 22

Which best describes diagram B?

1) It is a mixture that is composed of substances physically combined
2) It is a mixture that is composed of substances chemically combined
3) It is a compound that is composed of substances physically combined
4) It is a compound that is composed of substances chemically combined

Lesson 2 – Phases of Matter

Introduction

There are three phases of matter: solid, liquid, and gas. The fourth phase of matter, plasma, is not commonly discussed in high school chemistry.

The nature of a substance determines the phase in which the substance will exist under normal conditions. For example, gold will always be a solid at room temperature (23°C). At the same room temperature, water will always exist as a liquid, and oxygen will always exist as a gas.

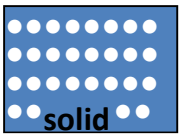
Most substances can change from one phase to another. The nature of a substance also determines the conditions (temperature and/or pressure) that the substance will change from one phase to another.

In this lesson, you will learn about the three phases of matter. You will also learn about phase changes and how they relate to temperature and energy.

10. Phases of matter

The notes below define and summarize characteristics of substances in the three phases.
To the right are diagrams showing particle arrangements of water in each phase.

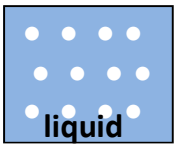
Solid (s) : A substance in the solid phase has the following characteristics:
. Definite volume and definite shape
. Particles arranged orderly in a *regular geometric pattern*
. Particles vibrating around a fixed point
. Particles with strong attractive force to one another
. Particles that cannot be easily compressed (incompressible)



H_2O(**s**)

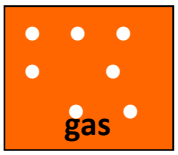
Orderly and regular geometric arrangement of particles in **solid** phase

Liquid (l) : A substance in the liquid phase has the following characteristics:
. Definite volume, but no definite shape (It takes the shape of its container)
. Particles that are less orderly arranged than those in the solid phase
. Particles with weaker attractive forces than those in the solid phase
. Particles that flow over each
. Particles that cannot be easily compressed (incompressible)



H_2O(**l**)

Gas (g) : A substance in the gas phase has the following characteristics:
. No definite volume and no definite shape (it takes volume and shape of its container)
. Particles far less orderly arranged (most random)
. Particles that move fast and freely throughout the space of the container
. Particles with very weak attractive force to each other
. Particles that can be easily compressed (compressible)



H_2O(**g**)

11. Phases of matter: Practice problems

Practice 23
Which phase of matter is described as having a definite volume but no definite shape?
1) Aqueous 2) Solid 3) Liquid 4) Gas

Practice 24
Substance X is a gas and substance Y is a liquid. One similarity between substance X and substance Y is that
1) Both have definite shape
2) Both have definite volume
3) Both are compressible
4) Both take the shapes of their containers

Practice 25
Which of the following substances have particles that are arranged in regular geometric pattern?
1) Al(s) 3) CCl_4(l)
2) Ar(g) 4) NH_3(aq)

Practice 26
Which substance takes the space and shape of its container?
1) Gold 3) Water
2) Iron 4) Hydrogen

12. Phase changes

During a phase change, a substance changes its form (or state) without changing its chemical composition. Therefore, a phase change is a physical change. Any substance can change from one phase to another given the right conditions of temperature and/or pressure. Most substances require a large change in temperature to go through one phase change. Water is one of only a few chemical substances that can change through all three phases within a narrow range of temperature change.

Below are six phase changes you need to know.

Fusion (also known as **melting**) is a change from *solid* to *liquid.*	H_2O***(s)*** ---------- > H_2O***(l)***
Freezing is a change of phase from *liquid* to *solid*	H_2O***(l)*** --------- --> H_2O***(s)***
Evaporation is a change of phase from *liquid* to *gas*	C_2H_5OH***(l)*** -------> C_2H_5OH***(g)***
Condensation is a change of phase from *gas* to *liquid*	C_2H_5OH***(g)*** ------> C_2HOH***(l)***
Deposition is a change of phase from *gas* to *solid*	CO_2***(g)*** ----------> CO_2***(s)***
Sublimation is a change of phase from *solid* to *gas*	CO_2***(s)*** ----------> CO_2***(g)***

NOTE: **CO_2*(s)*** , *solid* carbon dioxide (also known as dry ice) , and **I_2*(s),*** *solid* iodine, are two chemicals substances that readily sublime at room temperature because of the weak intermolecular forces holding their molecules together. Most substances do not sublime.

13. Phase change and energy

Each of the six phase changes defined above occurs when a substance had absorbed or released enough heat energy to rearrange its particles (atoms, ions or molecules) from one form to another. Some phase changes require a release of heat by a substance, while other phase changes require heat to be absorbed.

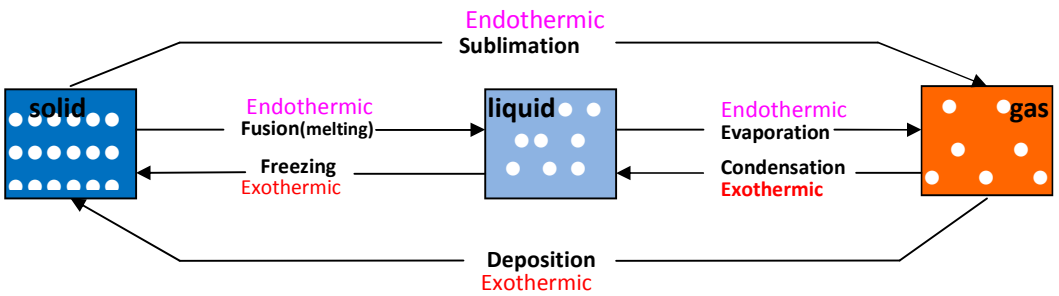
Endothermic describes a process that absorbs heat.

Fusion, evaporation and sublimation are endothermic phase changes.

Exothermic describes a process that releases heat.

Freezing, condensation and deposition are exothermic phase changes.

A diagram summarizing phase changes and their relationship to heat energy is shown below.



14. Phase change and energy: Practice problems

Practice 27
Which phase change equation is exothermic?
1) $N_2(l)$ ---------- > $N_2(g)$
2) $Hg(s)$ -------- > $Hg(l)$
3) $CH_4(g)$ -------- > $CH_4(l)$
4) $I_2(s)$ ---------- > $I_2(g)$

Practice 28
Which equation is showing the sublimation of iodine?
1) $I_2(g)$ ---- -> $I_2(s)$
2) $I_2(s)$ -----> $I_2(g)$
3) $I_2(s)$ ------> $I_2(l)$
4) $I_2(g)$ ------> $I_2(l)$

Practice 29
The change $NH_3(g)$ --------> $NH_3(s)$ is best described as
1) Sublimation
2) Evaporation
3) Condensation
4) Deposition

Practice 30
Heat will be absorbed by a substance as it changes from
1) Solid to gas
2) Liquid to solid
3) Gas to solid
4) Gas to liquid

Practice 31
Which is true of ethanol as it changes from a liquid state to a gas state?
1) It absorbs heat as it condenses
2) It absorbs heat as it evaporates
3) It releases heat as it condenses
4) It releases heat as it evaporates

15. Temperature

Temperature is a measure of the average kinetic energy of particles in matter.

Kinetic energy is energy due to the movements of particles in a substance.
. The higher the temperature of a substance, the greater its kinetic energy
. As temperature increases, the average kinetic energy also increases

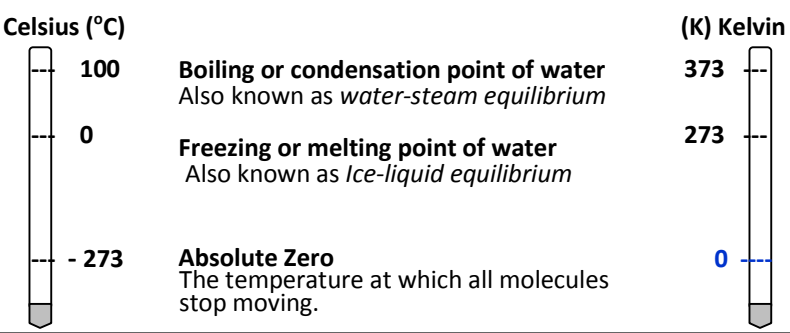
Thermometer is an equipment that is used for measuring temperature.
There are a few different units for measuring temperature. Degree Celsius (°C) and Kelvin (K) are the two most common temperature units used in chemistry. The mathematical relationship between Celsius and Kelvin is given by the equation:

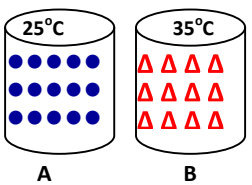
K = °C + 273 See Reference Table T

According to this equation, the Kevin temperature value is always 273 higher than the same temperature in Celsius.

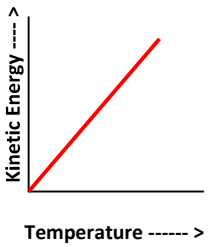
Creating a thermometer scale of any unit requires two fixed reference points. *The freezing point (0°C , 273K)* and the *boiling point (100°C , 373K)* of water are often used as the two reference points in creating a thermometer scale. Once the two reference points are marked on a thermometer, equal units is scaled and marked between the two points.

Important temperature points at normal pressure





Since particles Δ in **B** are at a higher temperature, Δ will be moving faster (higher kinetic energy) than particles ● in A



A graph showing a direct relationship between temperature and kinetic energy

16. Temperature conversion: Practice Problems

Concept Task: Be able to convert temperature between Celsius and Kelvin.

Recall: **K = °C + 273**

Practice 32
Which Celsius temperature is equivalent to +20 K?
1) -253
2) -293
3) +253
4) +293

Practice 33
The temperature of -30 °C is the same as
1) 30 K
2) 303 K
3) 243 K
4) 70 K

Practice 34
What is the equivalent of 546 K on a Celsius scale?
1) 273 °C
2) 818 °C
3) -273 °C
4) 546 °C

Practice 35
A liquid's freezing point is -38°C and its boiling point is 357°C. What is the number of Kelvin degrees between the boiling and the freezing point of the liquid?
1) 319
2) 668
3) 592
4) 395

Practice 36
Heat is being added to a given sample. Compared to the Celsius temperature of the sample, the Kelvin temperature will
1) Always be 273° lower
2) Always be 273° greater
3) Have the same reading at 273°C
4) Have the same reading at 0°C

17. Temperature and Kinetic Energy: Practice Problems

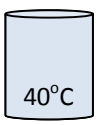
Concept Task: Be able to determine which temperature has the highest or lowest kinetic energy.

Recall:

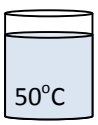
The higher the temperature, the higher the kinetic energy

Practice 37
Which substance will contain particles with the highest average kinetic energy?
1) NO (g) at 40°C
2) NO_2g) at 45°C
3) N_2O(g) at 30°C
4) N_2O_3(g) at 35°C

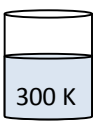
Practice 38
Which container contains water molecules with the lowest average kinetic energy?



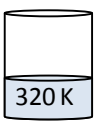
1)



2)



3)



4)

Practice 39
Which change in temperature is accompanied by greatest increase in average kinetic energy of a substance?
1) -20°C to 15°C
2) 15°C to -20 °C
3) -25°C to 30°C
4) 30°C to -25°C

Practice 40
A sample of substance X can change from one temperature to another. Which change will result in the highest increase in the average kinetic energy of the molecules?
1) 250 K to -10°C
2) 300 K to 57°C
3) 400K to 100°C
4) 100K to -60°C

18. Phase change diagrams: Understanding phase change diagrams

A **phase change diagram** shows the relationship between temperature and phase changes of a substance over a period of time as the substance is heating or cooling.

A heating or cooling experiment of a substance can be conducted in a laboratory to see the change in temperature of the substance over time. Data of time and temperature from the experiment can be collected, plotted, and graphed to generate a phase change diagram.

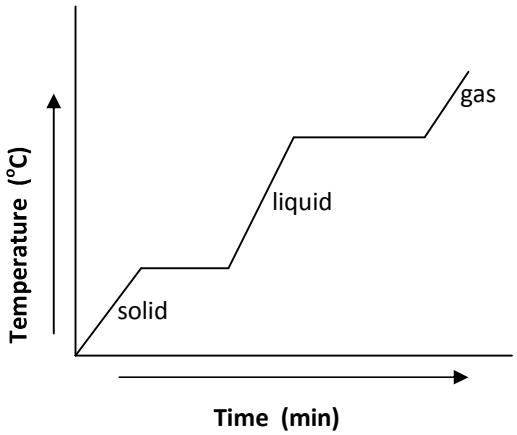
The unique thing about all phase change data and diagrams is that temperature of the substance changes only at certain times. The temperature remains constant at other times even though heat is continuously being added to (or removed from) the substance at a constant rate. Your ability to explain this phenomenon depends on your understanding of the relationship between heat, temperature, kinetic energy, potential energy, and particles arrangement of a substance in different phases.

The two phase diagrams are the heating and cooling curves.

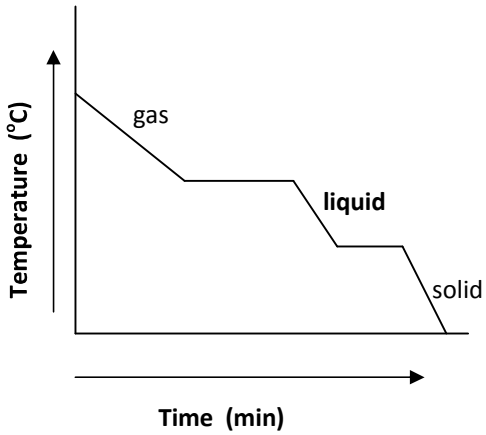
Heating curve:
. Shows changes of a substance starting with the substance in a more organized state (ex. from solid)
. Shows temperature change of a substance as heat is being absorbed (endothermic process)

Cooling curve
. Shows changes of a substance starting with the substance in a less organized state (ex. from gas)
. Shows temperature changes of a substance as heat is being released (exothermic process)

Heating curve (Endothermic change)



Cooling curve (Exothermic change)



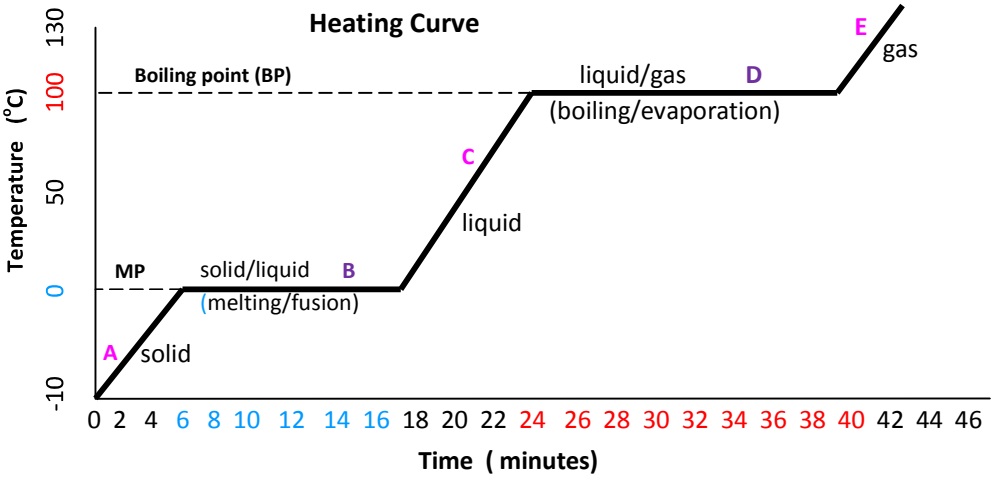
Understanding a phase change diagram can help you determine the following information about a substance:

. Freezing , melting, and boiling points of a substance
. When potential and kinetic energy are changing or remaining constant
. When a substance is in one phase: solid, liquid, or gas phase
. When a substance is in two phases: solid/liquid or liquid/gas mixture
. The total time a substance stays in any phase
. The total time it takes for a substance to go through any of the phase changes

Notes on the next section will show you how to determine the above information from any given phase change diagram. Follow the examples given when interpreting other phase change diagrams.

19. Phase change diagrams

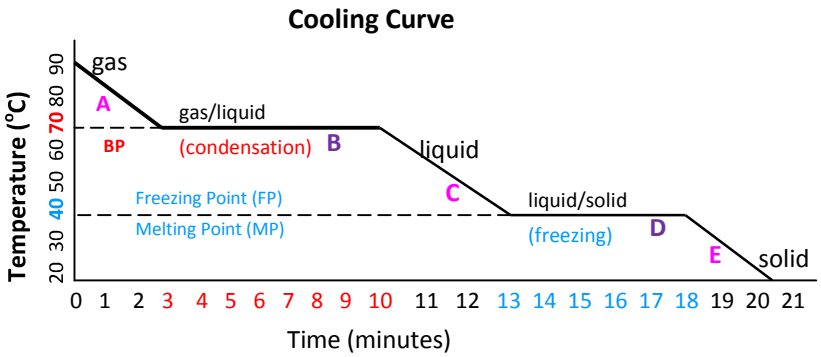
Concept Task: Be able to identify segments and interpret heating and cooling curves.



Some important information about the above heating curve .

Melting point / freezing point/ solid - liquid equilibrium occur at :	**0°C**
Boiling point / condensation point/ liquid-gas equilibrium occur at :	**100°C**
kinetic energy increases / potential energy remains constant during segments:	**A**, **C**, and **E**
The substance exists in one phase during segments:	**A, C,** and **E**
Potential energy increases / kinetic energy remains constant during segment:	**B** and **D**
The substance exists in two phases during segments:	**B** and **D**
Total time the substance goes through boiling (from 24 to 40 minutes) :	**16 minutes**

The substance is likely water because ice melts at 0°C and water boils at 100°C



Some important information about the above cooling curve:

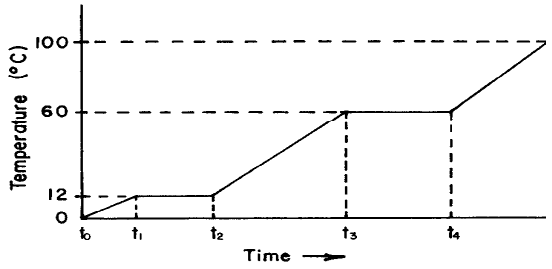
Melting point / freezing point/ liquid-solid equilibrium occur at :	**40°C**
Boiling point / condensation point/ gas-liquid equilibrium occur at :	**70°C**
kinetic energy decreases / potential energy remains constant during segments:	**A**, **C**, and **E**
Potential energy decreases / kinetic energy remains constant during segment:	**B** and **D**
Total time for substance to freeze (from 13 to 18 minutes) :	**5 minutes**

The substance is not water because the freezing and boiling points are different from those of water.

20. Phase Change diagrams: Practice Problems

Concept Task: Be able to identify boiling, freezing, and melting points on phase change diagrams

Practice questions 41–43 are based on graph below, which represents a uniform heating of a substance, starting with the substance as a solid below its melting point.



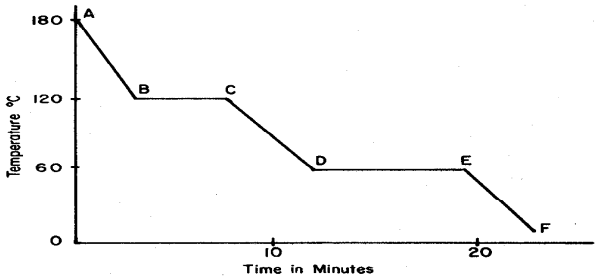
41. What is the melting point of this substance?
1) 0°C 3) 12°C
2) 60°C 4) 100°C

42. What is the boiling point of the substance?
1) 100°C 3) 60°C
2) 12°C 4) 0°C

43. The freezing point of the substance is
1) 100°C 3) 0°C
2) 60°C 4) 12°C

Concept Task: Be able to identify phase segments on phase change diagrams

Practice questions 44–46 are based on diagram below, which represents the relationship between temperature and time as heat is added at a constant rate to a substance, starting when the substance is a gas above its boiling point.



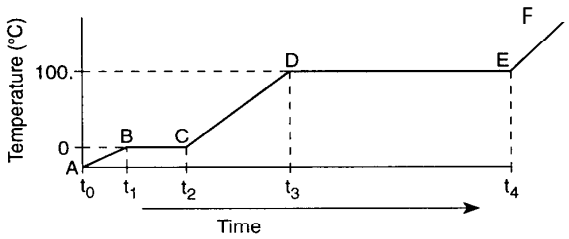
44. The liquid phase of the substance is represented by segment
1) BC 2) DE 3) CD 4) EF

45. Liquid/solid equilibrium of the substance is represented by which segment of the curve?
1) BC 2) AB 3) EF 4) DE

46. During which segment or segments does the substance exist in one phase?
1) AB only 3) AB and CD, only
2) BC only 4) AB, CD and EF, only

Concept Task: Be able to relate energy to phase change diagram

Practice questions 47-48 are based on graph below, which shows the uniform heating of a substance, starting with the substance as a solid below its melting point.



47. Which portions of the graph represent times when kinetic energy is increasing while potential energy remains constant?
1) AB , CD, and EF 3) BC and DE
2) AB , BC, and CD 4) CD and EF

48. Between which time intervals could the heat of fusion be determined?
1) t_o and t_1 3) t_2 and t_4
2) t_1 and t_2 4) t_3 and t_4

Concept Task: Be able to interpret phase change data.

DATA TABLE

Time (minutes)	Temperature (°C)
0	65
1	58
2	52
3	53
4	53
5	53
6	53
7	53
8	51
9	47
10	42

Practice questions 49 - 50 are based on data table below, which was collected as a substance in the liquid state cools.

49. Which temperature represents the freezing point of this substance?
1) 65°C 2) 42°C 3) 47°C 4) 53°C

50. Which is true of the kinetic energy and the potential energy of the substance from time 7 and 10 minute?
1) The kinetic energy is increasing and the potential energy is remaining constant
2) The kinetic energy is decreasing and the potential energy is remaining constant
3) The kinetic energy is remaining constant and the potential energy is decreasing
4) Both the kinetic energy and the potential energy are decreasing

Lesson 3 – Heat (thermal) energy and heat calculations

Introduction

Heat is a form of energy that can flow (or transfer) from one object to another. Heat (thermal) energy will always flow from an area or object of a higher temperature to an area or object of a lower temperature. During chemical and physical changes heat energy is either absorbed or released. The amount of heat energy absorbed or released can be determined using various methods. One of those methods (and the most convenience) is to take the temperature of the surrounding before and after a physical or chemical change. When other factors are known about the substance, the temperature difference can be used in a heat equation to calculate the amount of heat absorbed or released.

In this lesson, you will learn about heat and its relationship to temperature. You will also learn how to use heat equations to calculate heat absorbed or released during temperature and phase changes.

21. Heat

Heat is a form of energy that can flow from high to low temperature area.

Below are some important information related to heat energy.

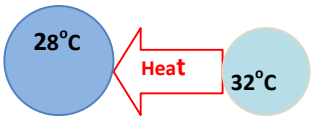
Joules and **calories** are the two most common units for measuring heat.

Calorimeter is a device used in measuring heat energy during physical and chemical changes.

Exothermic describes a process that releases (emits or loses) heat.
As an object or a substance releases heat, its temperature decreases.

Endothermic describes a process that absorbs (gains) heat.
As an object or a substance absorbs heat, its temperature increases.

Direction of heat flow



Lower temp Higher temp

*Heat will always flow from **high** temperature to **lower** temperature.*

22. Heat flow and temperature: Practice problems

Concept Task: Be able to determine and describe direction of heat flow .

Practice 51

Object A and object B are placed next to each other. If object B is at 12°C, heat will flow from object A to object B when the temperature of object A is at

1) 6°C 2) 10°C 3) 12°C 4) 15°C

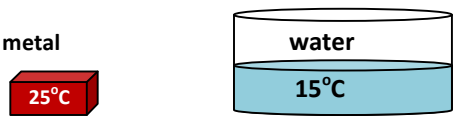
Practice 52

A solid material X is place in liquid Y. Heat will flow from Y to X when the temperature of

1) Y is 20°C and X is 30°C
2) Y is 10°C and X is 20°C
3) Y is 15°C and X 10°C
4) Y is 30°C and X is 40°C

Practice 53

Given the diagrams



Which correctly describes the energy transfer when the metal object is dropped into the water?

1) Thermal energy will flow from the metal to water, and the water temperature will decrease
2) Thermal energy will flow from the metal to water, and the water temperature will increase
3) Chemical energy will flow from the metal to water, and the water temperature will decrease
4) Chemical energy will flow from the metal to water , and the water temperature will increase

23. Heat constants and equations

Amount of heat energy absorbed or released by a substance can be calculated using a heat equation. There are three heat equations, and each heat equation contains a heat constant. The heat equations and heat constants for water are given on the Reference Tables.

Reference Table B
Heat constants for water

Specific Heat Capacity of $H_2O(l)$ (**C**)	4.18 J/g°C
Heat of fusion (**Hf**)	334 J/g
Heat of Vaporization (**Hv**)	2260 J/g

Reference Table T
Heat equations

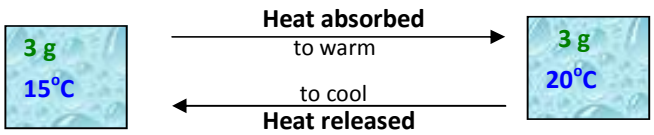
$q = m \cdot \mathbf{C} \cdot \Delta T$
$q = m \cdot \mathbf{Hf}$
$q = m \cdot \mathbf{Hv}$

q is heat
m is mass

The notes below explain more about the heat constants and equations.

24. Specific heat capacity

A substance can change from one temperature to another by either absorbing or releasing heat.
If heat is absorbed or gained, the temperature of the substance will increase.
If heat is released or lost, the temperature of the substance will decrease.



Heat = m x C x Δ T

If the specific heat capacity and mass of a substance are known, the amount of heat absorbed or released by the substance to change from one temperature to another can be calculated using the equation below:

Heat = m x C x Δ T

m = mass of the substance (g)
C = specific heat capacity (J/g.°C)
ΔT = difference in temperature (°C)
(ΔT = High temp - Low temp)

Specific heat capacity (C) of a substance is the amount of heat needed to change the temperature of a 1 gram sample of a substance by just 1°C.

Specific heat capacity (C) for water = 4.18 J/g.°C (See Reference Table B)

Interpretations:

It takes 4.18 Joules (J) of heat energy to change the temperature of a one gram (g) sample of water by just one degree Celsius (°C).

Or

A one gram sample of water must absorb (or release) 4.18 Joules of heat energy to change its temperature by just one Celsius degree (°C)

In heat equations, the specific heat capacity (C) serves as a conversion factor that allows you to calculate the amount of heat absorbed (or released) by any given mass (grams) of a substance to change between any to two temperatures.

Note: Specific heat capacities of other substances are different from that of water.

25. Heat of fusion

A substance can change between the solid and liquid phases by absorbing or releasing heat.
If heat is absorbed by a solid, the substance will change to its liquid state. This is called fusion (or melting).
If heat is released by a liquid, the substance will change to its solid state. This is called freezing.

If the heat of fusion and mass of a substance are known, the amount of heat absorbed or released by the substance to change between the solid an liquid states can be calculated using the heat equation below:

Heat = m x Hf

m = mass of solid or liquid (g)
Hf = Heat of fusion (J/g)

Heat of fusion (Hf) of a substance is the amount of heat needed to melt or freeze a one gram sample of the substance at constant meting temperature.

Heat of fusion for water = 334 J/g (See Reference Table B)

Interpretation:
It takes 334 Joules of heat to melt or freeze a one gram sample of water (at a constant melting point).

In the equation above, the heat of fusion (Hf) serves as a conversion factor that allows you to calculate the amount of heat absorbed or released by any given mass of a substance to melt or freeze.

Note: The heat of fusion of other substances are different from that of water.

26. Heat of vaporization

A substance can change between the liquid and gas phase by absorbing or releasing heat.
If heat is absorbed by a liquid, the substance will change to its gaseous state. This is called vaporization.
If heat is released by a gas, the substance will change to its liquid state. This is called condensation.

If the heat of vaporization and mass of a substance are known, the amount of heat absorbed or released by the substance to change between the liquid and gas states can be calculated using the heat equation below:

Heat = m x Hv

m = mass of the liquid or gas (g)
Hv = Heat of vaporization (J/g)

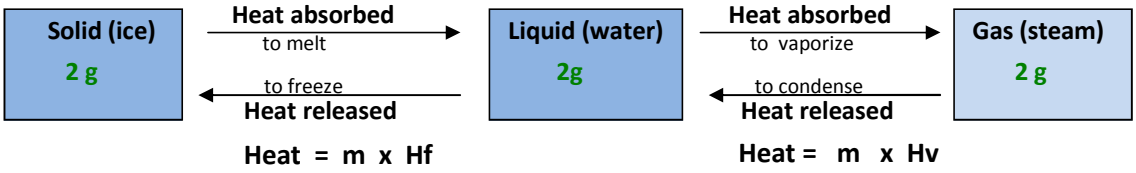
Heat of vaporization (Hv) of a substance is the amount of heat needed to change a one gram sample of the substance at a constant boiling temperature.

Heat of vaporization for water = 2260 J/g (See Reference Table B)

Interpretation:
It takes 2260 Joules of heat to vaporize or condense a one gram sample of water at its boiling point.

In the equation above, the heat of vaporization serves as a conversion factor that allows you to calculate the amount of heat absorbed (or released) by any given mass of a substance to vaporize or condense.

Note: The heat of vaporization of other substances are different from that of water.



27. Heat calculations: Examples and practice problems

Concept Task: Be able to use a heat equation to setup and calculate heat absorbed or released by a substance.

Heat equation for temperature change

$$\text{Heat} = m \times C \times \Delta T$$

Choose this equation if two different temperatures (or change in temp) are given in a heat problem.

Example

How much heat is released by a 3 gram sample of water to change its temperature from 15°C to 10°C ?
Show numerical setup and the calculated result

Step 1. Identify all known and unknown factors.

Known:		**Unknown**
Mass	= 3 g	Heat = ?
ΔT	= 15°C – 10°C = 5°C	
C	= 4.18 J/g.°C *(for water – see Table B)*	

Step 2: Write equation, setup and solve

Heat = m x C x ΔT
Heat = 3 x 4.18 x 5 *numerical setup*
Heat = **62.7 Joules** *calculated result*

Practice 54
How much heat is released by a 15-gram sample of water when it is cooled from 40°C to 30°C?
1) 630 J
2) 42 J
3) 63 J
4) 130 J

Practice 55
What is the total amount of heat energy needed to change the temperature of a 65-gram sample of water from 25.°C to 40°C?
1) 6.3×10^{-2} KJ
2) 4.1×10^{1} KJ
3) 1.1×10^{-1} KJ
4) 6.8×10^{1} KJ

Practice 56
What is the temperature change of a 5-gram sample of water that had absorbed 200 Joules of heat?
Show numerical setup and the calculated result.

Heat equation for fusion phase change

$$\text{Heat} = m \times Hf$$

Choose this equation if a heat question has words or phrase such as *to melt*, *to freeze*, *solid to liquid.* or if the temperature is constant at 0°C.

Example

What is the number of joules needed to melt a 6-g sample of ice to water at 0°C?
Show numerical setup and the calculated result

Step 1: Identify all known and unknown factors.

Mass = 6 g Heat = ?
Hf = 334 J/g *(for water – see Table B)*

Step 2: Write equation, setup and solve

Heat = m x Hf
Heat = 6 x 334 *numerical setup*
Heat = **2004 J** *calculated result*

Practice 57
The heat of fusion for an unknown substance is 220 J/g. How much heat is required to melt a 35-g sample of this substance at its melting point?
1) 255 J
2) 73480 J
3) 11690 J
4) 7700 J

Practice 58
1200 Joules is added to a sample of ice to change it to water at 0°C. What is the mass of the ice?
1) 3.6 g
2) 0.27 g
3) 334 g
4) 1.9 g

Practice 59
What is the heat of fusion of an unknown solid if 4.8 KJ of heat is required to completely melt a 10 gram sample of this solid?

28. Heat calculations. **Examples and Practice problems** continue

Heat equation for vaporization phase change

$$\text{Heat} = m \times Hv$$

Choose this equation if a heat question has words or phrase such as *to boil, to vaporize*, *liquid to gas,* or if the temperature is constant at 100°C.

Example

Liquid ammonia has a heat of vaporization of 1.35 KJ/g. How many kilojoules of heat are needed to evaporate a 5-gram sample of ammonia at its boiling point?

Show numerical setup and the calculated result

Step 1: Identify all known and unknown factors.

Mass = 5 g Heat = ?

Hv = 1.35 KJ/g *(NOT water, do not use Table B value)*

Step 2: Write equation, setup and solve

Heat = m x Hv

Heat = 5 x 1.35 *numerical setup*

Heat = **6.75 KJ** *calculated result*

Practice 60

How much heat must be removed from a 2.5-g sample of steam to condense it to water at a constant temperature of 100°C?

1) 828.5 J
2) 5650 J
3) 250 J
4) 1050 J

Practice 61

How much heat must be added to an 11-g sample of water to change it to steam at a constant temperature?

1) 2.3 KJ
2) 0.21 KJ
3) 25 KJ
4) 2486 KJ

Practice 62

A 23 g sample of an unknown liquid substance absorbed 34 KJ of heat to change to gas at its boiling point. What is the heat of vaporization of the unknown liquid?

Show numerical setup and the calculated result

29. Heat Problems from Data Table

Practice 63

The following information was collected by a student from a calorimetric experiment.

Mass of calorimeter + water	48.0 g
Mass of calorimeter	37.0 g
Initial temperature of water	60.0 °C
Final temperature of water	?

If the student determined that the water in the calorimeter had absorbed 400 Joules of heat, what would be the final temperature of the water?

Show numerical setup and the calculated result.

Practice 64

A student collected the following data from a calorimeter laboratory experiment

Mass of calorimeter + solid	72.5g
Mass of calorimeter	40.5 g
Heat absorbed by solid to melt	12736 J
Melting point of the solid	371 K

Based on the data collected by the student, what is the heat of fusion of the solid?

Show numerical setup and the calculated result.

Lesson 4 – Characteristics of gases and gas laws

Introduction

Behavior of gases is influenced by three key factors: volume (space), pressure and temperature. The relationships between these three factors are the basis for the gas laws and gas theories. These laws and theories attempt to explain how gases behave.

In this lesson you will learn about the kinetic molecular theories, the gas laws, and gas law calculations.

30. Kinetic Molecular Theory of an ideal gas

The **Kinetic Molecular Theory** of an ideal gas is a model (or properties) that is often used to explain behavior of gases.

An **ideal gas** is a theoretical (or assumed) gas that has all the properties described below.

Concept Facts: Study to memorize the characteristics below.

Summary of Kinetic Molecular Theory of an ideal gas.

. Gas is composed of individual particles
. Distances between gas particles are far apart
. Gas particles are in continuous, random, straight-line motion
. When two particles of a gas collide, energy is transferred from one particle to another
. Particles of gases have no attraction to each other
. Individual gas particles have no volume (negligible or insignificant volume)

A **real gas** is a gas that we know to exist.

Examples of real gases: *oxygen, carbon dioxide, hydrogen, helium.. etc*.

Since the kinetic molecular theory (summarized above) applies mainly to an ideal gas, the model cannot be used to predict the exact behavior of real gases. Therefore, real gases deviate from (do not behave exactly like) an ideal gas.

Reasons that real gases behave differently (deviate) from an ideal gas

. Real gas particles do attract each other (Ideal gas particles are assumed to have no attraction)
. Real gas particles do have volume (Ideal gas is assumed to have no volume)

Types of gases that behave most like an ideal gas

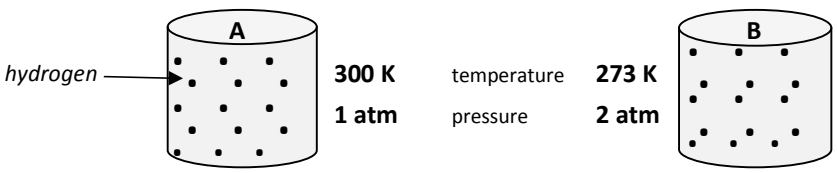
Real gases with small molecular masses behave most like an ideal gas.

Hydrogen (H) and Helium (He), the two smallest real gases by mass, behave most like an ideal gas.

Temperature and Pressure conditions that real gases behave most and least like an ideal gas

Real gases behave most like an ideal gas under *high temperature and low pressure*

Real gases behave least like an ideal gas under *low temperature and high pressure*



The hydrogen gas particles in container **A** will behave more like an ideal gas than those in container **B .**

31. Kinetic Molecular Theory and deviation: Practice problems

Practice 65
An ideal gas is made up of gas particles that
1) Have volume
2) Attract each other
3) Can be liquefied
4) Are in random motion

Practice 66
Real gases differ from an ideal gas because the molecules of real gases have
1) Some volume and no attraction for each other
2) Some volume and some attraction for each other
3) No volume and no attraction for each other
4) No volume and some attraction for each other

Practice 67
Under which two conditions do real gases behave least like an ideal gas?
1) High pressure and low temperature
2) Low pressure and high temperature
3) High pressure and high temperature
4) Low pressure and low temperature

Practice 68
The kinetic molecular theory assumes that the particles of ideal gas
1) Are in random, constant, straight line-motion
2) Are arranged in regular geometric pattern
3) Have strong attractive forces between them
4) Have collision that result in the system losing energy

Practice 69
At STP, which will behave most like an ideal gas?
1) Fluorine
2) Nitrogen
3) Oxygen
4) Chlorine

Practice 70
According to the Periodic Table, which of the following gases will behave least like an ideal gas?
1) Ar
2) Ne
3) Xe
4) Kr

Practice 71
Under which conditions of temperature and pressure would oxygen behaves most like an ideal gas?
1) 25°C and 100 kPa
2) 35°C and 100 kPa
3) 25°C and 80 kPa
4) 35°C and 80 kPa

Practice 72
A real gas will behave least like an ideal gas under which conditions of temperature and pressure?
1) 50°C and 0.5 atm
2) 50°C and 0.8 atm
3) 300 K and 0.5 atm
4) 300 K and 0.8 atm

32. Pressure, volume, temperature:

Behavior of gases is influenced by volume, pressure, and temperature of the gas.

Volume
Volume of a confined gas is a measure of the space the gas occupies (takes up).

Units: milliliters (ml) or liters (L) *1 L = 1000 ml*

Pressure
Pressure of a gas is a measure of how much force the gas particles exert on the walls of the container. This pressure is equal but opposite in magnitude to the external pressure exerted on the gas.

Units: atmosphere (atm) or Kilopascal (kPa) *1 atm = 101.3 kPa*

Temperature
Temperature of a gas is a measure of the average kinetic energy of the gas particles. As temperature increases, the gas particles move faster, and their average kinetic energy increases.

Units: degree Celsius (°C) or Kelvin (K) *K = °C + 273*

STP

Standard Temperature:	273 K or 0°C
Standard Pressure:	1 atm or 101.3 kPa

Reference Table A

The relationships between these three factors of a gas are discussed in the next few pages.

Practice 73
Express 0.267 liters of O_2 in milliliters.

Practice 74
What is the equivalent of 3487.2 ml of He in liters?

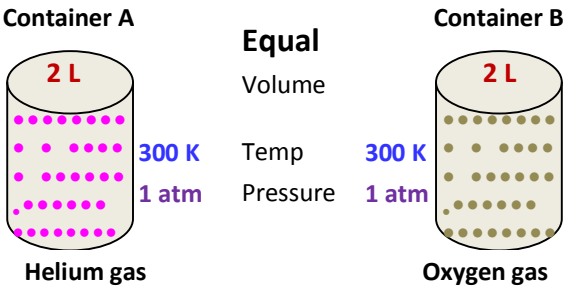
Practice 75
What pressure, in kPa, is equivalent to 1.7 atm?

Practice 76
What is the pressure of 65 kPa in atm?

33. Avogadro's law (hypothesis)

Avogadro's law states that under the same conditions of temperature and pressure:
Equal volume of gases contain equal number of molecules (particles).

In the example below, container A contains helium gas and container B contains oxygen gas.
NOTE that both containers have the same volume , and are at the same temperature and pressure.



If the number of helium gas molecules are counted in Container A and the number of oxygen gas molecules are counted in Container B, you will find that:
The number of molecules of helium in A is *the same* as the number of molecules of oxygen in B.

Practice 77
At STP, a 1.0 L sample of $H_2(g)$ would have the same number of gas molecules as
1) 0.5 L of He 2) 1.0 L of CO 3) 2.0 L of Ne 4) 3.0 L of N_2

Practice 78
Under which conditions would a 0.2 L sample of O_2 has the same number of molecules as a 0.2 L sample of N_2 that is at STP?
1) 0 K and 1 atm 2) 0 K and 2 atm 3) 273 K and 1 atm 4) 273 K and 2 atm

Practice 79
The table below gives the temperature and pressure of four different gas samples, each in a 1.5 L container:

Gas sample	Temperature (K)	Pressure (atm)
SO_2	200	1.5
Ar	300	3.0
N_2	200	1.5
O_2	300	1.5

Which two gas samples contain the same number of molecules?
1) Ar and O_2 2) Ar and N_2 3) SO_2 and Ar 4) SO_2 and N_2

Practice 80
A sample of oxygen gas is sealed in container X. A sample of hydrogen gas is sealed in container Z. Both samples have the same volume, temperature, and pressure. Which statement is true?

1) Container X contains more gas molecules than container Z.
2) Container X contains fewer gas molecules than container Z.
3) Containers X and Z both contain the same number of gas molecules.
4) Containers X and Z both contain the same mass of gas.

34. Boyle's law: Volume – Pressure relationship at constant temperature

Boyle's law describes the relationship between volume and pressure of a gas at constant temperature.

Concept Fact: Study to remember the following relationships.

At constant temperature, the *volume* of a set mass of a confined gas is *inversely proportional* to the *pressure* of the gas.

This fact can be expressed a few different ways:

As pressure is decreased on a gas, volume of the gas will increase proportionally. . If pressure on a gas is halved, volume of the gas will double

As pressure is increased on a gas, volume of the gas will decrease by same factor. . If pressure on a gas is doubled, volume of the gas will be half

(see diagram to the right)

Boyle's law equation (below) can be used to calculate a new volume of a gas when the pressure on the gas is changed at constant temperature.

$$P_1 V_1 = P_2 V_1$$

P_1 = Initial pressure (atm or KPa)

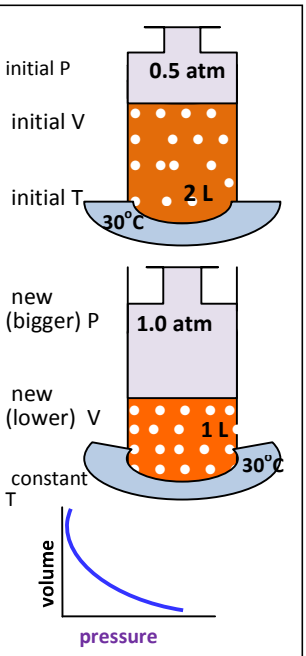
P_2 = New pressure (atm of kPa)

V_1 = Initial volume (ml or L)

V_2 = New volume (ml or L)

According to Boyle's law:

At constant temperature, the product of the new pressure (P_2) and volume (V_2) will always be equal to the product of the initial pressure (P_1) and volume (V_1).



Diagrams and graph showing pressure-volume relationship of a gas at constant temperature.

35. Boyle's law: Example and Practice problems

Concept Task: Be able to solve gas law problems at constant temperature

Example

At constant temperature, what will be the new of volume of a 3 L sample of oxygen gas if its pressure is changed from 0.5 atm to 0.25 atm?

Show numerical setup and the calculated result.

Step 1: Identify all known and unknown factors

V_1 = 3 L V_2 = ? (unknown)

P_1 = 0.5 atm P_2 = 0.25 atm

Step 2: *Write equation, setup, and solve*

$$P_1 V_1 = P_2 V_2$$

$$(0.5)(3) = (0.25)(V_2)$$

numerical setup

$$\frac{1.5}{0.25} = V_2$$

$$\mathbf{6\ L = V_2}$$ *calculated result*

Practice 81

The volume of a $CO_2(g)$ changes from 50 ml to 100 ml when pressure on the gas is changed to 0.6 atm. If the temperature of the gas is constant, what was the initial pressure on the gas?

1) 1.2 atm
2) 0.3 atm
3) 60 atm
4) 2 atm

Practice 82

A 0.8 L gas at STP had its pressure changed to 25.3 KPa. What is the new volume of the gas if the temperature is held constant?

Show numerical setup and the calculated result.

36. Charles' law: Volume – Temperature relationship at constant pressure

Charles's law describes the relationship between volume and Kelvin temperature of a gas at constant pressure.

Concept Facts: Study to remember the following relationships.

At constant pressure, the *volume* of a set mass of a confined gas *is directly proportional* to its *Kelvin temperature.*

This fact can be expressed in a few different ways:

As temperature is increased on a gas, volume of the gas will also increase proportionally.
. If temperature of a gas is doubled, volume will also double

As temperature of a gas is decreased, volume of the gas will also decrease by same factor.
. If temperature of a gas is halved, volume will also be halved
(see diagram to the right)

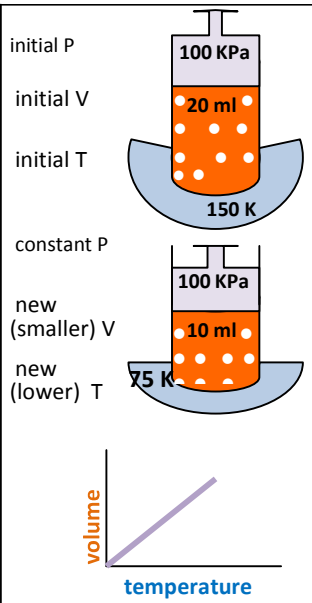
Charles' law equation (below) can be used to calculate a new volume of a gas when the temperature of the gas is changed at constant pressure.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

V_1 = Initial volume (ml or L)
V_2 = New volume (ml or L)
T_1 = Initial Kelvin temperature (K)
T_2 = New Kelvin temperature (K)

According to Charles' law:

At constant pressure, the ratio of new volume (V_2) to Kelvin temperature (T_2) will always be equal to the ratio of initial volume (V_1) to Kelvin temperature (T_1).



Diagrams and graph showing temperature – volume relationship of a gas at constant pressure

37. Charles' law: Example and practice problems

Concept Task: Be able to solve gas law problems at constant pressure.

Example

The volume of a confined gas is 25 ml at 280 K. At what temperature would the gas volume be 75 ml if the pressure is held constant?
Show numerical setup and the calculated result.

Step 1: Identify all known and unknown factors

V_1 = 25 ml V_2 = 75 ml
T_1 = 280 K T_2 = ? (unknown)

Step 2: Write equation, setup, and solve

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{25}{280} = \frac{75}{T_2}$$ *numerical setup*

$$\frac{(75)(280)}{25} = T_2$$

840 K = T_2 *calculated result*

Practice 83

A sample of oxygen gas has a volume of 150.ml at 300 K. If the pressure is held constant and the temperature is raised to 600 K, the new volume of the gas will be

1) 75.0 ml 3) 300 ml
2) 150 ml 4) 600 ml

Practice 84

A gas originally at STP has a volume of 0.8 L. If the pressure of the gas is held constant, at what temperature will the volume of the gas be decreased to 0. 6 L?
Show numerical setup and the calculated result.

38. Gay-Lussac's law: Pressure – Temperature relationship at constant volume

Gay-Lussac's law describes the relationship between pressure and Kelvin temperature of a gas at constant volume.

Concept Facts: Study to remember the following facts:

At constant volume, the *pressure* of a set mass of a confined gas *is directly proportional to* its *Kelvin temperature* .

This fact can be expressed a few different ways:

As temperature of a gas is decreased, pressure of the gas will also decrease . If temperature of a gas is halved, pressure will also be halved

As temperature is increased on a gas, pressure of the gas will also increase . If temperature of a gas is doubled, pressure of the gas will also double.

(See diagram to the right)

The Gay-Lussac's law equation below can be used to calculate the new pressure of a gas when temperature of the gas is changed at constant volume.

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

P_1 = Initial pressure (atm or kPa)

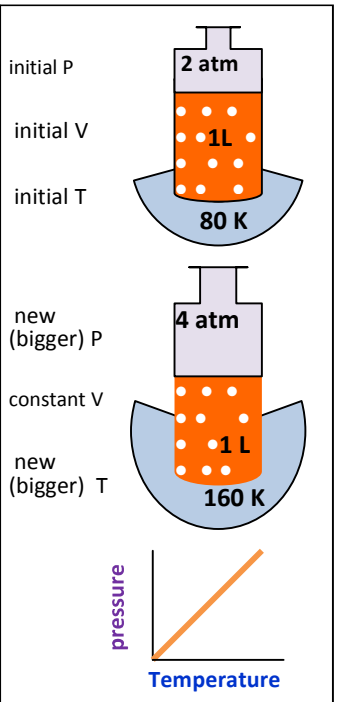
P_2 = New pressure (atm or kPa)

T_1 = Initial Kelvin temperature (K)

T_2 = New Kelvin temperature (K)

According to Gay-Lussac's law:

At constant volume, the ratio of new pressure (P_2) to temperature (T_2) will always be equal to the ratio of initial pressure (P_1) to temperature (T_1).



Diagrams and graph showing temperature-pressure relationship of a gas at constant volume

39. Gay-Lussac's law: Example and practice problems

Concept Task: Be able to solve gas law problems at constant volume.

Example

Pressure on a gas changes from 20 kPa to 50 kPa when the temperature of the gas is changed to 30°C. If volume was held constant, calculate the initial temperature of the gas? *Show setup and the calculated result.*

Step 1: Identify all known and unknown factors

P_1 = 20 kPa P_2 = 50 kPa

T_1 = ? T_2 = 30°C (must be in Kelvin)

T_2 = 30 + 273 = 303 K

Step 2: Write equation, setup, and solve

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{20}{T_1} = \frac{50}{303}$$ *numerical setup*

$$T_1 = 121\ K$$ *calculated result*

Practice 85

A gas sample at 546 K has a pressure of 0.4 atm. If the volume of the gas sample is unchanged, what will be the new pressure of the gas if its temperature is changed to 136.5 K ?

1) 0.4 atm 3) 0.8atm

2) 0.1 atm 4) 0.2 atm

Practice 86

A sample of CO_2 is at STP. If the volume of the CO_2 gas remains constant and its temperature is changed to 45°C, what will be the new pressure (in kilopascal) of the gas?

Show numerical setup and the calculated result.

40. Combined gas law

The **combined gas law** describes the relationship between all three factors : volume, pressure, and temperature: In the combined gas law, the only constant is the mass of the gas.

The combined gas law equation below is a combination of Boyle's, Charles' , and Gay-Lussac's law equations:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

See Reference Table T

NOTE: In all gas law problems, mass and the number of particles of the gas are always constant.

Eliminating the constant from the combined gas law equation will give you the equation needed to solve any gas law problem.

41. Combined gas law: Example and practice problems

Concept Task: Be able to solve combined gas law problems

Example

Hydrogen gas has a volume of 100 mL at STP. If temperature and pressure are changed to 0.5 atm and 546 K respectively, what will be the new volume of the gas?
Show setup and the calculated result.

Step 1: Identify all known and unknown factors

STP	V_1 = 100 mL	V_2 = ? (unknown)
	P_1 = 1 atm	P_2 = 0.5 atm
	T_1 = 273 K	T_2 = 546 K

Step 2: *Write out equation, setup, and solve*

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{(1)(100)}{273} = \frac{(0.5)(V_2)}{546}$$

numerical setup

$$\frac{(1)(100)(546)}{(273)(0.5)} = V_2$$

400 mL = V_2

calculated result

Practice 87

A gas sample has a volume of 1.4 L at a temperature of 20.K and a pressure of 1.0 atm. What will be the new volume when the temperature is changed to 40.K and the pressure is changed to 0.50 atm ?

1) 0.35 L
2) 0.75 L
3) 1.4 L
4) 5.6 L

Practice 88

A gas occupies a volume of 3 L at 1.5 atm and 80°C. Calculate the new volume of the gas if the temperature is changed to 150°C and the pressure is dropped to 1.0 atm.
Show numerical setup and the calculated result.

Practice 89

The volume of a 1.0 mole sample of an ideal gas will increase when the

1) Pressure decreases and the temperature decreases
2) Pressure decreases and the temperature increases
3) Pressure increases and the temperature decreases
4) Pressure increases and the temperature increases

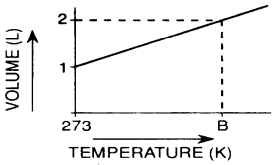
Practice 90

A gas is at STP, if the temperature of the gas is held constant while the volume of the gas is cut in half, the pressure of the gas will be

1) Double
2) Triple
3) Halve
4) Quadruple

Practice 91

The graph below shows a change in the volume of a gas sample as its temperature rises at constant pressure.



What temperature is represented by point B?

1) 546 K
2) 298 K
3) 273 K
4) 2 K

Lesson 5 – Physical and chemical properties and changes

Introduction

Properties are characteristics that can be used to identify and classify matter. Properties of matter can be classified as physical or chemical.

In this lesson, you will learn differences between physical and chemical properties, as well as the differences between physical and chemical changes of matter.

42. Physical and chemical properties

Physical properties and changes

A **physical property** is a characteristic of a substance that can be observed or measured without changing chemical composition of the substance. Some properties of a substance depend on sample size or amount, others do not.

Examples:
Extensive properties depend on sample size or amount present. Mass, weight and volume are examples of *extensive properties.*

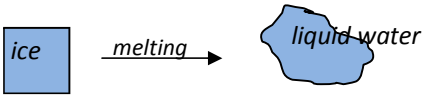
Intensive properties do not depend on sample size or amount. Melting, freezing and boiling points, density, solubility, color, odor, conductivity, luster, and hardness are *intensive properties.*

Differences in physical properties of substances make it possible to separate one substance from another in a mixture.

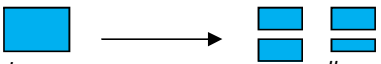
A **physical change** is a change of a substance from one form to another without changing its chemical composition.

Examples:

Phase change



Size change



Large piece *smaller pieces*

Dissolving $NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$

Chemical properties and changes

A **chemical property** is a characteristic of a substance that is observed or measured through interaction with other substances.

Examples:
It burns, it combusts, it decomposes, it reacts with, it combines with, or, it rusts are some of the phrases that can be used to describe chemical properties of a substance.

A **chemical change** is a change in composition and properties of one substance to those of other substances. **Chemical reactions** are ways by which chemical changes of substances occur.

Types of chemical reactions include *synthesis, decomposition, single replacement, and double replacement*.

LOOKING Ahead ⇨ Topic 5 – Formulas and Equations: You will learn more about these reactions.

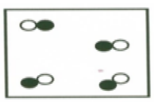
Practice 92
Which best describes a chemical property of sodium?
1) It is a shiny metal
2) It is smooth
3) It reacts vigorously with water
4) It is a hard solid

Practice 93
A large sample of a solid calcium sulfate is crushed into smaller pieces. Which two physical properties are the same for both the large sample and one of the smaller pieces?
1) Mass and density
2) Mass and volume
3) Solubility and density
4) Solubility and volume

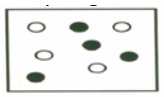
Practice 94
An example of a physical property of an element is the element's ability to
1) Form a compound
2) React with oxygen
3) React with an acid
4) Form an aqueous solution

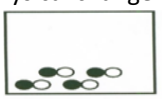
Practice 95
During a chemical change, a substance changes its
1) Density
2) Composition
3) Solubility
4) Phase

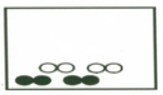
Practice 96
Given the particle diagram representing four molecules of a substance.

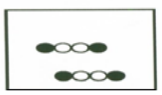


Which particle diagram best represents this same substance after a physical change has

1) 

3) 

2) 

4) 

Concept Terms

Below is a list of vocabulary terms from Topic 1. You should know the definition and facts related to each term.

1. Pure substance
2. Mixture
3. Element
4. Compound
5. Law of definite composition
6. Homogeneous mixture
7. Heterogeneous mixture
8. Aqueous solution
9. Decantation
10. Filtration
11. Distillation
12. Solid
13. Liquid
14. Gas
15. Fusion
16. Freezing
17. Condensation
18. Evaporation
19. Sublimation
20. Deposition
21. Exothermic
22. Endothermic
23. Temperature
24. Kinetic energy
25. Potential energy
26. Ice / liquid equilibrium
27. Water / steam equilibrium
28. Absolute Zero
29. Phase change diagram
30. Heat
31. Joules
32. Specific heat capacity
33. Heat of fusion
34. Heat of vaporization
35. Calorimeter
36. Kinetic molecular theory
37. Ideal gas
38. Avogadro's law
39. Boyle's law
40. Charles law
41. Gay – Lussac's law
42. Combined gas law
43. Physical property
44. Chemical property
45. Physical change
46. Chemical change

Concept Tasks

Below is a list of concept tasks from Topic 1. You should know how to solve problems and answer questions related to each concept task.

1. Recognizing chemical symbol of elements, compounds, and mixtures
2. Recognizing diagram representation of elements, compounds, and mixtures
3. Recognizing symbol representation of substances in different phases
4. Recognizing phase change equations
5. Determining substance with highest and lowest kinetic energy based on temperature
6. Temperature conversion between Kelvin and Celsius units
7. Interpreting phase change diagrams (heating and cooling curves)
8. Determining direction of heat flow based on temperatures of two objects
9. Heat calculation during temperature and phase changes
10. Determining gases that behave most or least like an ideal gas
11. Determining temperature and pressure that a gas behaves most or least like an ideal gas
12. Determining gases that contain equal number of molecules
13. Pressure conversion between atm and kPa units
14. Gas law calculations at constant temperature
15. Gas law calculations at constant pressure
16. Gas law calculation at constant volume
17. Combined gas law calculation
18. Determining physical and chemical properties of a substance
19. Determining physical and chemical changes of a substance

Topic outline

In this topic, you will learn the following concepts:

. Arrangements of the elements
. Types of elements and their properties
. Groups of elements and their properties
. Periodic trends
. Allotropes

Lesson 1 – Arrangement of the Elements

Introduction:

The modern Periodic Table contains all known elements that are arranged in the order of increasing atomic number.

There are more than on hundred known elements. Most of the elements are natural occurring, while others have been artificially produced in laboratories. Important information about an element can be found in the box of each element on the Periodic Table .

In this lesson, you will learn important facts about the Periodic Table, and the different arrangements of the elements.

1. Properties of the Modern Periodic Table

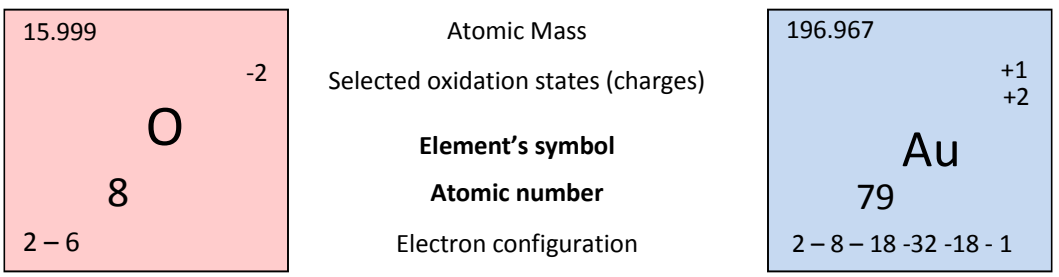
Concept Facts: Study to remember the followings about the Periodic Table.

. Elements are arranged in order of increasing atomic numbers
. Chemical properties of the elements are periodic function of their atomic numbers
. The elements on the Periodic Table are categorized as metals, nonmetals, or metalloids
. More than two thirds of the elements are metals
. The Periodic Table contains elements that are in all three phases (solid, liquid, and gas) at STP
. The majority of the elements exist as solids at STP
. Only two (mercury and bromine) are liquids at STP
. A few elements are gases at STP

The following information can be found in the box of each element.

LOOK on the Periodic Table for these two elements: Oxygen and Gold

NOTE all the information you can get from the box of each element.



Information listed in the box of each element reveal a lot about the atomic structure of the element.

LOOKING Ahead ⇨ Topic 3 - The Atomic Structure. You will learn to relate information on the Periodic Table to the atomic structures.

2. Groups and Periods

The elements are placed in Groups and Periods. Every element has a Group number and a Period number.
For example: Element phosphorous (P) is in Group 15, Period 3.

Groups (families) are the vertical arrangements of the elements.

. Elements in the same group have the same number of valance electrons and similar chemical properties

. There are eighteen (18) groups on the Periodic Table of the Elements

The Group names are listed below.

Group 1 :	Alkali metals
Group 2 :	Alkaline earth metals
Group 3 – 12:	Transition metals
Group 17:	Halogens
Group 18:	Noble (Inert) gases

Periods (rows) are the horizontal arrangements of the elements.

. Elements in the same Period have the same number of occupied electron shells (energy levels)

. There are seven (7) periods on the Periodic Table of the Elements

Periodic Law: The properties of the elements are periodic function of their atomic numbers.
In other words, by arranging the elements in the order of increasing atomic numbers, elements with similar properties end up in the same group.

3. Arrangements of the Elements: Practice Problems

Practice 1
Which of the following information cannot be found in the box of an element on the Periodic Table?
1) Oxidation state
2) Phase
3) Atomic number
4) Atomic mass

Practice 2
The Periodic Table of the Elements contains elements that are
1) Solids only
2) Solid and liquids only
3) Liquids and gases only
4) Solid, liquids and gases

Practice 3
The observed regularities in the properties of the elements are periodic functions of their
1) Atomic numbers
2) Oxidation state
3) Atomic mass
4) Reactivity

Practice 4
The similarities in chemical properties of elements within the same group is due to similarity in
1) Number of electron shells
2) Valance electrons
3) Oxidation state
4) Chemical properties

Practice 5
Majority of the elements on the Periodic Table are
1) Metals
2) Nonmetals
3) Metalloids
4) Noble gases

Practice 6
Which of these elements has similar chemical properties as iodine?
1) Xe 2) Te 3) Br 4) Se

Practice 7
Which list contains elements with greatest variation in chemical properties?
1) O, S and Se
2) Be, N, O
3) N, P and As
4) Ba, Sr and Ca

Practice 8
Which two elements have the same number of occupied electron shells?
1) Mg and Be
2) Mg and Al
3) Mg and O
4) Mg and Ca

Practice 9
Element Oxygen and Sulfur can both form a bond with sodium with similar chemical formula. The similarity in their formula is due to
1) Oxygen and Sulfur having the same number of kernel electrons
2) Oxygen and sulfur having the same number of valance electrons
3) Oxygen and sulfur having the same number of protons
4) Oxygen and sulfur having the same molecular structure

Lesson 2 – Types of elements and their Properties

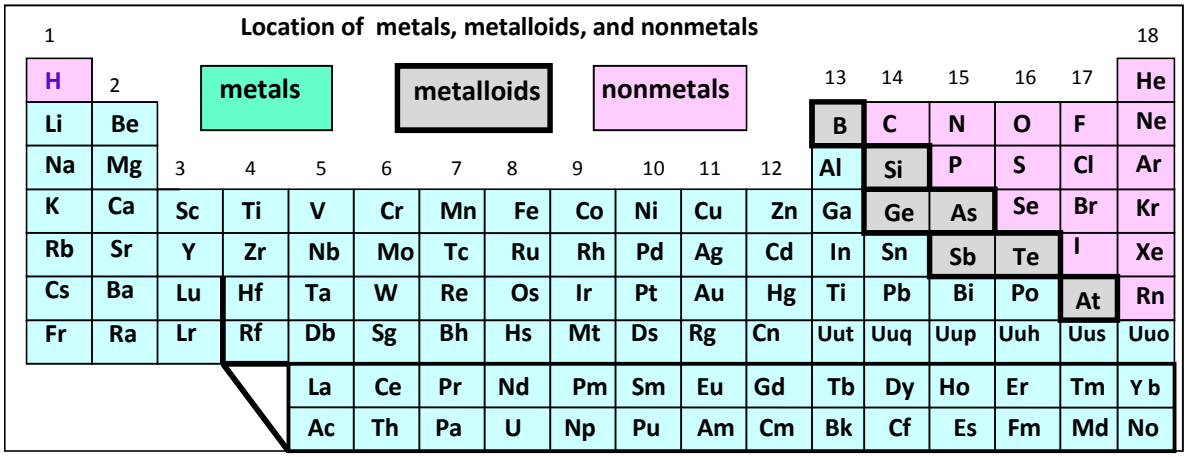
Introduction

There are three general categories of elements: metal, nonmetals, and metalloids.

Elements in one category have a set of physical and chemical properties that are used to distinguish them from elements in the other categories.

In this lesson, you will learn about the three types of elements, their locations on the Periodic Table, and their properties.

4. Types of elements



5. Physical properties of elements

There are several physical properties that can be used to describe and identify the elements.

The following is a list of these physical properties and their definitions.

Concept Facts: Study and to remember these properties.

Malleable describes a solid that is easily hammered into a thin sheet.

Ductile describes a solid that is easily drawn into thin wire.

Brittle describes a solid that is easily broken or shattered into pieces when struck

Luster describes the shininess of a substance.

Conductivity describes the ability to conduct heat or electricity.

Electronegativity describes atom's ability to attract electrons from another atom during bonding.

Ionization energy describes an atom's ability to lose its most loosely bound valance electrons.

Atomic radius describes the size of the atom of an element.

Density describes the mass to volume ratio of an element.

See Table S

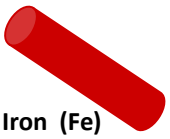
Use *Reference Table S* to find and compare electronegativity, ionization energy, atomic radius, and density values of the elements.

6. Metals

Metal elements are located to the left of the Periodic Table**.**

All elements in Group 1 – 12 (except hydrogen) are classified as metals.
The rest of the metal elements are located near the top of Groups 13 through 17

The majority (about 75%) of the elements are metals.



Iron (Fe)

Below are some general properties (characteristics) of metals.

Concept Facts: Study to remember these properties.

. Almost all metals are solids. Exception is mercury (Hg) , which is a liquid metal

. Solid metals are malleable, ductile, and have luster

. Metals tend to have high heat (thermal) and electrical conductivity due to their *mobile valance electrons*

. Metals tend to have low electronegativity values (because they do not attract electrons easily)

. Metals tend to have low ionization energy values (which is why metals lose their electrons easily)

. Metals generally lose electrons and form positive ions

. Radius (size) of a metal atom decreases as it loses electrons and form a positive ion

. The size of a positive (+) metal ion is always smaller than the size of the neutral metal atom

7. Metalloids

Metalloids (semi-metals) are the seven elements located between the metals and the nonmetals.
Metalloid elements are located on the Periodic Table along the thick zigzag line.

Below are some generally properties (characteristics) of metalloids.

Concept Facts: Study to remember these properties.

. Metalloids tend to have properties of both metals and nonmetals

. Metalloids properties are more like those of metals, and less like those of nonmetals

. Metalloids exist only as solids at STP.

Tellurium (Te)

8. Nonmetals

Nonmetal elements are located to the right of the Periodic Table.

All elements in Groups 17 and 18 are classified as nonmetals. The rest of the nonmetals are located near the bottom of Group 14, 15, and 16. Hydrogen (in Group 1) is also a nonmetal.

Sulfur (S)

Below are some general properties (characteristics) of nonmetals.

Concept Facts: Study to remember these properties.

. Nonmetals are found in all three phases: solid, liquid, and gas.

. Most nonmetals exist as molecular gases and solids. Bromine is the only liquid nonmetal

. Solid nonmetals are generally brittle and dull (lack luster, not shiny)

. Nonmetals have low (poor) electrical and heat conductivity

. Nonmetals tend to have high electronegativity values (because they attract and gain electrons easily)

. Nonmetals tend to have high ionization values (which is why nonmetals don't lose electrons easily)

. Nonmetals generally gain electrons and form negative ions

. Radius of a nonmetal atom generally increases as it gains electrons and forms a negative ion

. The size of a negative (-) nonmetal ion is always bigger than its neutral nonmetal atom

9. Types of elements: Summary of properties of metals, nonmetals, and metalloids

	Phases at STP	*Physical properties*	*Conductivity*	*Electrone-gativity*	*Ionization energy*	*Electrons In bonding*	*Common ion*	*Ionic size (radius)*
Metals	Solid Liquid	Malleable Luster Ductile	High	Low	Low	Lose electrons	+ (positive)	Smaller than atom
Nonmetals	Solid Liquid Gas	Brittle Dull	Low	High	High	Gain electrons	- (negative)	Bigger than atom
Metalloids	Solid only	Properties of metals and nonmetals	Low	varies	varies	Lose electrons	+ (positive)	Smaller than atom

10. Types of element: Practice problems

Practice 10
Elements that can be hammered into thin sheets are said to be
1) Ductile 2) Luster 3) Malleable 4) Brittle

Practice 11
The tendency for an atom to give away its electrons during bonding is measured by its
1) Atomic radius value
2) Density value
3) Electronegativity value
4) Ionization energy value

Practice 12
Nonmetal elements on the Periodic Table can be found in which phase or phases at STP?
1) Solid only
2) Liquid only
3) Solid or liquid only
4) Solid, liquid and gas

Practice 13
Which two characteristics are associated with nonmetals?
1) Low first ionization energy and low electronegativity
2) Low first ionization energy and high electronegativity
3) High first ionization energy and low electronegativity
4) High first ionization energy and high electronegativity

Practice 14
Metalloids tend to have properties resembling
1) Nonmetals only
2) Metals only
3) Both metals and nonmetals
4) Neither a metal nor a nonmetal

Practice 15
Which is a property of most metals?
1) They tend to gain electrons easily when bonding.
2) They tend to lose electrons easily when bonding.
3) They are poor conductors of heat.
4) They are poor conductors of electricity.

Practice 16
Which of these elements is a metalloid?
1) Gallium
2) Germanium
3) Phosphorous
4) Tin

Practice 17
Which list consists of a metal, nonmetal, and metalloid respectively?
1) Al, B, Si
2) Cr, C, Cl
3) Ni, Si, P
4) C, Si, Ge

Practice 18
Which element is brittle and a non conducting solid?
1) S 2) Ne 3) Ni 4) Hg

Practice 19
Which of these elements has high thermal and electrical conductivity?
1) Iodine
2) Phosphorous
3) Carbon
4) Iron

Practice 20
Which properties best describes the element mercury?
1) It has luster
2) It is brittle
3) It has a high electronegativity value
4) It a poor electrical conductor

Practice 21
Which is true of element carbon?
1) It is malleable
2) It has Luster
3) It has low electrical conductivity
4) It is a gas at STP

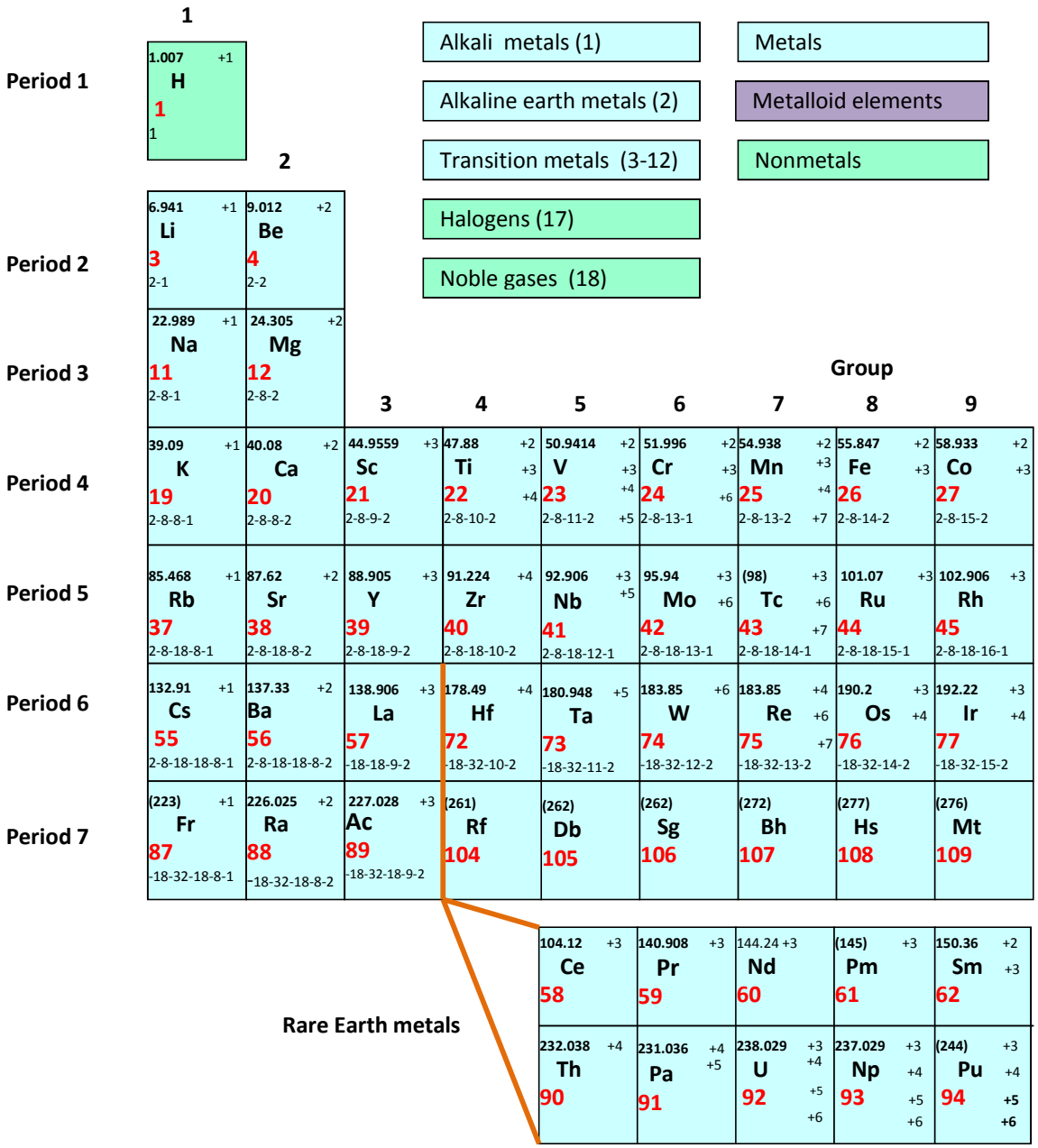
Lesson 3 – Groups name and their properties

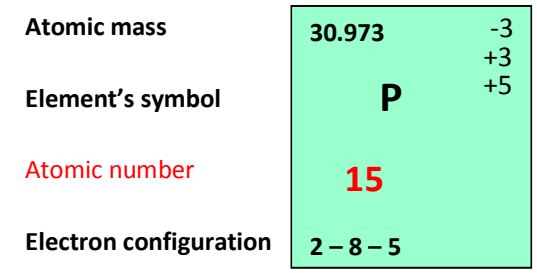
Introduction

There are 18 Groups (vertical arrangements) on the Periodic Table. Elements within each group share similar chemical characteristics because they have the same number of valance electrons.

In this lesson you will learn more about the groups, and general properties that characterized members of each group.

11. The Periodic Table of the Elements





	10	11	12	13	14	15	16	17	18	
									4.002 0 He 2 2	Period 1
				10.81 +3 B 5 2-3	12.011 -4 +2 C 6 +4 2-4	14.006 -3 +2 +3 +4 +5 N 7 2-5	15.999 -2 O 8 2-6	18.998 -1 F 9 2-7	20.179 0 Ne 10 2-8	Period 2
				26.981 +3 Al 13 2-8-3	28.085 -4 +2 Si 14 +4 2-8-4	30.973 -3 +3 P 15 +5 2-8-5	32.06 -2 +4 S 16 +6 2-8-6	35.453 -1 +1 +3 +5 +7 Cl 17 2-8-7	39.948 0 Ar 18 2-8-8	Period 3
	58.69 +2 +3 Ni 28 2-8-16-2	63.546 +1 +2 Cu 29 2-8-18-1	65.39 +2 Zn 30 2-8-18-2	69.72 +3 Ga 31 2-8-18-3	72.59 -4 +2 Ge 32 +4 2-8-18-4	74.921 -3 +4 As 33 2-8-18-5	78.96 -2 +4 Se 34 +6 2-8-18-6	79.904 -1 +1 Br 35 +5 2-8-18-7	83.80 0 +2 Kr 36 2-8-18-8	Period 4
	106.42 +2 +4 Pd 46 2-8-18-18	107.868 +1 Ag 47 2-8-18-18-1	112.41 +2 Cd 48 2-8-18-18-2	114.82 +3 In 49 2-8-18-18-3	118.71 +2 +4 Sn 50 2-8-18-18-4	121.75 - 3 +3 +5 Sb 51 2-8-18-18-5	127.60 - 2 +4 +6 Te 52 2-8-18-18-6	126.905 -1 +1 +5 +7 I 53 2-8-18-18-7	131.29 0 +2 +4 +6 Xe 54 2-8-18-18-8	Period 5
	195.08 +2 +4 Pt 78 -18-32-17-1	196.967 +1 +3 Au 79 -18-32-18-1	200.59 +1 +2 Hg 80 -18-32-18-2	204.383 +3 Ti 81 -18-32-18-3	207.2. +2 +4 Pb 82 -18-32-18-4	208.980 +3 +5 Bi 83 -18-32-18-5	(209) +2 +4 Po 84 +5 -18-32-18-6	(210) +2 +4 At 85 -18-32-18-7	(222) 0 Rn 86 -18-32-18-8	Period 6
	(281) Ds 110	(280) Rg 111	(285) Cn 112	(284) Uut 113	(289) Uuq 114	(288) Uup 115	(292) Uuh 116	(?) Uus 117	(294) Uuo 118	Period 7
	151.96 +2 +3 Eu 63	157.25 +3 Gd 64	158.925 +3 Tb 65	162.50 +3 Dy 66	164.930 +3 Ho 67	167.26 +3 Er 68	168.934 +3 Tm 69	173.04 +2 +3 Yb 70	174.967 +3 Lu 71	Lanthanoid Series
	(243) +3 +4 +5 +6 Am 95	(247) +3 Cm 96	(247) +3 Bk 97	(251) +3 Cf 98	(252) Es 99	(257) Fm 100	(258) Md 101	(259) No 102	(260) Lr 103	Actinoid Series

12. Group 1: Alkali Metals

Alkali metals are elements in Group 1 of the Periodic Table.

Members include lithium, sodium, potassium, rubidium, cesium and francium.

Hydrogen is *not* an alkali metal even though it is often placed in Group 1.

H
1

Properties (characteristics) of alkali metals are listed below.

Concept Facts: Study to remember these properties.

. One valance (outer shell) electron

. Form positive one (+1) ion from losing one valance electron during bonding

. Very low electronegativity and very low ionization energy values.

. Found in nature as compounds, not as free elements, due to high reactivity

. Are obtained from electrolytic reduction of fused salts (**Na**Cl, **K**Br..etc)

. If **X** represents a **Group 1** atom

XY is the general formula of a Group 1 atom bonding with a Group 17 halogen (**Y**)

$\mathbf{X_2O}$ is the general formula of a Group 1 atom bonding with **O** (to form an oxide)

. Francium (Fr) is the most reactive metal in Group 1, and of all metals

. Francium is also radioactive.

. All alkali metals exist as solids at STP

Group 1 Alkali	Group 2
Li 3	
Na 11	
K 19	
Rb 37	
Cs 55	
Fr 87	

13. Group 2: Alkaline Earth metals

Alkaline Earth metals are elements in Group 2 of the Periodic Table.

Members include beryllium, magnesium, calcium, strontium, barium, and radium.

Properties (characteristics) of alkaline earth metals are listed below.

Concept Facts: Study to remember these properties.

. Two valence (outer shell) electrons

. Form positive two (+2) ion from losing all two valance electrons during bonding

. Found in nature as compounds, not as free elements, due to high reactivity

. Are obtained from fused salt compounds ($MgCl_2$, $CaBr_2$..etc)

. If **M** represents a Group 2 atom

MY_2 is the general formula of a **Group 2** atom bonding with a Group 17 halogen (**Y**)

MO is the general formula of a **Group 2** atom bonding with **O** (to form an oxide)

. Radium (Ra) is the most reactive metal in this group. Radium is also radioactive.

. All alkaline earth metals exist as solids at STP

Group 1	**Group 2 Alkaline Earth**
	Be 4
	Mg 12
	Ca 20
	Sr 38
	Ba 56
	Ra 88

14. Group 3 – 12: Transition metals

Transition metals are elements in Groups 3 – 12 of the Periodic Table

Properties of these elements vary widely. However, a few unique properties can be observed among them.

Properties (characteristics) of transition metals are listed below.

Concept Facts: Study to remember these properties.

. They tend to form multiple positive oxidation numbers

. They can lose electrons in two or more different sublevels of their atoms

. Their ions usually form colorful compounds

CuCl_2 – is a bluish color compound

FeCl_2 - is an orange color compound

Transition metals

3	4	5	6	7	8	9	10	11	12
Sc	Ti	V	Cr	Mn	**Fe**	Co	Ni	**Cu**	Zn
Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg
Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub

15. Group 17: Halogens

Halogens are elements in Group 17 of the Periodic Table.

Members include fluorine, chlorine, bromine, and iodine

Properties (characteristics) of halogens are listed below.

Concept Facts: Study to remember these properties.

. They exist as diatomic (two-atom) elements; (F_2, Cl_2, Br_2)

. Seven (7) valance electrons

. Very high electronegativity and high ionization energy values

. Form negative one (-1) ion from gaining one electron to fill their valance shell

. F and Cl are obtained from their fused salt (Na**F**, Na**Cl**..etc) because of high reactivity

. If **Y** is a Group 17 halogen

X**Y** is the general formula of a **Group 17** halogen bonding with a Group 1 (**X**) atom

MY_2 is the general formula of a **Group 17** atom bonding with a Group 2 (**M**) atom

. The only group containing elements in all three phases at STP

Gases (Fluorine and Chlorine) Liquid (Bromine) Solid (Iodine)

. Fluorine is the most reactive of the group, and the most reactive nonmetal overall

. Astatine (At) in this group is a radioactive element, and behaves quiet differently from the other four

Group 18

Group 17 Halogens	
F 9	
Cl 17	
Br 35	
I 53	
At 85	

16. Group 18 - Noble (inert) gases

Noble gases are elements in **Group 18** of the Periodic Table.

Members include helium, neon, argon, krypton, xenon, and radon

Properties (characteristics) of noble gases are listed below.

Concept Facts: Study to remember these properties.

. They exist as monatomic (one - atom) nonpolar elements (Ne, He, Kr…)

. All are gases are at STP

. They all have full valance shell with eight electrons

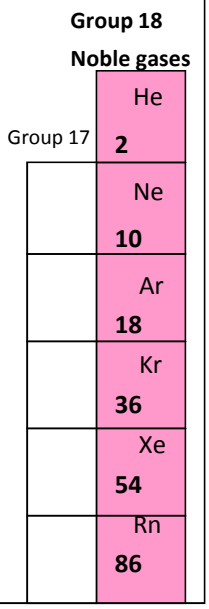
(Exception: Helium is full with only two electrons)

. They neither gain nor lose electrons because their valance shells are full

. They are very stable and are nonreactive (do not form too many compounds)

. Argon (Ar) and Xenon (Xe) have been found to produce a few stable compounds with fluorine.

Example; **Xe**F_4 (xenon tetrafluoride)



17. Groups and Group Properties: Summary Table

Concept Fasts: Study to learn properties of elements within each Group.

Group number	*Group name*	*Types of elements in the group*	*Phases (at STP)*	*Valance electrons (during bonding)*	*Common oxidation number (charge)*	*Chemical bonding (general formula)*
1	Alkali metals	Metal	Solid (all)	1 (lose)	+1	**X**Y with halogens (17) $\mathbf{X}_2$O with oxygen (16)
2	Alkaline earth	Metal	Solid (all)	2 (lose)	+2	**M**Y_2 with halogens (17) **M**O with oxygen (16))
3-12	Transition metals	Metal	Liquid (Hg) Solid (the rest)	(lose)	Multiple + charges	varies (form colorful compounds)
13	-	Metalloid Metal	Solid (all	3 (lose)	+3	**L**Y_3 with halogens (17) $\mathbf{L}_2O_3$ with oxygen (16)
14	-	Nonmetal Metalloid Metal	Solid (all)	4 (some share) (some lose)	vary	varies
15	-	Nonmetal Metalloid Metal	Gas (N) Solid (the rest)	5 (gain or share)	-3	varies
16	Oxygen group	Nonmetal Metalloid	Gas (O) Solid (the rest)	6 (gain or share)	-2	X_2**O** with alkali metals (1) M**O** with alkaline earth (2)
17	Halogens (Diatomic)	Nonmetal	Gas (F and Cl) Liquid (Br) Solid (I)	7 (gain or share)	-1	X**Y** with alkali metals (1) M**Y** with alkaline earths (2)
18	Noble gases (Monatomic)	Nonmetal	Gas (all)	8 (neither gain nor share)	0	Forms very few compounds. **Xe**F_4 is the most common.

18. Groups and Group properties: Practice problems

Concept Task: Be able to identify an element based on group name

Practice 22

Which element is a noble gas?

1) Neon
2) Oxygen
3) Fluorine
4) Nitrogen

Practice 23

Which of these element is an alkaline earth element?

1) Na
2) H
3) K
4) Ra

Practice 24

Iron is best classified as

1) A transition nonmetal
2) A transition metal
3) An alkali metal
4) An alkaline earth metal

Practice 25

The element in Group 17 Period 4 is

1) A transition metal
2) A halogen
3) An alkali metal
4) A noble gas

Concept Task: Be able to identify and classify an element based on group properties.

Practice 26

Which set contains elements that are never found in nature in their atomic state?

1) K and Na
2) K and S
3) Na and Ne
4) Na and C

Practice 27

Element X is a solid that is brittle, lack luster, and has six valance electrons. In which group on the Periodic Table would element X be found?

1) 1
2) 2
3) 15
4) 16

Practice 28

Element Z is in Period 3 of the Periodic Table. Which element is Z if it forms an oxide with a formula of Z_2O_3?

1) Na
2) Al
3) Mg
4) Cl

Practice 29

Which of these oxides will likely form a colored solution when dissolved in water?

1) Na_2O
2) SO_2
3) CaO
4) FeO

Lesson 3. Periodic Trends

Introduction

Periodic trends refer to patterns of properties that exist in a group or period as elements are considered from one end of the table to the other.

Trend in atomic number is a good example (and the most obvious) of a periodic trend found on the Periodic Table.

As the elements are considered one after the other from:

Left to **Right** across a Period: *Atomic number of successive element increases*

Bottom to **Top** up a Group: *Atomic number of successive element decreases*

Many other trends exist on the periodic table even though they are not so obvious.

In this lesson, you will learn of the following trends.

Trends in atomic and ionic radius (size).
Trends in metallic and nonmetallic properties.
Trends in electronegativity and ionization energy.

19. Trends in atomic size (atomic radius)

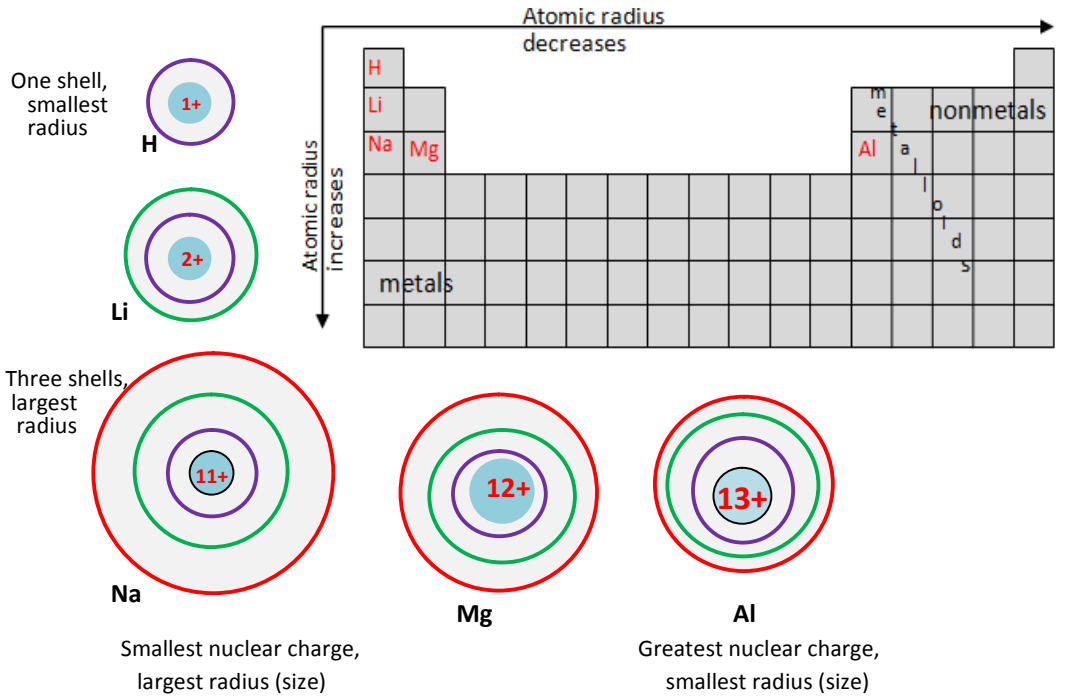
Atomic radius is defined as half the distance between two nuclei of the same atom when they are joined together. Atomic radius value gives a good approximation of the size of an atom.
The atomic radii of the elements can be found on **Reference Table S.**

General trends in atomic radius found on the Periodic Table are as follow:

Concept Facts: Study to remember the following trends.

Top to **Bottom** down a **Group**: *Atomic radius increases due to an increase in the number of electron shells.*

Left to **Right** across a **Period**: *Atomic radius decreases due to an increase in nuclear charges.*



20. Trends in atomic size: Practice problems

Concept Task: Be able to determine element with the largest or smallest radius (size). **Use Table S**

Practice 30

Which of the following elements has the largest atomic radius?

1) K 2) Ca 3) Al 4) Na

Practice 31

Which list of elements is arranged in order of increasing atomic radii?

1) Li, Be, B, C
2) Sr, Ca, Mg, Be
3) Sc, Ti, V, Cr
4) F, Cl, Br, I

Practice 32

The atom of which element is bigger than the atom of the element calcium?

1) Sr 2) Sc 3) Mg 4) Be

Practice 33

Which atom has a bigger atomic radius than the atom of Sulfur?

1) Oxygen, because it has more electron shells
2) Oxygen, because it has a smaller nuclear charge
3) Phosphorous, because it more electron shells
4) Phosphorous, because it has a smaller nuclear charge

21. Trends in metallic and nonmetallic properties

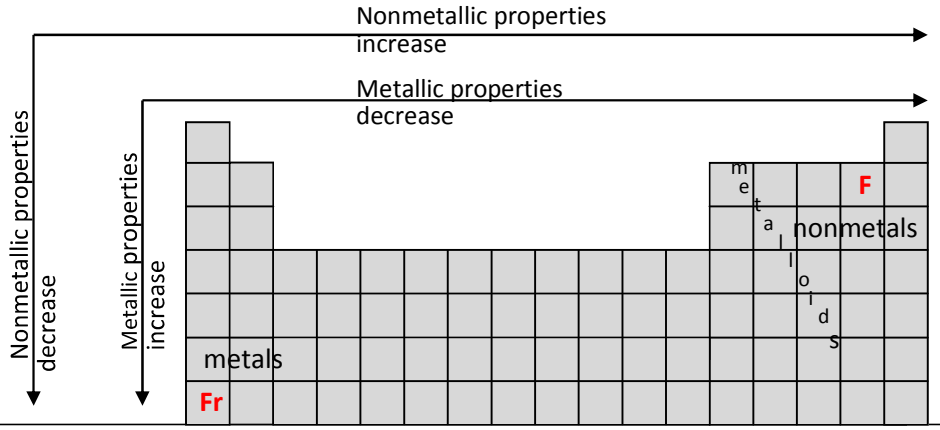
Trends in properties and reactivity vary between metals and nonmetals. The bottom left corner contains the most reactive metals. ***Francium*** is the most reactive of all metals. The top right corner contains the most reactive nonmetals. ***Fluorine*** is the most reactive of all nonmetals.

Trends in metallic and nonmetallic properties and reactivity are summarized below.

Concept Facts: Study to remember the following trends.

Top to **Bottom** down a **Group**: Metallic properties and reactivity increase.
Nonmetallic properties and reactivity decrease

Left to **Right** across a **Period:** Metallic properties and reactivity decrease.
Nonmetallic properties and reactivity increase



22. Trends in metallic and nonmetallic properties: Practice problems

Concept Task: Be able to determine which element has the most (or least) metallic or nonmetallic properties

Element farthest Left and Lowest down: Strongest metallic / Least nonmetallic

Element farthest right and Highest up: Least metallic / Strongest nonmetallic

Practice 34

Which of the following element has the most pronounced metallic characteristics?

1) C 2) Co 3) Al 4) Rb

Practice 35

Which of these elements has greatest nonmetallic properties?

1) Se 2) Te 3) Br 4) I

Practice 36

Which of these halogens is the least reactive on the Period Table?

1) I 2) Br 3) Cl 4) F

Practice 37

Which of these elements has stronger metallic characteristics than aluminum?

1) He 2) Mg 3) Ga 4) Si

Practice 38

Which of these element has stronger nonmetallic properties than chlorine?

1) Sulfur
2) Argon
3) Fluorine
4) Oxygen

Practice 39

Which part of the Periodic Table contains elements with the strongest nonmetallic properties?

1) Upper right
2) Lower right
3) Upper left
4) Lower left

23. Trends in electronegativity and ionization energy

Electronegativity measures an atom's ability to attract or gain electrons from another atom during chemical bonding. Electronegativity values of the elements are assigned relative to one another. The higher the electronegativity value of an atom, the more likely it is for that atom to gain electrons and form a negative ion.

In general, nonmetals are assigned the highest electronegativity values because they have great tendency to attract electrons. *Fluorine,* the most reactive nonmetal, is assigned the highest electronegativity value of 4. *Fluorine*, therefore, has the greatest tendency of all the elements to attract and gain electrons during chemical bonding.

In general, metals are assigned the lowest electronegativity values because they have low tendency to attract electrons. *Francium,* the most reactive metal, is assigned the lowest value of 0.7. Francium, therefore, has the least tendency of all the elements to attract electrons during chemical bonding.

Ionization energy is the amount of energy needed to remove an electron from a gaseous atom. **First Ionization energy** refers to the energy needed to remove the most loosely bound electron of an atom. The lower the ionization energy of an atom, the easier it for that atom to lose its electrons and form a positive ion.

Metals lose electrons because of their low ionization energies. The *alkali metals* in Group 1 generally have the lowest ionization energy, which allow them to lose their one valance electrons most readily.

Nonmetals have low tendency to lose electrons because of their high ionization energies. The *noble gases* in group 18 tend to have the highest ionization energy values. Since these elements already have full valance shell of electrons, high amount of energy is required to remove any electron from their atoms.

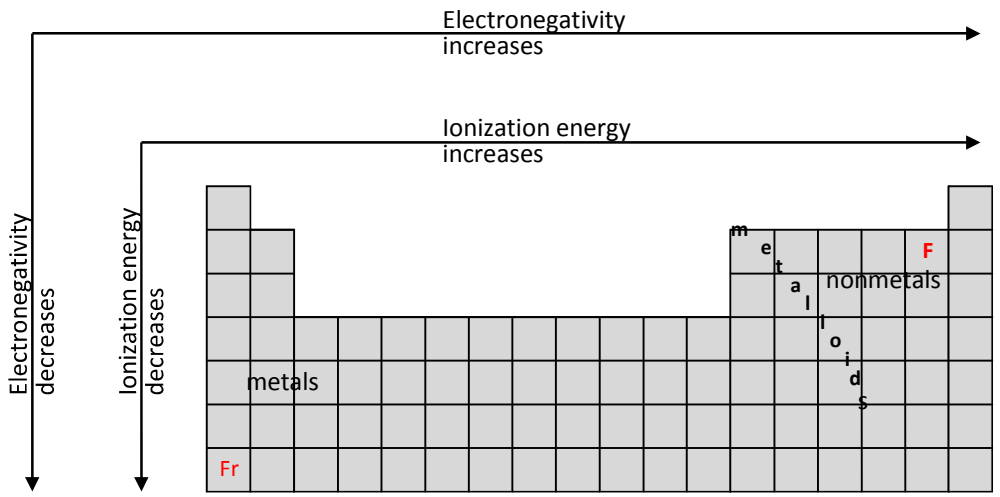
Electronegativity and first ionization energy values for the elements can be found on *Reference Table S.*

The general trends in electronegativity and ionization energy are as follows.

Concept Facts: Study to remember the following trends.

Top to **Bottom** down a **Group**: Electronegativity (tendency to gain or attract electrons) decreases.
Ionization energy (tendency to lose electrons) decreases

Left to **Right** across a **Period**: Electronegativity increases
Ionization energy increases



24. Trends in electronegativity and ionization energy: Practice problems

Concept Task: Be able to determine an element that has the greatest or least tendency to attract electrons.

Greatest attraction for electrons (most likely to gain):
Element with the HIGHEST electronegativity value

Least attraction for electrons (least likely to gain)
Element with the LOWEST electronegativity value

Concept Task: Be able to determine which element has the greatest or the least tendency to lose electrons.

Greatest tendency to lose electrons
Element with the LOWEST ionization energy value

Least tendency to lose electrons
Element with the HIGHEST ionization energy value

Use ***Reference Table S*** to locate ionization energy values

Practice 40
As the elements of Group 1 on the Periodic Table are considered in order of increasing atomic radius, the ionization energy of each successive element generally

1) decreases
2) increases
3) remains the same

Practice 41
Which of these elements is most likely to attract electrons from another atom during chemical bonding?

1) Fe *2) C* 3) Al 4) Fr

Practice 42
Which elements has a greater tendency to attract electron than phosphorous?

1) Silicon
2) Arsenic
3) Boron
4) Sulfur

Practice 43
Which of the following elements has the greatest tendency to lose its valance electrons?

1) Be 2) S 3) Ne 4) Ca

Practice 44
Aluminum will lose its most loosely bound electron less readily than

1) Calcium
2) Nitrogen
3) Indium
4) Scandium

Practice 45
Which sequence of elements is arranged in order of decrease tendency to attract electrons during chemical bonding?

1) Al, Si, P
2) I, Br, Cl
3) Cs, Na, Li
4) C, B, Be

25. Allotropes

Allotropes refer to two or more different molecular forms of the same element in the solid state.

Differences in molecular structures give allotropes of the same element different physical properties (color, shape, density, melting point..etc) AND different chemical properties (reactivity)

Examples of some common allotropes:

Oxygen allotropes: Air (O_2) and Ozone (O_3), both considered oxygen, have different molecular structures and different chemical and physical properties.

Carbon allotropes: Diamond , graphite, and buckminsterfullerene
are different molecular forms of carbon. Each form has different chemical and different physical characteristics.

Phosphorous allotropes: White , Red, and Black are all different forms of element phosphorous.

Concept Terms

Key vocabulary terms and concepts from Topic 2 are listed below. You should know definition and facts related to each term and concept.

1. Periodic aw
2. Group
3. Period
4. Metal
5. Nonmetal
6. Metalloid
7. Alkali metal
8. Alkaline Earth metal
9. Transition element
10. Halogen
11. Noble gas
12. Malleable
13. Luster
14. Ductile
15. Brittle
16. Density
17. Ionization energy
18. Electronegativity
19. Atomic radius
20. Conductivity
21. Properties of metals
22. Properties of nonmetals
23. Properties of metalloids
24. Properties of Group 1 alkali metals
25. Properties of Group 2 alkaline earth metals
26. Properties of Groups 3 – 12 transition metals
27. Properties of Group 17 halogens
28. Properties of Group 18 noble gases
29. Trends in metallic and nonmetallic properties
30. Trends in atomic size or radius
31. Trends in ionization energy
32. Trends in electronegativity

Concept Task:

Concept tasks from Topic 2 are listed below. You should know how to solve problems and answer questions related to each concept task.

1. Determining elements with the same characteristics
2. Identifying an element as a metal, metalloid, or nonmetal
3. Determining element's name or symbol based on given properties
4. Determining property or properties of a given elements name or symbol
5. Identifying an element based on a given group name
6. Relating elements name or symbol to group properties
7. Determining element with the largest or smallest atomic radius
8. Determining element that has the most or least metallic properties
9. Determining element that has the most or least nonmetallic properties
10. Determining element with greatest or least tendency to attract electrons
11. Determining element with greatest or least tendency to lose electrons

Topic 3 – The Atomic structure

Topic outline

In this topic, you will learn the following concepts:

.The historical development of the modern atom
. The subatomic particles; protons, electrons, neutrons
. Atomic number, mass number and atomic mass
. Isotopes
. Electron shells and electron configurations
. Ground and excited state of atoms
. Bright-line spectra
. Valance electrons, neutral atoms and ions

Lesson 1 - Historical development of the modern atomic model

Introduction:

The **atom** is the most basic unit of matter. Since atoms are very small and cannot be seen with the most sophisticated equipment, several scientists for thousands of years have proposed many different models of atom to help explain the nature and behavior of matter.

In this lesson, you will learn about these historical scientists, their experiments and proposed models of atom.

1. Historical scientists

Many scientists over many years have contributed to the development of the modern atomic model.

*The **wave mechanical-model*** is the current and most widely accepted model of the atom. According to the wave-mechanical model :

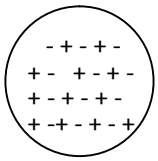
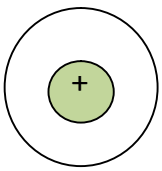
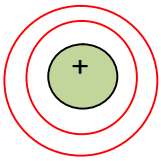
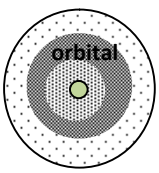
. Each atom has small dense positive nucleus

. Electrons are found outside the nucleus in a region called orbital

Orbital is the most probable location of finding an electron with certain energy in an atom.

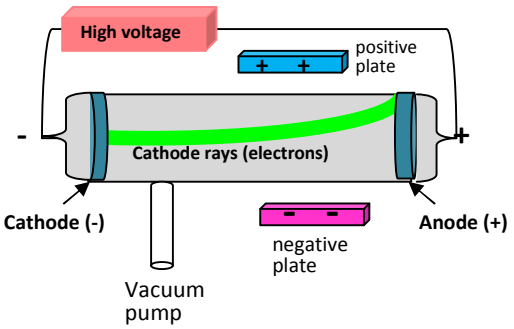
Below is a list of some historical scientists and their proposed models of atom in order from the earliest model to the current model. Descriptions and key features of each model are also given.

Concept Facts: Study to remember order of proposed atomic models.

John Dalton (Earliest model)	**J.J. Thompson**	**Earnest Rutherford**	**Neil Bohr**	**Many scientists** (Current model)
				
Hard sphere model (Cannonball model) .No internal structure	**Plum pudding model** .Electrons and positive charges disperse throughout the atom.	**Empty space model** (Nuclear model) .Small dense positive nucleus . Electrons revolve around the nucleus	**Bohr's model** (Planetary model) . Electrons in specific orbits . Orbits have fixed energy .Orbits create electron shells	**Wave mechanical** (electron cloud) .Electrons in orbital **. Orbital** is the area an electron is likely to be found

2. The Cathode Ray experiment

J.J. Thompson conducted the cathode ray experiment that further supports the existence of negative charge particles in atoms.



The set up

A tube with a metal disk at each end was set up to trace a beam from an electrical source. The metals were connected to an electrical source.

Anode: The Metal disk that becomes + charge

Cathode: The Metal disk that becomes – charge

Results

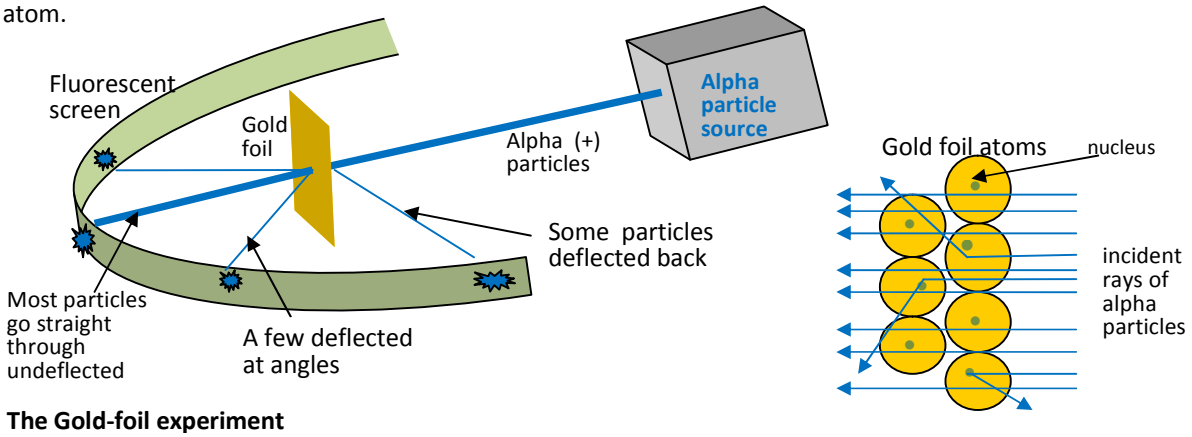
A beam of light (ray) travels from the *cathode* end to the anode end of the tube. When electrically charged **+** and **-** plates were brought near the tube, the beam (ray) is deflected toward (attracted) the positive plate. The beam was repelled by the negative plate.

Conclusions

The beam is composed of negatively charged particles. The term "electron" was used much later to describe the negatively charged particle of an atom.

3. The Gold-Foil Experiment

Earnest Rutherford conducted the gold-foil experiment that led to the proposed empty-space theory of atom.



The Gold-foil experiment

The set up

Equipment was set up to fire alpha particles at a gold foil.

. Alpha particle area positively charged helium nuclei

A Fluorescent screen was set around the foil

. The Screen is to detect the path of the particles once they hit the gold foil

Result 1

Most of the alpha particles went straight through the gold foil undeflected.

Conclusions 1

Atom is mostly empty space .

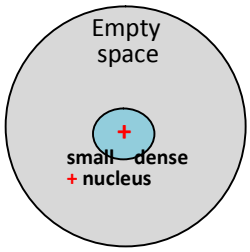
Result 2

A few of the particles were deflected back or hit the screen at angles.

Conclusion 2

The center of the atom is dense , positive, and very small.

Rutherford's atom



4. Historical Development of the modern atomic model: Practice problems

Practice 1
The modern model of an atom shows that electrons are
1) Orbiting the nucleus in fixed path
2) Found in regions called orbital
3) Combined with neutrons in the nucleus
4) Located in a solid sphere covering the nucleus

Practice 2
In the wave-mechanical model, the orbital is a region in space of an atom where there is
1) High probability of finding an electron
2) High probability of finding a neutron
3) Circular path in which electrons are found
4) Circular path in which neutrons are found

Practice 3
The modern model of the atom is based on the work of
1) One Scientist over a short period of time
2) One scientist over a long period of time
3) Many Scientists over a short period of time
4) Many scientists over a long period of time

Practice 4
Which conclusion is based on the "gold foil experiment" and the resulting model of the atom?
1) An atom has hardly any empty space, and the nucleus is positive charge
2) An atom has hardly any empty space, and the nucleus is negative charge
3) An atom is mainly empty space, and the nucleus has a positive charge
4) An atom is mainly empty space, and the nucleus has a negative charge

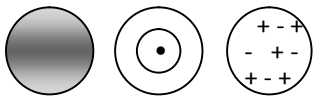
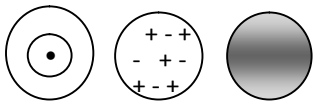
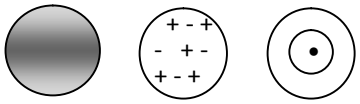
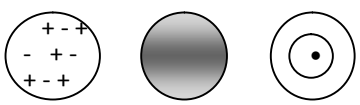
Practice 5
Which group of atomic models is listed in order from the earliest to the most recent?
1) Hard-sphere model, wave-mechanical model, electron-shell model
2) Hard-sphere model, electron-shell model, wave mechanical model
3) Electron-shell model, wave-mechanical model, hard-sphere model
4) Electron-shell model, hard-sphere model, wave-mechanical model

Practice 6
Subatomic particles can usually pass undeflected through an atom because the volume of an atom is composed mainly by
1) Uncharged nucleus
2) Unoccupied space
3) Neutrons only
4) Protons only

Practice 7
Experiment evidence indicates that atoms
1) Have uniform distribution of positive charges
2) Have uniform distribution of negative charges
3) Contains a positively charged , dense center
4) Contains a negatively charged, dense center

Practice 8
Compare to the entire atom, the nucleus of an atom is
1) Smaller and contains most of atom's mass
2) Smaller and contains little of atom's mass
3) Larger and contains most of atom's mass
4) Larger and contains little of atom's mass

Practice 9
Which order of diagrams correctly shows the historical models of the atom from the earliest to the most modern?

1) 
2) 
3) 
4) 

Lesson 2 – Structure of an Atom

Introduction

Although the atom is described as the smallest unit of matter, but it is also composed of much smaller particles called the ***subatomic particles***. The three *subatomic particles* are: proton, electron, and neutron.

In this lesson, you will learn more about the modern atom and the subatomic particles. You will also learn the relationships between subatomic particles, atomic number, and mass number.

5. Atom

The **atom** is the basic unit of matter. It is composed of three **subatomic particles**: Protons, electrons and neutrons. The only atom with no neutron is a hydrogen atom with a mass of 1. (^{1}H)

Concept Facts: Study to remember the followings about the atom.

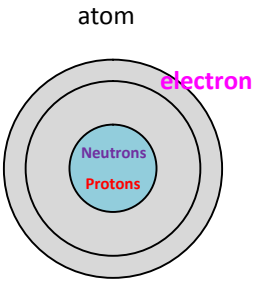
. An atom is mostly empty space

. Atoms have small dense positive core (nucleus), and negative electron cloud surrounding the nucleus

. Elements are composed of atoms with the same atomic number

. Atoms of the same element are similar

. Atoms of different elements are different



6. Nucleus

The **nucleus** is the center (core) of an atom.

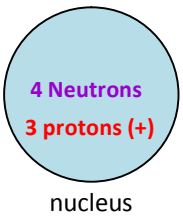
Concept Facts: Study to remember the followings about the nucleus

. The nucleus contains protons (+) and neutrons (no charge)

. Overall charge of the nucleus is positive (+) due to the protons

. The nucleus is very small and very dense relative to the entire atom

. Most of atom's mass is due to the mass of the nucleus



7. Protons

Protons are positively charged subatomic particles that are found in the nucleus of atoms.

Concept Facts: Study to remember the followings about protons

. A proton has a mass of one atomic mass unit (1 amu) and a +1 charge

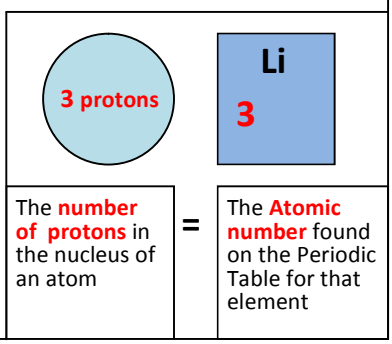
. A proton is about 1836 times more massive (heavier) than an electron

. Protons are located inside the nucleus

. The number of protons is the same as the atomic number of the element

. All atoms of the same element must have the same number of protons

. The number of protons in the nucleus is also the nuclear charge of the element



8. Electrons

Electrons are negatively charged subatomic particles that are found in orbitals outside the nucleus of atoms.

Concept Facts: Study to remember the followings about electrons

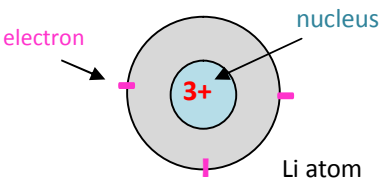
. An electron has insignificant mass (zero) and a -1 charge.

. An electron has a mass that is $^{1}/_{1836}{}^{th}$ that of a proton (or neutron)

. Electrons are found in ***orbitals*** outside the nucleus

. Electron arrangements in an atom determine the chemical properties of the element

. Number of electrons is always equal to the number of protons in a a neutral atom



In a Li atom, the number of electrons (3 e-) is equal to the number of protons (3+).

In all neutral atoms, there are equal numbers of electrons to protons.

9. Neutrons

Neutrons are neutral (no charge) subatomic particles that are located inside the nucleus of atoms.

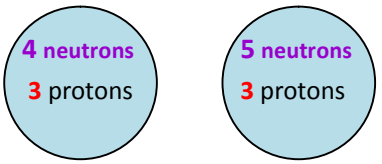
Concept Facts: Study to remember the followings about neutrons

. A neutron has a mass of 1 amu and zero charge

. A neutron has the same mass (1 amu) as a proton

. Neutrons are located in the nucleus along with protons

. Atoms of the same element differ in their numbers of neutrons



Nuclei from two different atoms of Lithium have the same number of protons but different numbers of neutrons.

10. The subatomic particles: Summary Table

Protons, electrons and neutrons are different in mass, charge, and location in an atom.

The table below summarizes information about all three particles.

NOTE: Some information on this Table can be found on **Reference Table O.**

Subatomic particle	*Symbol*	*Mass*	*Charge*	*Location*
Proton	$^{1}_{+1}p$	1 amu	+1	Nucleus
Neutron	$^{1}_{0}n$	1 amu	0	Nucleus
Electron	$^{0}_{-1}e$	0 amu	-1	Orbital (outside the nucleus)

11. Atomic number

Atomic number identifies each element.

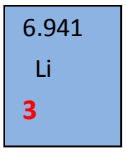
Concept Facts: Study to remember the followings about atomic number

. Atomic number of an element is *equal* to the number of protons

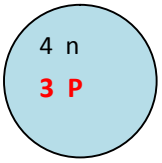
. All atoms of the same element have the same atomic number because they have the same number of protons.

. Atomic number can be found on the Periodic Table

. Elements on the Periodic Table are arranged in order of increasing atomic number



Periodic Table



Lithium Nucleus

Lithium (Li) has *atomic number of 3.*
Nucleus of all Li atoms contains *3 protons.*
No other atoms can have 3 protons.

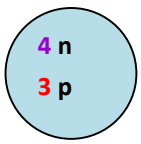
12. Nucleons

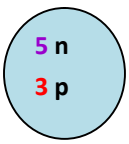
Nucleons are particles (protons and neutrons) in the nucleus of an atom

Concept Facts: Study to remember the followings about nucleons

. Nucleons account for the total mass of an atom

. The total number of nucleons in an atom is equal to the sum of protons *plus* neutrons





The Total number of nucleons for this Li atom is **7**
(**3** p + **4** n = **7**)

The total number of nucleons of this Li atom is **8**
(**3** p + **5** n = **8**)

13. Mass number

Mass number identifies different isotopes of the same element.

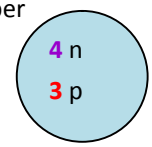
Concept Facts: Study to remember the followings about mass number

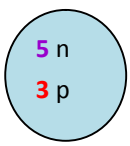
. Atoms of the same element differ by their mass numbers

. Mass number is equal to the number of protons ***plus*** neutrons

. The mass number shows the total number of nucleons

Two different nuclei of Li atoms





The mass number of this Li atom is **7**
(**3 + 4 = 7 amu**)

The mass number of this Li atom is **8**
(**3 + 5 = 8 amu**)

14. Relating one particle to another in neutral atoms. Practice problems

Concept Task: Be able to determine and compare number of subatomic particles.

Summary of relationships between the atomic particles in neutral atoms

protons = atomic # = nuclear charge = electrons = mass # - neutrons = nucleons - neutrons

electrons = atomic # = nuclear charge = protons = mass # - neutrons = nucleons - neutrons

neutrons = mass # - protons = mass# – atomic number = Mass # - electrons = nucleons – protons

mass # = nucleons = protons + neutrons = nuclear charge + neutrons = atomic # + neutrons

Practice 10
Which particles are found in the nucleus of an atom?
1) Electron, only
2) Neutrons, only
3) Protons and electrons
4) Protons and neutrons

Practice 11
Compare to the entire atom, the nucleus of an atom is
1) Smaller and contains most of atom's mass
2) Larger and contains most of atom's mass
3) Smaller and contains little of atom's mass
4) Larger and contains little of atom's mass

Practice 12
Which is true of protons and neutrons?
1) They have approximately the same mass and the same charge
2) They have approximately the same mass but different charge
3) The have different mass and different charge
4) They have different mass but the same charge

Practice 13
An electron has a charge of
1) -1 and the same mass as a proton
2) -1 and a smaller mass than a proton
3) +1 and the same mass a proton
4) +1 and a smaller mass than a proton

Practice 14
The mass of a proton is approximately
1) 1/2000 times the mass of a neutron and a unit positive charge
2) 1/2000 times the mass of a neutron and a unit negative charge
3) 2000 times the mass of an electron and a unit positive charge
4) 2000 times the mass of an electron and a unit negative charge

Practice 15
The mass number of an element is always equal to the number of
1) Protons plus electron
2) Protons plus positrons
3) Neutrons plus protons
4) Neutrons plus positrons

Practice 16
The number of neutrons in the nucleus of an atom can be determined by
1) Adding the mass number to the atomic number of the atom
2) Adding the mass number to the number of electrons of the atom
3) Subtracting the atomic number from the mass number of the atom
4) Subtracting the mass number from the atomic number of the atom

Practice 17
A neutral atom contains 12 neutrons and 11 electrons. The number of protons in this atom is
1) 1 2) 11 3) 12 4) 23

Practice 18
What is the number of electrons in a neutral atom of Fluorine?
1) 9 2) 19 3) 10 4) 28

Practice 19
The number of neutrons in a neutral atom with a mass number of 86 and 37 electrons is
1) 86 2) 37 3) 123 4) 49

Practice 20
What is the atomic number of a neutral element whose atoms contain 60 neutrons and 47 electrons?
1) 13 2) 47 3) 60 4) 107

Practice 21
What is the mass number of an atom that contains 19 protons, 18 electrons, and 20 neutrons?
1) 19 2) 38 3) 39 4) 58

Practice 22
How many nucleons are there in an atom with a nuclear charge of +20 and 23 neutrons?
1) 58 2) 20 3) 3 4) 43

Practice 23
What is the nuclear charge of an atom with 16 protons, 18 electrons, and 17 neutrons?
1) +16 2) +17 3) +18 4) +33

15. Isotopes

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

*For example, t*here are a few different atoms of the element Lithium. All atoms of Lithium contain the same number of protons in their nucleus. The difference between these atoms is the number of neutrons.

Since all Lithium atoms have the same number of protons (3), they all have the same atomic number, 3. Since they have different number of neutrons, they each have a different mass number. These different atoms of lithium are *isotopes* of lithium.

Isotopes of the same element must have:

. *Different* mass numbers (nucleons)

. *Different* number of neutrons

. *Same* atomic number

. *Same* number of protons (nuclear charge)

. *Same* number of electrons

. *Same* chemical reactivity

Symbols showing two isotopes of Lithium

7 Li	mass number	**8** Li
3	atomic number	**3**

16. Isotope symbols

Different isotopes of an element have different mass numbers. Therefore, the mass number of an isotope is written next to the element's name (or symbol) to distinguish it from the other isotopes.

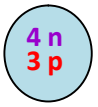
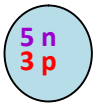
Lithium – 7 and Lithium – 8 are names to two of lithium isotopes. The 7 and the 8 are the mass numbers of these two lithium isotopes.

There are other notations that are used to represent isotopes of elements.

When studying the notations below:

. *Pay attention* to how Lithium-**7** and Lithium-**8** are similar, and also how they are different in each notation

. Also pay attention to how each notation of the same isotope is related to the other notations

Element – **mass number** (isotope's name)	*Lithium* – **7**	*Lithium* – **8**
Symbol – **mass number** notation	*Li* – **7**	*Li* – **8**
Common isotope notation	**7** **3** Li	**8** **3** Li
Nuclear diagram notation		

17. Isotope symbols: Practice problems

Concept Task: Be able recognize symbols that are isotopes of the same element.

Practice 24

Which two notations represent isotopes of the same element?

1) $^{40}_{19}K$ and $^{40}_{20}Ca$

2) $^{20}_{10}Ne$ and $^{22}_{10}Ne$

3) $^{23}_{11}Na$ and $^{24}_{12}Na$

4) $^{16}_{8}O$ and $^{17}_{8}N$

Practice 25

Which pair are isotopes of the same element?

1) $^{226}_{91}X$ and $^{226}_{91}X$

2) $^{227}_{91}X$ and $^{227}_{90}X$

3) $^{226}_{91}X$ and $^{227}_{91}X$

4) $^{226}_{90}X$ and $^{227}_{91}X$

Practice 26

Which symbol could represent an isotope of element iron ?

1) $^{55}_{55}Fe$

2) $^{55}_{26}Fe$

3) $^{26}_{55}Fe$

4) $^{26}_{8}Fe$

Practice 27

Which symbol could be an isotope of calcium ?

1) $^{20}_{20}X$

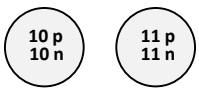
2) $^{40}_{20}X$

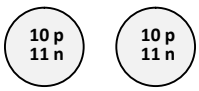
3) $^{20}_{40}X$

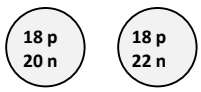
4) $^{40}_{40}X$

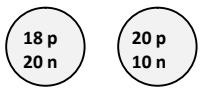
Practice 28

Which two nucleus diagrams are from atoms of the same element?

1) 

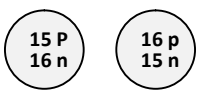
2) 

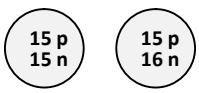
3) 

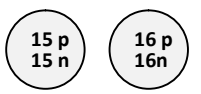
4) 

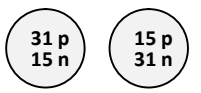
Practice 29

Which two nuclei are isotopes of phosphorous?

1) 

2) 

3) 

4) 

Concept Task: Be able to interpret isotope symbols

Practice 30

The isotope symbol $^{27}_{13}Al$ can also be represented as

1) Aluminum–13

2) Aluminum–14

3) Aluminum–27

4) Aluminum-40

Practice 31

Which nuclide name is correct for the symbol $^{223}_{85}X$

1) Fr – 85

2) Fr – 138

3) Fr – 223

4) Fr – 308

Practice 32

Chlorine – 37 can also be represented as

1) $^{35}_{17}Cl$

2) $^{17}_{35}Cl$

3) $^{37}_{17}Cl$

4) $^{17}_{37}Cl$

Practice 33

Which isotope notation is correct for magnesium -26 ?

1) $^{26}_{26}Mg$

2) $^{12}_{26}Mg$

3) $^{26}_{12}Mg$

4) $^{12}_{12}Mg$

Practice 34

Which diagram correctly represents the nucleus for the isotope symbol $^{59}_{28}X$?

1) 

2) 

3) 

4) 

Practice 35

The nucleus of an atom is shown below:

Which isotope symbol correctly represents this atom?

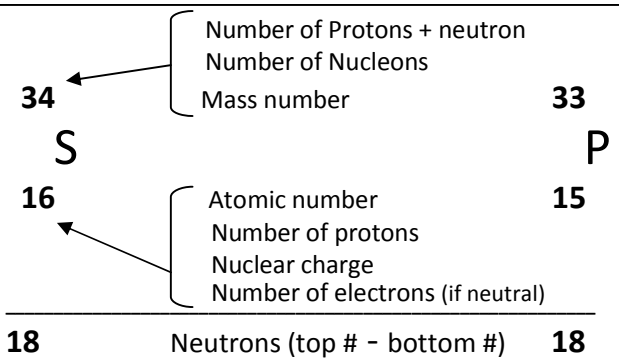
1) $^{35}_{45}Rh$ 2) $^{80}_{45}Rh$ 3) $^{80}_{35}Br$ 4) $^{45}_{35}Br$

18. Determining and comparing particles in Isotope symbols

In any given isotope notations, you should be able to determine and compare the following information.

. Mass number, number of nucleons, and the sum of protons and neutrons
. Atomic number, number of protons, nuclear charge, and number of electrons
. Number of neutrons

Two isotope symbols are given below. Note the differences and similarities in the number of particles between them.



The following comparisons can be made of the two isotope symbols to the left:

^{34}S has **more nucleons** than ^{33}P

$^{33}_{15}P$ has one **fewer proton** than $^{34}_{16}S$

$^{34}_{15}S$ has a **greater nuclear charge** than $^{33}_{16}P$

P-**33** has the **same** number of **neutrons** as S-**34**

19. Determining and comparing particles in Isotope symbols: Practice problems

Concept Tasks: Be able to determine and compare the number of subatomic particles from given isotope notations. *Be sure to utilize the Periodic Table.*

Practice 36

What is the total number of protons and neutrons in the nuclide $^{127}_{53}I$

1) 53 2) 127 3) 74 4) 180

Practice 37

The nucleus of the atom $^{107}_{47}Ag$ contains

1) 60 neutrons, and has a nuclear charge of +47
2) 60 electrons, and has a nuclear charge of +47
3) 47 neutrons, and has a nuclear charge of +107
4) 47 electrons, and has a nuclear charge of +107

Practice 38

What is the structure of of krypton - 85?

1) 49 electrons, 49 protons, and 85 neutrons
2) 49 electrons, 49 protons, and 49 neutrons
3) 36 electrons, 36 protons, and 85 neutrons
4) 36 electrons, 36 protons, and 49 neutrons

Practice 39

The nucleus of chlorine – 35 has

1) 17 protons, and the atom has a mass number of 35
2) 17 electrons, and the atom has a mass number of 35
3) 35 protons, and the atom has a mass number of 17
4) 35 electrons, and the atom has a mass number of 17

Practice 40

An atom of K- 37 and an atom of K – 42 differ in their total number of

1) Electrons 3) Neutrons
2) Protons 4) Positron

Practice 41

Compare to the atom of $^{40}_{20}Ca$, the atom of $^{38}_{18}Ar$ has

1) a greater nuclear charge
2) the same number of nuclear charge
3) greater number of neutrons
4) the same number of neutrons

Practice 42

Which nuclide contains the greatest number of neutrons?

1) ^{207}Pb 2) ^{203}Hg 3) ^{207}Ti 4) ^{208}Bi

Practice 43

Which symbol has the smallest nuclear charge?

1) Cu – 65 3) Zn – 64
2) Ga – 69 4) Ge - 72

Practice 44

In which nucleus is the ratio of protons to neutrons 1 : 1?

1) B – 12 3) C – 13
2) N – 14 4) O – 15

20. Atomic mass unit

Atomic mass unit (amu) is the unit for measuring mass of atoms relative to the mass of carbon – 12.

1 amu = $^{1}/_{12}^{th}$ the mass of ^{12}C

Interpretations:

Hydrogen – **1** (^{1}H) has a mass that is 1/12th the mass of ^{12}C

Lithium – **6** (^{6}Li) has a mass that is 6/12th or half the mass of ^{12}C

Magnesium – **24** (^{24}Mg) has a mass that is 24/12th or 2 times the mass of ^{12}C

Practice 45

Which could have an atom with a mass that is approximately three times that is of C-12 ?

1) O 3) Li

2) Cl 4) Kr

21. Atomic mass

Atomic mass of an element is the average mass of all its naturally occurring stable isotopes.

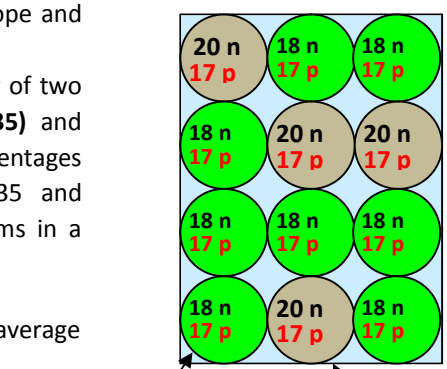
Atomic mass is based on the masses of the stable isotopes and their percent abundance in a sample.

To get a better understanding of what this means, read the explanation below.

A natural sample of an element consists of a mix of two or more isotopes (different atoms). Usually, there is a lot of one isotope and very little of the others.

For an example: a natural sample of chlorine consists mainly of two chlorine isotopes: Chlorine atoms with a mass of 35 **(Cl-35)** and chlorine atoms with a mass of 37 **(Cl-37).** The relative percentages (abundances) of these isotopes are approximately 75% of Cl-35 and 25% of Cl-37. That means three of every four chlorine atoms in a natural sample of chlorine will have a mass of 35 amu.

The atomic mass of Chlorine given on the Periodic Table is the average mass of these two isotopes.



Nucleus of Cl-35

(**3** of 4, or 75% of the nuclei)

Nucleus of Cl-37

(**1** of 4, or 25% of the nuclei **)**

Atomic mass → **35.453** Cl 17

Although the atomic mass of the elements can be found on the Periodic Table, students are often asked to calculate atomic mass of an element from given percentages and mass numbers of its isotopes.

On the next page you will see an example of how to calculate the average atomic mass of an element.

22. Average atomic mass calculation: Example and practice problems

Concept Task: Be able to calculate the average atomic mass of an element given the mass numbers and percent abundances of its isotopes .

Study the steps below.

Example

A natural sample of chlorine contains 75% of ^{35}Cl and 25% of ^{37}Cl. Calculate the atomic mass of chlorine?

	Step 1 *(Change % to decimal)*		***Step 2*** *(multiply by mass #)*		*product*	***step 3*** *(add all products to get **mass**)*
75% of ^{35}Cl	.75	x	35	=	26.25	+ = **35.5 amu**
25% of ^{37}Cl	.25	x	37	=	9.25	

The above numerical setup (*steps 1 – 3*) can also be written as:

(.75 x 35) + (.25 x 37) = 35. 5 amu

Practice 46

Which statement best explains why most atomic masses on the Periodic Table are decimal numbers?

1) Atomic masses are determined relative to an H–1 standard.
2) Atomic masses are determined relative to an O–16 standard.
3) Atomic masses are a weighted average of the naturally occurring isotopes.
4) Atomic masses are an estimated average of the artificially produced isotopes.

Practice 47

Two isotopes of elements X have average atomic mass of 54 amu. What are the relative percentages of these two isotopes of element X?

1) 80% of ^{50}X and 20% of ^{55}X
2) 20 % of ^{50}X and 80% of ^{55}X
3) 50% of ^{50}X and 50% of ^{55}X
4) 75 % of ^{50}X and 25 % of ^{55}X

Practice 48

A 100.00-gram sample of naturally occurring boron contains 19.78 grams of boron-10 (atomic mass = 10.01 amu) and 80.22 grams of boron-11 (atomic mass = 11.01 amu). Which numerical setup can be used to determine the atomic mass of naturally occurring boron?

1) (0.1978)(10.01) + (0.8022)(11.01)
2) $\frac{(0.1978)(10.01)}{(0.8022)(11.01)}$
3) (0.8022)(10.01) + (0.1978)(11.01)
4) $\frac{(0.8022)(10.01)}{(0.1978)(11.01)}$

Practice 49

Element X has two naturally occurring isotopes. If 72% of the atoms have a mass of 85 amu and 28% of the atoms have a mass of 87 amu, what is the atomic mass of element X. Show numerical setup and the calculated result.

Practice 50

Show the numerical setup and the calculated atomic mass of silicon given the following three natural isotopes.

92.23% ^{28}Si

4.67% ^{29}Si

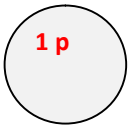
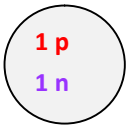
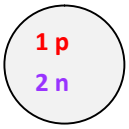
3.10% ^{30}Si

23. Isotopes of hydrogen:

Element hydrogen has three main isotopes: protium, deuterium, and tritium

As with all isotopes, these three isotopes of hydrogen differ in their numbers of neutrons.

Names, symbol notations and nuclear diagrams of these isotopes are shown below.

	Isotopes of hydrogen		
	Protium	*Deuterium*	*Tritium*
Nuclide name	Hydrogen-**1** (H-**1**)	Hydrogen-**2** (H-**2**)	Hydrogen-**3** (H-**3**)
Isotope symbol	$^{1}_{1}H$	$^{2}_{1}H$	$^{3}_{1}H$
Mass number	**1**	**2**	**3**
Protons (atomic number)	1	1	1
Neutrons	0	1	2
Nuclear diagram			

Protium

Hydrogen-1 atom has the most basic atomic structure of all atoms. It is composed of 1 proton and 1 electron. It is the only atom without a neutron in its nucleus. When H-1 loses its only electron, the hydrogen ion (H+) that forms is just a proton.

A sample of hydrogen is composed almost entirely (about 99.9%) of protium (H-1). Only traces of deuterium (H-2) and tritium (H-3) would be found in a natural sample of hydrogen.

The H-1 is the main hydrogen isotope found in water ($^{1}H_2O$).

Deuterium.

In a sample of water, there will be traces of $^{2}H_2O$ *molecules*. This is called *heavy water* because the molecule is composed of the heavier hydrogen atom, deuterium. Heavy water is commonly used in nuclear power plants to cool down the reactors.

Tritium

Tritium's main application is also in nuclear reactions. It is the most commonly used reactant in nuclear fusion. A tritium atom can fuse (join) with another hydrogen isotope to form a helium atom, and a release of a tremendous amount of nuclear energy.

LOOKING Ahead ⇨ Topic 12-Nuclear chemistry: You will learn about nuclear fusion.

Lesson 3 – Electrons location and arrangements

Introduction

According to the wave-mechanical model of atoms, electrons are found in orbitals outside the nucleus.

An **orbital** is the most probable region outside the nucleus where an electron is likely to be found.

The orbital of an electron depends on the energy of the electron. Some electron of an atom may have enough energy to occupy an orbital far from the nucleus, other electrons of the atom may have just enough energy to occupy regions closer to the nucleus. The result is the formation of energy levels (or electron shells) around the nucleus of the atom.

The **Bohr's atomic model** is often used to show arrangement of electrons in electron shells (energy levels) of an atom. Each electron shell in Bohr's atomic model corresponds to a specific amount of energy of the electrons occupying that shell.

Arrangement of electrons in atoms is complex. In this lesson, you will learn the basic and simplified arrangements of electrons in electron shells. You will also learn of electron transition (movement) from one level to another, and the production of spectral lines.

24. Electron shells and electron configurations

Electron shells refer to the energy levels of electrons of an atom.

Electron configuration shows how electrons are arranged in the electron shells of an atom.

Concept Facts: Study to remember the followings about electron shells

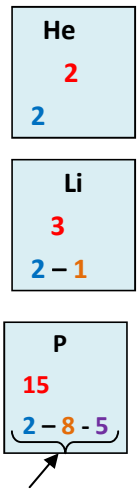
. An atom may have one or more electron shells

. The electron shell (1^{st}) closest to the nucleus always contains electrons with the least amount of energy

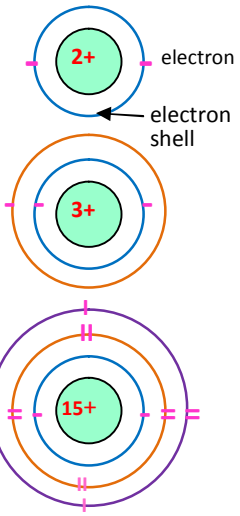
. The electron shell farthest from the nucleus contains electrons with the most amount of energy

. On the Periodic Table, the Period (horizontal row) number indicates the total number of electron shells in the atoms of the elements

A Bohr's atomic model (shell diagram**)** can be drawn to show electrons in the electron shells of an atom. Below, Bohr's atomic models for three atoms are drawn using information from the Periodic Table.



Electron configuration



Bohr's atomic model

According to the electron configuration, a helium atom has all its electrons in **ONE** electron shell:

- 1^{st} shell: **2** electrons

According to the electron configuration, a lithium atom has all its electrons in **TWO** electron shells:

- 1^{st} shell: **2** electrons (electrons with lowest energy)
- 2^{nd} shell : **1** electron (electron with greatest energy)

According to the electron configuration, a phosphorous atom has all its electrons in **THREE** electron shells:

- 1^{st} shell: **2** electrons (electrons with least energy)
- 2^{nd} shell : **8** electrons (electrons with a little more energy)
- 3^{rd} shell : **5** electrons (electrons with greatest energy)

25. Electron Configurations

Concept Task: Be able to interpret electron configurations

Study the electron configuration below.

2 – 8 – 8 – *1*

1st 2nd 3rd 4th

ELECTRON SHELLS

The configuration shows:

4 electron shells (the atom is of a **4th** Period element)
1st shell is the shell containing electrons with lowest energy
4th shell is the shell containing electrons with greatest energy
4th shell is the valance (outermost) shell
1 is the number of valance electrons
19 is the total number of electrons (2 + 8 + 8 + 1 = 19)

Practice 51
How many electron shells containing electrons are found in an atom of strontium?
1) 2 2) 5 3) 18 4) 38

Practice 52
The total number of electron shells in the configuration 2 – 8 – 1 is
1) 1 2) 2 3) 3 4) 11

Practice 53
In which electron shell would an electron with the most energy be found in an atom of astatine?
1) 2 2) 6 3) 7 4) 18

Practice 54
Which electron configuration is of an atom with three electron shells?
1) 2 – 1
2) 2 - 3
3) 2 – 8 - 8
4) 2 – 8 – 18 – 3

Practice 55
Which of these atoms in the ground state has the most number of electron shells containing electrons?
1) Cs-132
2) I - 127
3) Xe - 134
4) Na - 23

Practice 56
In the electron configuration below,
2 – 8 – 3 – 1
Which shell contains electrons with the greatest energy?
1) 1st 2) 2nd 3) 3rd 4) 4th

Practice 57
In a bromine atom in the ground state, the electrons that has the least amount of energy are located in the
1) First electron shell
2) Second electron shell
3) Third electron shell
4) Fourth electron shell

Practice 58
How do the energy and the most probable location of an electron in the third shell of an atom compare to the energy and the most probable location of an electron in the first shell of the same atom?
1) In the third shell, an electron has more energy and is closer to the nucleus.
2) In the third shell, an electron has more energy and is farther from the nucleus.
3) In the third shell, an electron has less energy and is closer to the nucleus.
4) In the third shell, an electron has less energy and is farther from the nucleus.

Practice 59
How many electrons are in the 4th electron shell of a neutral zirconium atom ?
1) 2 2) 5 3) 8 4) 10

Practice 60
The total number of electrons in the configuration 2 – 8 – 17 – 2 is
1) 4 2) 2 3) 29 4) 11

Practice 61
What is the total number of valence electrons in a germanium atom in the ground state?
1) 8 2) 2 3) 14 4) 4

Practice 62
Which element has a total of 5 valance electrons present in the fifth shell?
1) Sb 2) Bi 3) I 4) Br

Practice 63
Which set of symbols represents atoms with valence electrons in the same electron shell?
1) Ba, Br, Bi
2) Sr, Sn, I
3) O, S, Te
4) Mn, Hg, Cu

26. Maximum number of electrons in an electron shell : Practice problems

Each electron shell has the maximum number of electrons that can occupy that shell.

If **n** represents the electron shell in question: For example: n = 1 means the 1st shell, n= 3 means 3rd shell .

Maximum number of electrons in a shell = $2(n)^2$ Square the electron shell in question, then multiply by 2

Concept Task: Be able to determine maximum number of electrons in any given electron shell

Example

What is the maximum number of electrons that can occupy the third shell of an atom?

For third shell: **n = 3**

Maximum e- = $2(n)^2 = 2(3)^2 = 2(9) =$ 18 electrons in 3rd

Practice 64

What is the maximum number of electrons that can occupy the second energy level of an atom?

1) 2 2) 8 3) 7 4) 17

Practice 65

What is the most number of electrons that can be found in the 4th energy level of an atom?

1) 2 2) 8 3) 18 4) 32

Practice 66

Which electron shell of an atom can hold a maximum of 72 electrons?

1) 7th shell
2) 6th shell
3) 5th shell
4) 4th shell

27. Completely and partially filled shells: Example and practice problems

An electron shell (n) is completely filled if it has the maximum number of electrons according to the equation $2(n)^2$. A partially or an incompletely filled shell, therefore, has less than the maximum number of electrons that can occupy that shell.

Concept Task: Be able to determine an atom with a completely or partially filled electron shell

Example

Which of these elements has a completely filled third electron shell?

1) Al 2) Ca 3) Ar 4) Kr

Note their electron configurations (use Periodic Table)

Al	Ca	Ar	Kr
2 – 8 – 3	2 – 8 – 8 – 2	2 – 8 – 8	2 – 8 – **18** – 8

Note:
18 is the maximum number of e- in the third shell. (see example above)

An atom with a completely filled third shell must have 18 in the third spot of its configuration.

Choice 4: Of the the four choices, only Kr has 18 electrons in the third shell

Practice 67

Which of these ground state electron configurations is of an atom with two partially filled electron shells?

1) 2 – 8 – 8 – 1
2) 2 – 8 – 18 – 7
3) 2 – 8 – 18 – 2
4) 2 – 8 – 2

Practice 68

Which element has an incomplete 4th electron shell?

1) Hg 2) Rn 3) Cs 4) W

Practice 69

An atom of which element in the ground state has a partially filled second electron shell ?

1) Hydrogen
2) Potassium
3) Lithium
4) Sodium

Practice 70

Which Period 5 atom in the ground state has a half-filled fourth shell?

1) Rh 2) Tc 3) Y 4) Rb

28. Ground state, Excited state, and Spectral lines

An atom is most stable when its electrons occupy the lowest available electron shells. When this is the case, the atom is said to be in the **ground state.** When one or more electrons of an atom occupy a higher energy level than they should, the atom is said to be in the **excited state**. The electron configurations given for all the elements on the Periodic Table are of atoms in the ground state. This means that each configuration on the Periodic Table shows electrons of the atoms filling from the lowest to the highest electron shells.

Below are definitions and facts related to ground and excited state atoms and spectral lines

Concept Facts: Study to remember the followings

Ground state

When an atom is in the ground state:

. Electron configuration is the same as given on the Periodic Table

. Electrons are filled in order from lowest to highest energy shells

. The energy of the atom is at its lowest, and the atom is stable

. An electron in a ground state atom must absorb energy to go from a lower level to a higher level

. As an electron of a ground state atom absorbs energy and moves to the excited state, the energy of the electron and of the atom increases

N
7
2 – 5

Ground state configuration for Nitrogen.

Same as on the Periodic Table

Excited state:

When an atom is in the excited state:

. Electron configuration is different from that of the Periodic Table

. The energy of the atom is at its highest , and the atom is unstable

. An electron in the excited state atom must release energy to return from a higher level to a lower level

. As an electron in the excited state atom releases energy to return to the ground state, the energy of the electron and of the atom decreases.

. *Spectrum of colors* are produced when excited electrons release energy and return to the ground state

N
7
2 – 4 – 1
1 – 6

Two possible excited state configurations for Nitrogen.

NOTE:

Configurations are different from that of the Periodic Table for Nitrogen

BUT

the total number of electrons in each excited state configuration is still **7**

Quanta is a discrete (specific) amount of energy absorbed or released by an electron to go from one level to another.

Spectral lines:

Spectral lines are band of colors produced when the energy released by excited electrons is viewed through a spectroscope.

. Spectral lines are produced from energy released by excited electrons as they returned to the ground state

. Spectral lines are called "fingerprints' of the elements because each element has its own unique patterns (wavelength of colors)

Spectral lines (bright-line spectra)

29. Excited and Ground State: Examples and practice problems

Concept Task: Be able to determine which electron configuration is of an atom in the ground or excited state. Be sure to utilize the Periodic Table.

Examples:

2 – 8 – 5 is the ***ground state*** configuration for P

2 – 7 – 6 is an e***xcited state*** configuration for P

Practice 71

Which is the ground state configuration for a chlorine atom?

1) 2 – 8 – 7 – 1
2) 2 – 8 – 8 – 1
3) 2 – 8 – 8 – 7
4) 2 – 8 – 6 – 1

Practice 72

What is the ground state electron configuration of a neutral atom with 27 protons?

1) 2 – 8 – 14 – 3
2) 2 – 8 – 8 – 8 – 1
3) 2 – 8 – 15 – 2
4) 2 – 8 – 17

Practice 73

Which electron configuration is possible for a strontium atom in the excited state?

1) 2 – 8 – 18 – 10
2) 2 – 8 – 18 – 7 – 3
3) 2 – 8 – 18 – 8 – 1
4) 2 – 8 – 18 – 8 – 2

Practice 74

Which is an excited state electron configuration for a neutral atom with 16 protons and 18 neutrons?

1) 2 – 8 – 5 – 1
2) 2 – 8 – 8
3) 2 – 8 – 6 – 2
4) 2 – 8 – 6

Practice 75

The electron configuration 2 – 8 – 2 is of a

1) Sodium atom in the ground state
2) Magnesium atom in the ground state
3) Sodium atom in the excited state
4) Magnesium atom in the excited state

Practice 76

The electron configuration 2–8–18–5–1 could be of

1) an arsenic atom in the ground state
2) an arsenic atom in the excited state
3) a selenium atom in the ground state
4) a selenium atom in the excited state

Practice 77

The electron configuration 2 – 8 – 18 – 2 – 1 is of

1) Ga atom in the excited state
2) Al atom in the excited state
3) Ga atom in the ground state
4) Al atom in the ground state

30. Spectral lines: Example and practice problems

Concept Task: Be able to determine which electron transition will produce spectral lines.

Note:

Electron transition from:

Low to **higher** shell

Ex: 5^{th} shell to 6^{th} shell

. Energy is absorbed (gained) by the electron

. Energy of the atom increases

High to **Lower** shell

Ex: 6^{th} shell to 5^{th} shell

. Energy is released (emitted) by the electron

. Produces bright-line spectrum (spectra) of colors

. Energy of the atom decreases

NOTE:

The greater the difference between the two electron shells, the more energy is absorbed or released.

Practice 78

As an electron moves from 3^{rd} electron shell to the 4^{th} electron shell, the energy of the atom

1) Increases as the electron absorbs energy
2) Increases as the electron releases energy
3) Decreases as the electron absorbs energy
4) Decreases as the electron releases energy

Practice 79

Electron transition between which two electron shells will produce bright-line spectrum of colors?

1) 2^{nd} to 3^{rd}
2) 3^{rd} to 4^{th}
3) 1^{st} to 4^{th}
4) 2^{nd} to 1^{st}

Practice 80

As an electron in an atom moves between electron shells, which transition would cause the electron to absorb the most energy?

1) 1^{st} to 2^{nd}
2) 2^{nd} to 1^{st}
3) 2^{nd} to 4^{th}
4) 4^{th} to 2^{nd}

31. Flame test and spectral chart

Flame test is a lab procedure in which compounds of metallic ions are heated to produce different flame colors.

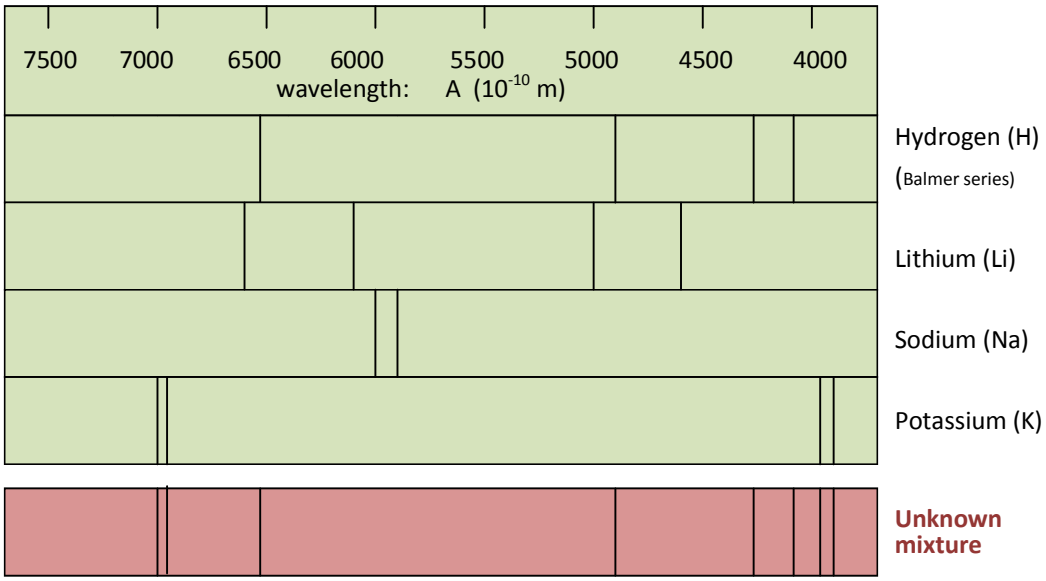
. Flame colors produced are due to the energy released by excited electrons in the metal atoms as they return from high (excited) state to low (ground) state

. Flame colors produced can be used to identify the metal ions present in the substances. However, since two or more metallic ions can produce flame colors that are similar, flame test results are not very reliable for identification.

Spectroscope is equipment that is used to separate a light into color patterns (spectrum of colors) at different wavelengths. Color flames produced during flame tests can be viewed through a spectroscope. The bright-line spectra of each color flame will be unique to each metallic ion, and will provide a more reliable result for identification.

A chart showing bright-line spectra for hydrogen, lithium, sodium and potassium is shown below.

Bright-line spectra of an unknown mixture was compared to those of H, Li, Na and K. Substances in the unknown can be identified by matching the lines in the unknown to the lines for H, Li, Na and K.



Concept Task: Be able to interpret spectral lines chart

Practice 81

Which elements are in the unknown substance?

1) H and Na 2) K and Li 3) H and K 4) K and Na

Practice 82

Which element produces bright line spectra with the following wavelengths:

6600 x10^{-10} A, 6100 x 10^{-10} A, 5000 x 10^{-10} A and 4600 x 10^{-10} A

1) H 2) Li 3) Na 4) K

Lesson 4 – Valance electrons and ions

Introduction:

Most atoms (with the exception of the noble gases) are unstable because they have incomplete valance (outermost) electron shells. For this reason, most atoms need to lose, gain or share electrons to fill their valance shell so they can become stable. When an atom loses or gains electrons, it forms an ion.

In this lesson, you will learn about valance electrons, neutral atoms and ions.

LOOKING Ahead ⇨ Topic 4: Chemical Bonding. You will learn more about the role of valance electrons in chemical bonding.

32. Valance electrons

Valance electrons are electrons in the outermost electron shell of an atom. Valance shell of an atom is the last (outermost) shell that contains electrons.

Recall: Elements in the same Group (vertical column) of the Periodic Table have the same number of valance electrons, and similar chemical reactivity.

Concept Task: Be able to determine the number of valance for any atom or a given configuration.

In any electron configuration, the last number is always the number of valance electrons.

P
15
2 – 8 – 5

LOOK on the Periodic Table for Phosphorous:

The configuration for phosphorous is : 2 – 8 – **5**

The last number is **5**.

Phosphorous has **5** valance electrons in its valance (third) shell.

33. Ions (charged atom) and neutral atoms

For most atoms, a completely filled valance shell must have eight (8) electrons.

NOTE: H and He need only two (2) to fill their valance shell.

A neutral atom may lose its entire valance electrons to form a new valance shell that is completely filled.

A neutral atom may also gain electron(s) to fill its valance shell.

An Ion is formed when a neutral atom loses or gains electrons.

Below, definitions and facts related to neutral atoms and ions

Concept Facts: Study to remember these facts.

Neutral atom

. A neutral atom has equal number of protons and electrons
. The electron configurations given on the Periodic Table are for neutral atoms of the elements in the ground state

Ion

. An ion is a charged atom with unequal number of protons to electrons
. An ion is formed when an atom loses or gains electrons

Positive ion

. A positive ion is a charged atom containing *fewer* electrons (-) than protons (+)
. A positive ion is formed when a neutral atom loses one or more electrons
. Metals and metalloids tend to lose electrons and form positive ions

Negative ion

. A negative ion is a charged atom containing *more* electrons (-) than protons (+)
. A negative ion is formed when a neutral atom gains one or more electrons
. Nonmetals tend to gain electrons and form negative ions

Symbols of neutral atoms and ions	
Na	a neutral sodium atom
S	a neutral sulfur atom
Na^+	a positive sodium ion
S^{2-}	a negative sulfide ion

34. Ion vs. neutral atom

When electrons are lost or gained by a neutral atom, the ion formed will be different in many ways from the neutral atom. Number of electrons, electron configuration, size, as well as properties of the ion will all be different from that of the neutral atom.

The following note summarizes the comparisons between positive and negative ions to their parent neutral atoms.

Concept Facts: Study to learn these comparisons.

Comparing a positive ion to its neutral (metallic) atom.
When a neutral atom (usually a metal or metalloid) loses its valance electron(s):

. The positive ion has *fewer* electrons than the parent neutral atom
. The positive ion electron configuration has one fewer electron shell than the neutral atom
. As the neutral atom loses electrons, its size (atomic radius) decreases
. Ionic radius (size) of a positive ion is always smaller than the atomic radius of the neutral atom
. The positive ion has a different chemical reactivity than the neutral atom

Below, Bohr's diagrams showing size comparison of a neutral Na atom to Na^+ ion.

Na (atom)	symbols	Na^+ (ion)
11+	protons	11+
11 e-	electrons	10 e-
2 – 8 – 1	electron configurations	2 – 8

Comparing a negative ion to its neutral (nonmetallic) atom.
When a neutral atom (usually a nonmetal) gains electrons to fill its valance shell:

. The negative ion has *more* electrons than its parent neutral atom
. The negative ion electron configuration has the same number of electron shell as the neutral atom
. As the neutral atom gains electrons, its size (atomic radius) increases
. Ionic radius (size) of a negative ion is always larger than the atomic radius of the neutral atom
. The negative ion has a different chemical reactivity than the neutral atom

Below, Bohr's diagrams showing size comparison of a neutral S atom to S^{2-} ion

S (atom)	symbols	S^{2-} (ion)
16 +	protons	16 +
16 e-	electrons	18 e-
2 – 8 – 6	electron configurations	2 – 8 - 8

NOTE: Electron configuration of an ion is similar to that of the nearest Group 18 Noble gas element.

Sulfur is Atomic # 16

Argon, atomic # 18, is the closest noble gas to Sulfur.

The configuration of a sulfur ion (2 – 8 – 8) is the same as that of Argon. (Look on the Periodic Table to confirm)

35. Ions: Examples and practice problems

Concept Task: Be able to determine number of electrons and electron configuration of ions.

Number of electrons in ion = Atomic # - Charge
= Protons - Charge

Charge of an ion = protons - electrons

Electron configuration of an ion **is** similar to that of the nearest noble gas atom.

Concept Task: Be able to recognize the correct comparisons between ion and atom.

Examples:

Na^+ ion has 1 ***FEWER*** electron than Na atom

S atom is ***SMALLER*** than S^{2-} ion.

Practice 83
The total number of electrons in a Br^- ion is
1) 36 2) 35 3) 34 4) 54

Practice 84
How many electrons are in a N^{2-} ion?
1) 7 2) 9 3) 10 4) 5

Practice 85
What is the total number of electrons in a Cr^{3+} ion?
1) 3 2) 21 3) 24 4) 27

Practice 86
How many electrons will be found in a particle with a nuclear charge of +41 and a +5 charge?
1) 41 2) 46 3) 205 4) 36

Practice 87
An atom has a nuclear charge of +50 and 46 electrons. The net ionic charge of this atom is
1) +46 2) -46 3) -4 4) +4

Practice 88
An atom has a nuclear charge of +7, 10 electrons, and 8 neutrons. What is the ionic charge of this atom?
1) +7 2) -1 3) -3 4) +3

Practice 89
Which electron configuration is correct for B^{3+} ion?
1) 2 – 2 – 1 2) 2 – 2 – 1 3) 2 – 3 4) 2

Practice 90
Which is the correct electron configuration for Ca^{2+}?
1) 2 – 8 – 2
2) 2 – 8
3) 2 – 8 – 8
4) 2 – 6 – 1 – 1

Practice 91
The electron configuration for As^{3-} is
1) 2 – 8 – 18 – 5
2) 2 – 8 – 18 – 8
3) 2 – 8 – 17 – 6
4) 2 – 8 – 18 – 5 – 3

Practice 92
The electron configuration 2 – 8 – 18 – 8 could represent which particle?
1) Ca^{2+} 2) Ge^{4+} 3) Cl^- 4) Br^{5+}

Practice 93
Which changes occur as an atom becomes a positively charge ion?
1) The atom gains electrons, and the number of protons increases
2) The atom gains electrons, and the number of protons remains the same
3) The atom loses electrons, and the number of protons decreases
4) The atom loses electrons, and the number of protons remains the same

Practice 94
Compared to a phosphorus atom, a P^{3-} ion has
1) More electrons and a larger radius
2) More electrons and a smaller radius
3) Fewer electrons and a larger radius
4) Fewer electrons and a smaller radius

Practice 95
A neutral oxygen atom (O) differs from an ion of oxygen (O^{2-}) in that the atom has
1) More protons
2) More electrons
3) Fewer protons
4) Fewer electrons

Practice 96
Which changes occur as a cadmium atom, Cd, becomes a cadmium ion, Cd^{2+}?
1) The Cd atom gains two electrons and its radius decreases.
2) The Cd atom gains two electrons and its radius increases.
3) The Cd atom loses two electrons and its radius decreases.
4) The Cd atom loses two electrons and its radius increases.

Practice 97
How does the size of N^{3-} ion compares to N atom?
1) N^{3-} is bigger than N because the N^{3-} has 3 more electrons
2) N^{3-} is bigger than N because the N^{3-} has 3 fewer electrons
3) N^{3-} is smaller than N because the N^{3-} has 3 more electrons
4) N^{3-} is smaller than N because the N^{3-} has 3 fewer electrons

Concept Terms

Key vocabulary terms and concepts from Topic 3 are listed below. You should know definition and facts related to each term and concept.

1. Atom
2. Hard sphere model
3. Plum-pudding model
4. Empty space model
5. Bohr's atomic model
6. Wave mechanical model
7. Gold foil experiment
8. Cathode ray experiment
9. Orbital
10. Nucleus
11. Neutron
12. Proton
13. Electron
14. Nucleon
15. Nuclear charge
16. Atomic number
17. Mass number
18. Atomic mass
19. Atomic mass unit
20. Isotope
21. Electron shell
22. Electron configuration
23. Ground state
24. Excited state
25. Flame test
26. Spectral lines (bright line spectrum)
27. Balmer series
28. Valance electron
29. neutral atom
30. Ion
31. Positive ion
32. Negative ion
33. Ionic configuration
34. Ionic radius

Concept Tasks

Concept tasks from Topic 3 are listed below. You should know how to solve problems and answer questions related to each concept task.

1. Determining and comparing number of one subatomic particle to another
2. Determining or recognizing which two symbols are of isotopes of the same element
3. Determine number of subatomic particles from a given isotope notation
4. Comparing number of subatomic particles of two given isotope symbols
5. Calculating average atomic mass from mass numbers and percentages of isotopes
6. Drawing Bohr's atomic model from electron configuration
7. Determine number of electron shells in an atom or a configuration
8. Determining the electron shell containing electrons with highest or lowest energy.
9. Determining number (or total number) of electrons in any electron shell of an atom or configuration
10. Determining electron transition between electron shells that will produce spectral lines
11. Interpreting electron transition between electron shells
12. Determining and interpreting electron configuration in ground or excited state.
13. Interpreting spectral lines chart
14. Determining and comparing number particles between an ion and the neutral atom.
15. Determining number of electrons and/or protons of an ion.
16. Determining the correct charge of an atom from number of protons and electrons
17. Determining and interpreting ionic configuration

Topic 4 – Chemical Bonding

Topic outline

In this topic, you will learn the following concepts:

. Chemical bonds and stability of atoms
. Chemical bonding and energy
.Types of chemical bonds between atoms
. Molecular substances and molecular polarity
. Intermolecular forces
. Types of substances and their properties

Lesson 1: Chemical bonding and Stability of atoms

Introduction

Chemical bonding is the simultaneous attraction of positive nuclei to negative electrons.
Chemical bonding is said to be the "glue" that holds particles (atoms, ions, molecules) together in matter.
When atoms bond they become much more stable than when they are in their free states. Since most atoms do not have a full valance shell, they are unstable. For these atoms to attain a full valance shell and be stable, they bond with other atoms.

1. Chemical bonding and stability

Atoms bond so they can attain full valance shells and become stable.

Octet of electrons is when an atom has a full valance (outermost) shell with 8 electrons.
Note: Not every atom need eight (8) valance electrons to be stable.

An atom can get a full and stable valance shell configuration by :
Transferring or Accepting electrons (in ionic bonding) or *Sharing* electrons (in covalent bonding)

Recall that all noble gas atoms have full valance shell of electrons , which make them very stable.
. The electron configuration of a bonded atom is similar to that of the nearest noble gas (Group 18) atom

2. Chemical bonding and atom stability : Practice problems

Concept Task: Be able to determine which noble gas elements that atoms in a bond resemble.

Note
Most atoms in a bond has the same number of electrons and similar electron configuration as the nearest noble gas (Group 18) atom.

Example
In a bond between sodium and chlorine in the formula NaCl: Na resembles Ne. Cl resembles Ar.

Na (atomic # 11) closest noble gas is Ne (atomic #10).

In **Na**Cl, **Na** is **Na+** ion (10 electrons) . Its configuration is 2–8 , which is similar to that of Ne (2–8)

Cl (atomic # 17) closest noble gas is Ar (atomic # 18).

In Na**Cl**, Cl is **Cl-** ion (18 electrons) **.** Its configuration is 2–8–8 , which is similar to that of Ar (2–8–8)

Practice 1
When a sulfur atom bonds with sodium atoms to form the compound Na_2O, the configuration of oxygen in the compound is similar to
1) Na 2) O 3) Ne 4) Ar

Practice 2
The electron configuration of Sr and H ions in the formula SrH_2 are similar to those of elements
1) Kr and He
2) Rb and He
3) Ar and Ne
4) Ca and Li

Practice 3
Atom X and atom Y bond to form a compound. The electron configuration of X in the bond is 2 – 8 – 8. The electron configuration of Y in the compound is 2 – 8. Which two atoms could be X and Y ?
1) X could be magnesium and Y could be sulfur
2) X could be calcium and Y could be sulfur
3) X could be magnesium and Y could be nitrogen
4) X could be calcium and Y could be nitrogen

Topic 4 – Chemical Bonding

Lesson 2 – Chemical bonding and energy

Introduction

All chemical substances contain certain amount of potential energy.

Potential energy is stored in the bonds holding particles of substances together.

The amount of potential energy of a substance depends on *composition and structure* of the substance.

In this lesson, you will learn the relationship between bonding and energy.

3. Bond and energy

Bond formation between two atoms is exothermic. ***Exothermic*** describes a process that releases heat energy. When two atoms come together to form a bond, heat energy is always released. Since energy is released, the energy of the atoms decreases. The atoms are more stable when they are bonded than when they were not.

H + Cl ------> H – Cl + **Energy**

A chemical bond formed between H and Cl atoms. The bonded H and Cl atoms are more stable than the free H and Cl atoms on the left.

Summary of bond formation and energy

Concept Facts: Study to remember these facts

. Bond formation is exothermic (heat energy released)

. As energy is released during bond formation

- Potential energy of the atoms decreases
- Stability of the atoms increases
- Stability of the chemical system increases

Bond breaking is endothermic .

Endothermic describes a process that absorbs heat energy.

When a bond between atoms of a substance is to be broken, energy is always absorbed. Since energy is absorbed, the energy of the atoms increases. The atoms, separated, are now less stable than when they were bonded together.

H – Cl + **Energy** ------ > H + Cl

A chemical bond to be broken

Summary of bond breaking and energy.

Concept Facts: Study to remember these facts

. Bond formation is endothermic (heat energy absorbed)

. As energy is absorbed during bond breaking

- Potential energy of the atoms increases
- Stability of the atoms decreases
- Stability of the chemical system decreases

Concept Task: Be able to relate energy to bonding

Practice 4

When two atoms form a bond to produce a chemical substance, the stability of the chemical system

1) Decreases as energy is absorbed
2) Increases as energy is absorbed
3) Decreases as energy is released
4) Increases as energy is released

Practice 5

Given the balanced equation:

I_2 + energy ----------> I + I

Which statement describes the process represented by this equation?

1) A bond is formed, and energy is absorbed
2) A bond is formed, and energy is released
3) A bond is broken, and energy is absorbed
4) A bond is broken, and energy is released

Practice 6

Given the equation

H_2 + O_2 --------> H_2O

Which statement best describes the process taking place as bonds are broken and formed?

1) The breaking of O–O bond releases energy
2) The breaking of H–H bond releases energy
3) The forming of H–O bond absorbs energy
4) The forming of H–O bond releases energy

Practice 7

When two fluorine atoms combined to form a molecule of fluorine, energy is

1) Always absorbed
2) Always released
3) Sometimes absorbed
4) Sometimes released

14 Days of Questions for Regents and Final Exams Practice

The following section contains day-by-day practice question sets for preparing for any end-of-the-year chemistry exam.

Day 1: Matter and Energy - Multiple Choices

1. Which of these terms refers to matter that could be heterogeneous?
   1) Element 2) Mixture 3) Compound 4) Solution

2. One similarity between all mixtures and compounds is that both
   1) Are heterogeneous
   2) Are homogeneous
   3) Combine in definite ratio
   4) Consist of two or more substances

3. Which correctly describes particles of a substance in the gas phase?
   1) Particles are arranged in regular geometric pattern and are far apart
   2) Particles are in fixed rigid position and are close together
   3) Particles are moving freely in a straight path
   4) Particles are move freely and are close together.

4. When a substance evaporates, it is changing from
   1) Liquid to gas 2) Gas to liquid 3) Solid to gas 4) Gas to solid

5. Energy that is stored in chemical substances is called
   1) Potential energy 2) Activation energy 3) Kinetic energy 4) Ionization energy

6. The specific heat capacity of water is 4.18 J/^{o}C.g . Adding 4.18 Joules of heat to a 1-gram sample of water will cause the water to
   1) Change from solid to liquid
   2) Change from liquid to solid
   3) Change its temperature 1 degree Celsius
   4) Change its temperature 4.18 degree Celsius

7. Real gases differ from an ideal gas because the molecules of real gases have
   1) Some volume and no attraction for each other
   2) Some attraction and some attraction for each other
   3) No volume and no attraction for each other
   4) No volume and some attraction for each other

8. Under which two conditions do real gases behave most like an ideal gas?
   1) High pressure and low temperature
   2) Low pressure and high temperature
   3) High pressure and high temperature
   4) Low pressure and low temperature

9. At constant pressure, the volume of a confined gas varies
   1) Directly with the Kelvin temperature
   2) Indirectly with the Kelvin temperature
   3) Directly with the mass of the gas
   4) Indirectly with the mass of the gas

10. Under which conditions would a volume of a given sample of a gas decrease?
   1) Decrease pressure and increase temperature
   2) Decrease pressure and decrease temperature
   3) Increase pressure and decrease temperature
   4) Increase pressure and increase temperature

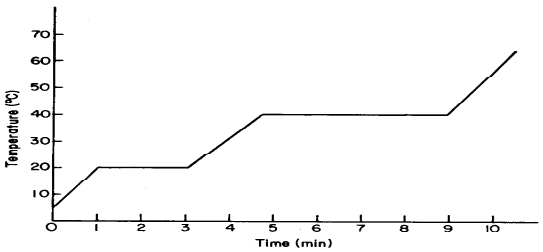
11. Which statement describes a chemical property of iron?
   1) Iron can be flattened into sheets.
   2) Iron conducts electricity and heat.
   3) Iron combines with oxygen to form rust.
   4) Iron can be drawn into a wire.

12. Which sample at STP has the same number of molecules as 5 liters of $NO_2(g)$ at STP?
   1) 5 grams of $H_2(g)$
   2) 5 liters of $CH_4(g)$
   3) 5 moles of $O^2(g)$
   4) 5×10^{23} molecules of $CO_2(g)$

Day 1: Matter and Energy - Multiple Choices

13. Which substance can be decomposed by a chemical change?
    1) Ammonia
    2) Potassium
    3) Aluminum
    4) Helium

14. The graph below represents the relationship between temperature and time as heat is added at a constant rate to a substance, starting when the substance is a solid below its melting point



During which time period (in minutes) is the substance average kinetic energy remains the same?
1) 0 – 1 2) 1 – 3 3) 3 - 5 4) 9 – 10

15. Molecules of which substance have the lowest average kinetic energy?
    1) NO(g) at 20°C
    2) NO_2(g) at -30°C
    3) NO_2 at 35 K
    4) N_2O_3 at 110 K

16. At STP, the difference between the boiling point and the freezing point of water in Kelvin scale is
    1) 373 2) 273 3) 180 4) 100

17. How much heat is needed to change a 5.0 gram sample of water from 65°C to 75°C?
    1) 210 J 2) 14 J 3) 21 J 4) 43

18. A real gas will behave most like an ideal gas under which conditions of temperature and pressure?
    1) 0°C and 1 atm
    2) 0°C and 2 atm
    3) 273°C and 1 atm
    4) 273°C and 2 atm

19. A 2.0 L sample of O_2(g) at STP had its volume changed to 1.5 L. If the temperature of the gas was held constant, what is the new pressure of the gas in kilopascal?
    1) 3.0 kPa 2) 152 kPa 3) 101.3 kPa 4) 135 kPa

20. A gas occupies a volume of 6 L at 3 atm and 70°C. Which setup is correct for calculating the new volume of the gas if the temperature is changed to 150°C and the pressure is dropped to 1.0 atm?

    1) $6 \times \frac{3 \times 150}{1 \times 70}$
    2) $6 \times \frac{3 \times 80}{1 \times 150}$
    3) $6 \times \frac{3 \times 423}{1 \times 343}$
    4) $6 \times \frac{3 \times 343}{1 \times 423}$

21. Given the balanced particle-diagram equation:

Key
○ = an atom of an element
● = an atom of a different element

Which statement describes the type of change and the chemical properties of the product and reactants?

1) The equation represents a physical change, with the product and reactants having different chemical properties.
2) The equation represents a physical change, with the product and reactants having identical chemical properties.
3) The equation represents a chemical change, with the product and reactants having different chemical properties.
4) The equation represents a chemical change, with the product and reactants having identical chemical properties.

Day 1: Matter and Energy - Constructed Responses

Based your answers to questions 22 to 25 on the diagram of a molecule of nitrogen shown below.

 represents one molecule of nitrogen.

Write your answers here

22. Draw a particle model that shows at least six molecules of nitrogen gas. 22.

23. Draw a particle model that shows at least six molecules of liquid nitrogen. 23.

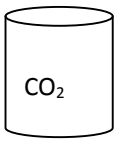
24. Describe, in terms of particle arrangement, the difference between nitrogen gas and liquid nitrogen. 24.

25. Good models should reflect the true nature of the concept being represented. What is the limitation of two-dimensional models. 25.

Base your answer to questions 26 through 28 on the information and diagrams below.

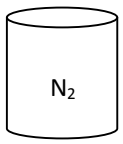
Cylinder A contains 22.0 grams of $CO_2(g)$ and Cylinder B contains $N_2(g)$. The volumes, pressures, and temperatures of the two gases are indicated under each cylinder.

A



V = 12.3 L
P = 1.0 atm
T = 300. K

B



V = 12.3 L
P = 1.0 atm
T = 300. K

Show work and answers here

26. How does the number molecules of $CO_2(g)$ in cylinder A compares to the number of molecules of $N_2(g)$ in container B. Your answer must include both $CO_2(g)$ and $N_2(g)$. 26.

27. The temperature of $CO_2(g)$ is increased to 450. K and the volume of cylinder A remains constant. Show a correct numerical setup for calculating the new pressure of $CO_2(g)$ in cylinder A. 27.

28. Calculate the new pressure of $CO_2(g)$ in cylinder A based on your setup. 28.

Day 1: Matter and Energy - Constructed Responses

Base your answers to questions 29 through 33 on the information below.

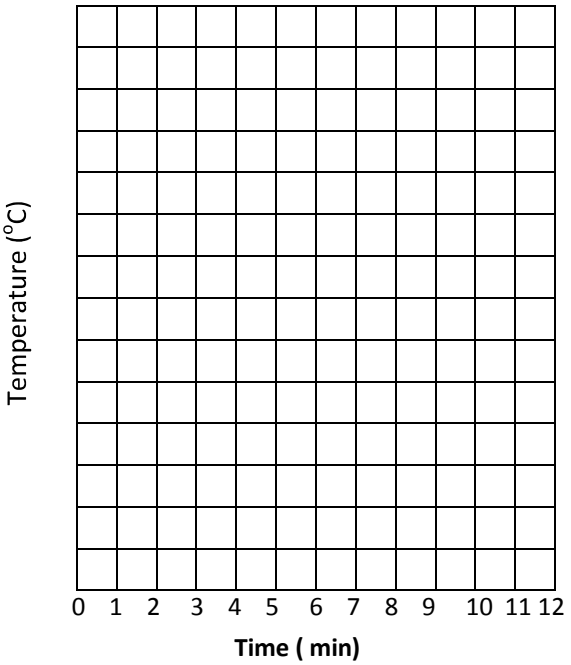
A substance is a solid at 15°C . A student heated a sample of the substance and recorded the temperature at one-minute intervals in the data table below.

Time (min)	0	1	2	3	4	5	6	7	8	9	10	11	12
Temperature (°C)	15	32	46	53	53	53	53	53	53	53	53	60	65

29. On the grid , mark an appropriate scale on the axis labeled " Temperature (°C) ." An appropriate scale is one that allows a trend to be seen.

30 . Plot the data from the data table. Circle and connect the points

Heating Curve



Write your answers on this side.

31. Based on the data table, what is the melting point of the substance? 31.

32. What is the evidence that the average kinetic energy of the particles of the substance is increasing during the first three minutes? 32.

33. The heat of fusion for this substance is 122 joules per gram. How many joules of heat are needed to melt 7.50 grams of this substance at its melting point 33.

Day 2: The Periodic Table - Multiple Choices

1. Which determines the order of placement of the elements on the modern Periodic Table?
   1) Atomic mass
   2) Atomic number
   3) The number of neutrons, only
   4) The number of neutrons and protons

2. The elements located in the lower left corner of the Periodic Table are classified as
   1) Metals 2) Nonmetals 3) Metalloids 4) Noble gases

3. The strength of an atom's attraction for the electrons in a chemical bond is the measured by the
   1) density 2) ionization energy 3) heat of reaction 4) electronegativity

4. What is a property of most metals?
   1) They tend to gain electrons easily when bonding.
   2) They tend to lose electrons easily when bonding.
   3) They are poor conductors of heat.
   4) They are poor conductors of electricity.

5. A metal, M, forms an oxide compound with the general formula M_2O. In which group on the Periodic Table could metal M be found?
   1) Group 1 2) Group 2 3) Group 16 4) Group 17

6. Which halogen is correctly paired with the phase it exists as at STP?
   1) Br is a liquid 2) F is a solid 3) I is a gas 4) Cl is a liquid

7. As the elements in Group 1 of the Periodic Table are considered in order of increasing atomic number, the atomic radius of each successive element increases. This is primarily due to an increase in the number of
   1) Neutrons in the nucleus
   2) Unpaired electrons
   3) Valance electrons
   4) Electrons shells

8. When elements within Period 3 are considered in order of decreasing atomic number, ionization energy of each successive element generally
   1) Increases due to increase in atomic size
   2) Increase due to decrease in atomic size
   3) Decrease due to increase in atomic size
   4) Decrease due to decrease in atomic size

9. Which set of characteristics of is true of elements in Group 2 of the Periodic Table?
   1) They all have two energy level and share different chemical characteristics
   2) They all have two energy level and share similar chemical characteristics
   3) They all have two valance electrons and share similar chemical properties
   4) They all have two valance electrons and share different chemical properties

10. At STP, solid carbon can exist as graphite or as diamond. These two forms of carbon have
   1) The same properties and the same crystal structures
   2) The same properties and different crystal structures
   3) different properties and the same crystal structures
   4) different properties and the different crystal structures

11. Which grouping of circles, when considered in order from the top to the bottom, best represents the relative size of the atoms of Li, Na, K, and Rb, respectively?

1) 2) 3) 4)

Day 2: The Periodic Table - Multiple Choices

12. Elements strontium and beryllium both form a bond with fluorine with similar chemical formula. The similarity in their formulas is due to
    1) Strontium and beryllium having the same number of kernel electrons
    2) Strontium and beryllium having the same number of valance electrons
    3) Strontium and beryllium having the same number of protons
    4) Strontium and beryllium having the same molecular structure

13. The element Antimony is a
    1) Metal 2) Nonmetal 3) Metalloid 4) Halogen

14. Which of these elements in Period 2 is likely to form a negative ion?
    1) Oxygen 2) Boron 3) Ne 4) Li

15. Which of these characteristics best describes the element sulfur at STP?
    1) It is brittle 2) It is malleable 3) It has luster 4) It is ductile

16. Which of these elements has the highest thermal and electrical conductivity
    1) Iodine 2) Carbon 3) Phosphorous 4) Iron

17. Chlorine will bond with which metallic element to form a colorful compound?
    1) Aluminum 2) Sodium 3) Strontium 4)Manganese

18. According to the Periodic Table, which sequence correctly places the elements in order of increasing atomic size?
    1) Na ----- > Li ------ > H ----- > K
    2) Ba ----- > Sr ----- > Sr ----- > Ca
    3) Te ----- > Sb ------- > Sn ------ > In
    4) H ------ > He ------- > Li ------ > Be

19. Which of these elements has stronger metallic characteristics than Aluminum?
    1) He 2) Mg 3) Ga 4) Si

20. Which element has a greater tendency to attract electron than phosphorous?
    1) Silicon 2) Arsenic 3) Boron 4) Sulfur

21. Which element has the greatest density at STP?
    1) barium 2) magnesium 3) beryllium 4) radium

22. An element that is malleable and a good conductor of heat and electricity could have an atomic number of
    1) 16 2) 18 3) 29 4) 35

23. Sodium atoms, potassium atoms, and cesium atoms have the same
    1) Atomic radius
    2) Total number of protons
    3) First ionization energy
    4) Oxidation state

24. When the elements in Group 1 are considered in order from top to bottom, each successive element at standard pressure has
    1) a higher melting point and a higher boiling point
    2) a higher melting point and a lower boiling point
    3) a lower melting point and a higher boiling point
    4) a lower melting point and a lower boiling point

25. Elements Q, X, and Z are in the same group on the Periodic Table and are listed in order of increasing atomic number. The melting point of element Q is –219°C and the melting point of element Z is –7°C. Which temperature is closest to the melting point of element X?
    1) –7°C 2) –101°C 3) –219°C 4) –226°C

Day 2: The Periodic Table - Constructed Responses

Base your answer to questions 26 through 29 on the information below.

A metal, M, was obtained from compound in a rock sample. Experiments have determined that the element is a member of Group 2 on the Periodic Table of the Elements.

Write answers here.

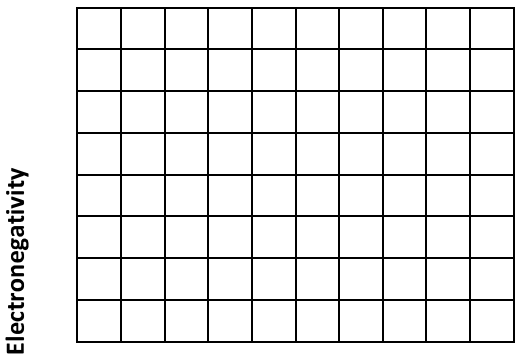
26. What is the phase of element M at STP? 26.

27. Explain, in terms of electrons, why element M is a good conductor of electricity. 27.

28. Explain why the radius of a positive ion of element M is smaller than the radius of an atom of element M. 28.

29. Using the element symbol M for the element, write the chemical formula for the compound that forms when element M reacts with Iodine? 29.

The table below shows the electronegativity of selected elements of the Periodic Table.



Element	Atomic Number	Electronegativity
Beryllium	4	1.6
Boron	5	2.0
Carbon	6	2.6
Fluorine	9	4.0
Lithium	3	1.0
Oxygen	8	3.4

30. On the grid set up a scale for electronegativity on the y-axis. Plot the data by drawing a best-fit line. Write answers here.

31. Using the graph, predict the electronegativity of Nitrogen. 31. _____

32. For these elements, state the trend in electronegativity in terms of atomic number. 32.

Day 3: Atomic Structure - Multiple Choices

1. Which conclusion was a direct result of the gold foil experiment?
   1) An atom is composed of at least three types of subatomic particles.
   2) An atom is mostly empty space with a dense, positively charged nucleus.
   3) An electron has a positive charge and is located inside the nucleus.
   4) An electron has properties of both waves and particles.

2. In the wave-mechanical model of the atom, orbitals are regions of the most probable locations of
   1) protons 2) positrons 3) neutrons 4) electrons

3. What is the charge and mass of an electron?
   1) Charge of +1 and a mass of 1 amu
   2) Charge of -1 and a mass of 1 amu
   3) Charge of +1 and a mass of 1/1836 amu
   4) Charge of -1 and a mass of 1/1836 amu

4. Which phrase describes an atom?
   1) a positively charged electron cloud surrounding a positively charged nucleus
   2) a positively charged electron cloud surrounding a negatively charged nucleus
   3) a negatively charged electron cloud surrounding a positively charged nucleus
   4) a negatively charged electron cloud surrounding a negatively charged nucleus

5. Which total mass is the smallest?
   1) the mass of 2 electrons
   2) the mass of 2 neutrons
   3) the mass of 1 electron plus the mass of 1 proton
   4) the mass of 1 neutron plus the mass of 1 electron

6. Which statement concerning elements is true?
   1) Different elements must have different numbers of isotopes.
   2) Different elements must have different numbers of neutrons.
   3) All atoms of a given element must have the same mass number.
   4) All atoms of a given element must have the same atomic number.

7. Which value of an element is calculated using both the mass and the relative abundance of each of the naturally occurring isotopes of this element?
   1) Atomic number 2) Atomic mass 3) Half-life 4) Molar volume

8. Which sequence represents a correct order of historical developments leading to the modern model of the atom?
   1) Atom is a hard sphere --> atom is mostly empty space --> electrons exist in orbital outside the nucleus
   2) Atom is a hard sphere --> electrons exist in orbital outside the nucleus --> atom is mostly empty space
   3) Atom is mostly empty space --> the atom is a hard sphere --> electrons exist in orbital outside the nucleus
   4) Atom is empty space --> electrons exist in orbital outside the nucleus --> the atom is a hard sphere

9. An atom is electrically neutral because the
   1) number of protons equals the number of electrons
   2) number of protons equals the number of neutrons
   3) ratio of the number of neutrons to the number of electrons is 1:1
   4) ratio of the number of neutrons to the number of protons is 2:1

10. How do the energy and the most probable location of an electron in the third shell of an atom compare to the energy and the most probable location of an electron in the first shell of the same atom?
   1) In the third shell, an electron has more energy and is closer to the nucleus.
   2) In the third shell, an electron has more energy and is farther from the nucleus.
   3) In the third shell, an electron has less energy and is closer to the nucleus.
   4) In the third shell, an electron has less energy and is farther from the nucleus.

11. During a flame test, ions of a specific metal are heated in the flame of a gas burner. A characteristic color of light is emitted by these ions in the flame when the electrons
   1) gain energy as they return to lower energy levels
   2) gain energy as they move to higher energy levels
   3) emit energy as they return to lower energy levels
   4) emit energy as they move to higher energy levels

Day 3: Atomic Structure - Multiple Choices

12. A particle of an atom contains 26 protons, 23 electrons, and 56 neutrons. What will be the correct atomic number for this particle?
    1) 26 2) 23 3) 56 4) 33

13. An atom with 21 neutrons and 40 nucleons has
    1) A nuclear charge of +19
    2) A nuclear charge of +40
    3) A mass number of 61
    4) A mass number of 19

14. Which element could have a mass number of 86 atomic mass unit and 49 neutrons in its nucleus?
    1) In 2) Rb 3) Rn 4) Au

15. Which pair of atoms are isotopes of the same element X?

    1) $^{226}_{91}X$ and $^{226}_{91}X$ 2) $^{226}_{91}X$ and $^{227}_{91}X$ 3) $^{227}_{91}X$ and $^{227}_{90}X$ 4) $^{226}_{90}X$ and $^{227}_{91}X$

16. Which atom is an isotope of Oxygen?

    1) $^{14}_{7}N$ 2) $^{16}_{8}N$ 3) $^{14}_{7}O$ 4) $^{17}_{8}O$

17. What is the total number of nucleons in the nuclide $^{65}_{30}Zn$?

    1) 65 2) 30 3) 35 4) 95

18. In which pair of atoms do the nuclei contain the same number of neutrons?
    1) Calcium-40 and Calcium-42
    2) Chlorine-35 and Sulfur- 34
    3) Bromine – 83 and Krypton - 83
    4) Iodine – 127 and Bromine – 80

19. Which is a ground state electron configuration of an atom in the fourth electron shell?
    1) 2 – 8 – 4 2) 2 – 8 – 18 – 4 3) 2 – 8 – 18 – 18 – 4 4) 2 – 4

20. The total number of electrons found in the configuration of a neutral chromium atom is
    1) 24 2)6 3)13 4) 52

21. The highest amount of energy will be emitted by an electron when it moves from
    1) 4^{th} to 1^{st} electron shell
    2) 1^{st} to 4^{th} electron shell
    3) 1^{st} to 5^{th} electron shell
    4) 5^{th} to 4^{th} electron shell

22. What is the total number of electrons in a Cr^{3+} ion?
    1) 3 2) 21 3) 24 4) 27

23. Which symbol represents a particle with a total of 10 electrons?
    1) N 2) Al 3) N^{3+} 4) Al^{3+}

24. Which electron configuration represents an atom of aluminum in an excited state?
    1) 2-7-4 2) 2-8-3 3) 2-7-7 4) 2-8-6

25. Element X has two isotopes. If 72.0% of the element has an isotopic mass of 84.9 amu, and 28.0% of the element has an isotopic mass of 87.0 amu, the average atomic mass of element X is numerically equal to

    1) $(72.0 + 84.9) \times (28.0 + 87.0)$

    2) $(72.0 - 84.9) \times (28.0 + 87.0)$

    3) $\frac{(72.0 \times 84.9)}{100} + \frac{(28.0 \times 87.0)}{100}$

    4) $\frac{(72.0 \times 84.9)}{100} - \frac{(28.0 \times 87.0)}{100}$

26. the diagram below represents the nucleus of an atom

What are the atomic number and mass number of this atom?

1) The atomic number is 9 and the mass number is 19.

2) The atomic number is 9 and the mass number is 20.

3) The atomic number is 11 and the mass number is 19.

4) The atomic number is 11 and the mass number is 20.

Day 3: Atomic Structure – Constructed Responses

Base your answers to questions 27 through 29 on the information below.

In the modern model of the atom, each atom is composed of three major subatomic (or fundamental) particles.

Write your answers here.

27. Name the subatomic particles contained in the nucleus. 27.

28. State the charge associated with each type of subatomic particle contained in the nucleus of the atom. 28.

29. What is the sign of the net charge of the nucleus? 29.

Base your answers to questions 30 through 32 on the data table below, which shows three isotopes of neon.

Isotope	Atomic Mass (atomic mass units)	Percent Natural Abundance
^{20}Ne	19.99	90.9 %
^{21}Ne	20.99	0.3 %
^{22}Ne	21.99	8.8 %

Write your answers here.

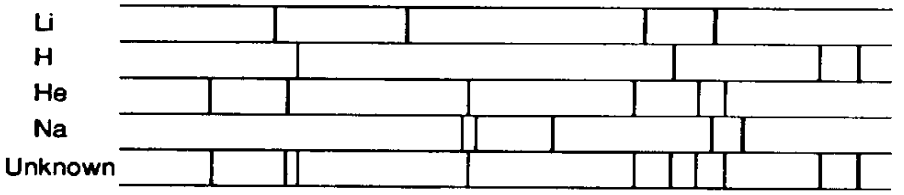
30. Based on the atomic mass and the natural abundances shown in the data table show a correct numerical set-up for calculating the average atomic mass of neon. 30.

31. Based on natural abundances, the average atomic mass of neon is closest to which whole number? 31.

32. In terms of atomic particles, state one difference between these three isotopes of neon. 32.

Day 3: Atomic Structure – Constructed Responses

Base your answers to questions 33 and 34 on the diagram below, which shows bright-line spectra of selected elements.

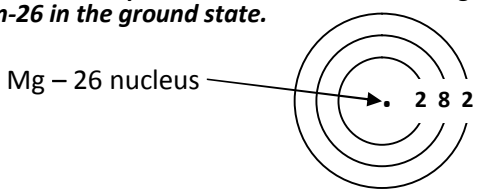


Write your answers here.

33. Explain, in terms of excited state, energy transition, and ground state, how a bright-line spectrum is produced. 33.

34. Identify the two elements in the unknown spectrum. 34.

Base your answers to questions 35 and 36 on the diagram below, which represents an atom of magnesium-26 in the ground state.



Write your answers here.

35. Write an appropriate number of electrons in each shell to represent a Mg – 26 atom in an excited state. Your answer may include additional shells. 35.

36. What is the total number of valance electrons in an atom of Mg-26 in the ground state. 36.

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