Surviving Chemistry

Guided Study Book

High School Chemistry

2015 Revision

with

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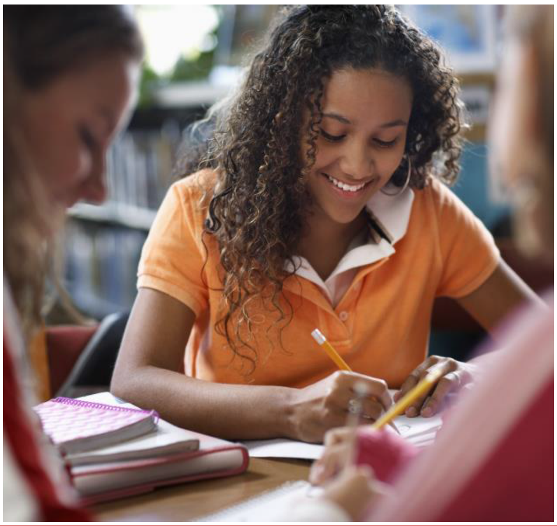

Surviving Chemistry Books

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Surviving Chemistry

Guided Study Book

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Topic Outline

In this topic you will learn about these concepts:

- Types of Matter and their Characteristics
- Phases of Matter and their Characteristics
- Phase Changes and Energy
- Phase Change Diagrams
- 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 other words, 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.
- *cannot* 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

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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
- *can be* decomposed into simpler substances by chemical methods
- has the same unique set of properties in all samples

Note: Properties of a compound are different from those of the elements in which it is composed.

Law of definite composition states that compounds contain two or more different atoms combined in a fixed ratio by mass. For an example:
The mass ratio in a 9 gram sample of water, H_2O, is 8 g of O to 1 g H.
The percent of H and O by mass in water is always 88.9 % O to 11.1 % H.
These ratio and percentages remain the same in all samples of water.

Examples of Compounds

$H_2O(\ell)$	(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 $KCl(aq)$
2) $CO(aq)$ and $CO_2(g)$
3) $Co(s)$ and $CaCl_2(s)$
4) $LiBr(s)$ and $CCl_4(\ell)$

Practice 6

Which change 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 the properties of the individual 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) $Cl_2(g)$
2) $H_2O(\ell)$
3) $MgCl_2(s)$
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

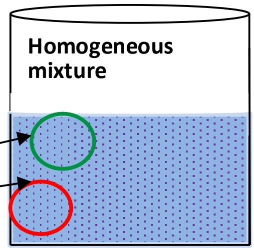
A mixture is classified as homogeneous if it has the following properties:

- 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 an 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.

Examples

NaCl*(aq)* and CO_2*(aq)*



Sample 1 and Sample 2 have the same composition.

Salt solution

Particles of salt and water are evenly and uniformly mixed

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

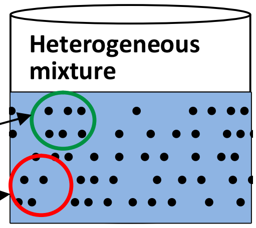
Heterogeneous mixtures

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

Concrete, soil, and salt-in-sand mixture.



Sample 1 and Sample 2 have different compositions.

Particles • and water are NOT uniformly mixed

6 Classification of Matter: Summary Diagram

Matter
(stuff)

→ **Pure Substances**
- Fixed and definite composition

→ **Mixtures**
- Varying composition
- Physical combination of two or more substances
- Can be physically separated

Pure Substances → **Elements**
- Composed of identical atoms
- Cannot be decomposed

Elements → **Metals** (Topic 2), **Nonmetals**, **Metalloids**

Pure Substances → **Compounds**
- Chemical combination of two or more different atoms
- Can be chemically decomposed

Compounds → **Inorganic**, **Organic** (Topic 10)

Mixtures → **Homogeneous**
- Uniformly and evenly mixed

Homogeneous → **Aqueous solution** (Topic 7)

Mixtures → **Heterogeneous**
- Unevenly mixed

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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 the 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.

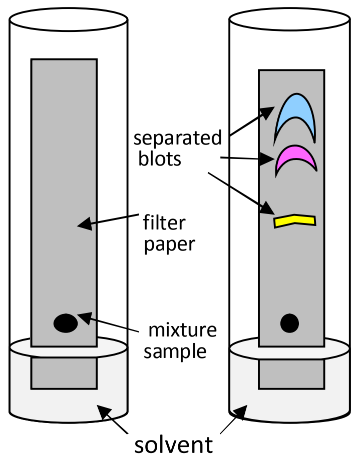
Examples of mixtures that can be separated by distillation include:
- Water and alcohol mixture.
- Crude oil (a mixture of gases; methane, ethane, propane. etc.).
- Salt-water mixture can be separated by boiling off the water and leaving the salt behind.

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 a stationary phase.

In ***gas chromatography,*** a sample of a mixture is placed in an equipment that vaporizes the components of the mixture so they can 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 the 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 used to identify the different components of the mixture. Pigment or ink separation is often done by paper chromatography.

Paper chromatography set up



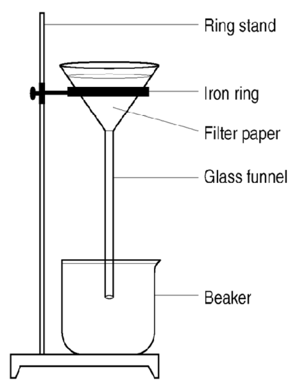
Separation of Heterogeneous Mixtures.

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 mix well or evenly) are often separated by decantation. A mixture of water and oil can be separated by this method.

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 an 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 saltwater and sand can be separated using a filtration process. The aqueous components (salt and water) will go through the filter paper because molecules of water and particles of salt are smaller than the holes of a filter. The sand component of the mixture will stay on the filter because sand particles are generally larger than the holes of a filter paper.

A filtration setup



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 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 atoms 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 a(n)
1) compound 2) mixture 3) element 4) solution

Practice 14
When $NaNO_3(s)$ 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 compound
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 a(n)
1) compound 2) substance 3) element 4) 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.

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9. Diagram Representations of Matter

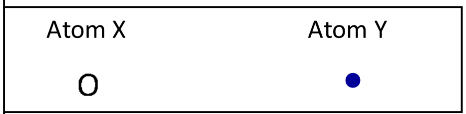
Diagrams can be used to show compositions of elements, compounds and mixtures

Examples are given below.

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

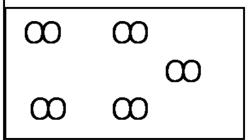
Examples

Given the following symbols:

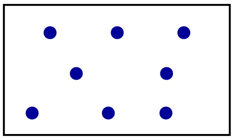


Elements

The diagrams below represent elements because the composition in each diagram consists of identical atoms.



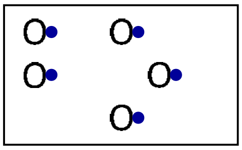
A diatomic element X



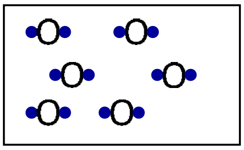
A monatomic element Y

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.



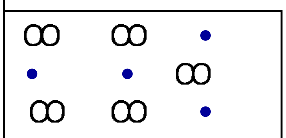
A compound composed of one atom X and one atom Y (Five identical units of O•)



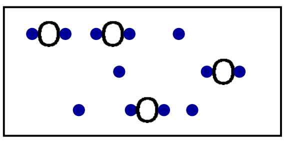
A compound composed of two Y atoms and one X atom (Six identical units of •O•)

Mixtures

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

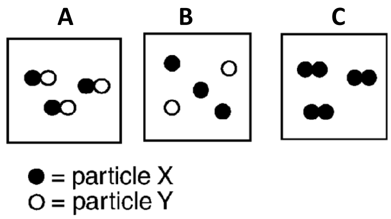


A mixture of diatomic element X and monatomic element Y



A mixture of compound XY and element Y.

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



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 composed of physically combined substances.

2) It is a mixture composed of chemically combined substances.

3) It is a compound composed of physically combined substances.

4) It is a compound composed of chemically combined substances.

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

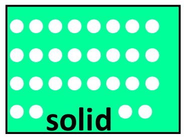
Most substances can change from one phase to another. The type of a substance also determines the conditions (temperature and/or pressure) that it will change from one phase to another.

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.
The diagrams show particle arrangements of water in the three phases.

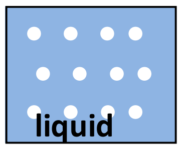
Solid*(s)*: A substance in the solid phase has the following characteristics:
- Definite volume and definite shape
- Particles arranged orderly in a *regular geometric pattern*
- Particles vibrating around a fixed point
- Particles with strong attractive forces to one another
- Particles that cannot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



$H_2O(s)$

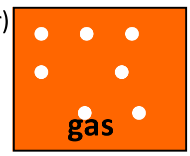
Orderly and regular geometric arrangement of particles in **solid** phase

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 other
- Particles that cannot be easily compressed (incompressible)



$H_2O(\ell)$

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 forces to each other
- Particles that can be easily compressed (compressible)



$H_2O(g)$

11. Phases of Matter: Practice Problems

Practice 23
In which phase does a substance has 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) $CCl_4(\ell)$
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

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12. Phase Changes

During a phase change a substance changes its form (or state) without changing its chemical compositions. 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.

Phase changes and example equations representing each change are given below.

Fusion (also known as melting) is a change from *solid* to *liquid.* $H_2O(s) \rightarrow H_2O(\ell)$

Freezing is a change of phase from liquid to *solid* $H_2O(\ell) \rightarrow H_2O(s)$

Evaporation is a change of phase from *liquid* to *gas* $C_2H_5OH(\ell) \rightarrow C_2H_5OH(g)$

Condensation is a change of phase from *gas* to *liquid* $C_2H_5OH(g) \rightarrow C_2H_5OH(\ell)$

Deposition is a change of phase from *gas* to *solid* $CO_2(g) \rightarrow CO_2(s)$

Sublimation is a change of phase from *solid* to *gas* $CO_2(s) \rightarrow CO_2(g)$

NOTE: **$CO_2(s)$**, carbon dioxide *solid* (dry ice), and **$I_2(s)$,** iodine *solid*, are two chemical 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 has 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.

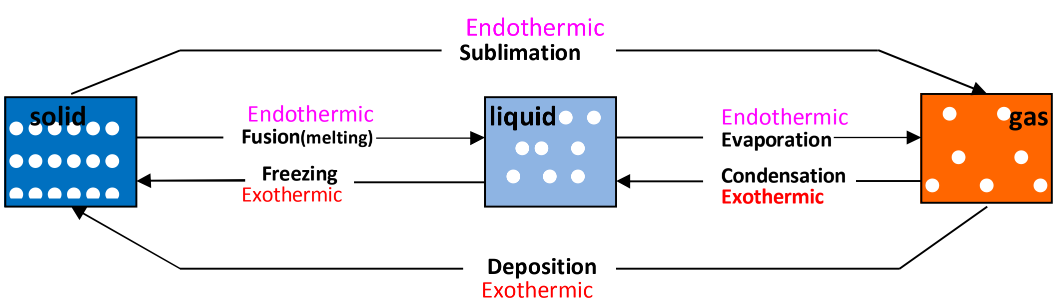
Endothermic describes a process that absorbs heat.

Fusion, evaporation and sublimation are endothermic phase changes.

Exothermic describes a process that releases heat.

Freezing, condensation and deposition are exothermic phase changes.

A summary diagram of the phase changes and energy is shown below.



14. Phase Change and Energy: Practice Problems

Practice 27
Which phase change equation is exothermic?
1) $N_2(\ell) \rightarrow N_2(g)$
2) $Hg(s) \rightarrow Hg(\ell)$
3) $CH_4(g) \rightarrow CH_4(\ell)$
4) $I_2(s) \rightarrow I_2(g)$

Practice 28
Which equation is showing the sublimation of iodine?
1) $I_2(g) \rightarrow I_2(s)$
2) $I_2(s) \rightarrow I_2(g)$
3) $I_2(s) \rightarrow I_2(\ell)$
4) $I_2(g) \rightarrow I_2(\ell)$

Practice 29
$NH_3(g) \rightarrow NH_3(s)$
The change represented above is
1) sublimation
2) evaporation
3) condensation
4) deposition

Practice 30
Heat will be absorbed by a substance when 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 the liquid state to the 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 a substance.

Kinetic energy is the energy due to the movement 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

A **thermometer** is an equipment for measuring temperature.
Degree Celsius (°C) and Kelvin (K) are the two most common units for measuring temperature. The mathematical relationship between Celsius and Kelvin is given by the equation:

$$K = {}^{o}C + 273$$

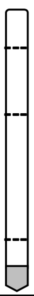
See Reference Table T

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, 273 K)* and the *boiling point (100°C, 373 K)* 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 are scaled and marked between the two points.

Important temperature points at normal pressure

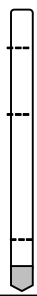
Celsius (°C) **(K) Kelvin**

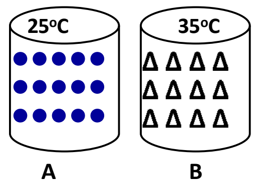


100 **Boiling or condensation point of water** **373**
Also known as *water-steam equilibrium*

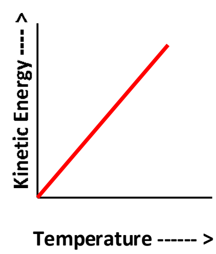
0 **Freezing or melting point of water** **273**
Also known as *Ice-liquid equilibrium*

- 273 **Absolute Zero** **0**
The temperature at which all molecules stop moving.





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 the direct relationship between temperature and kinetic energy.

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16. Temperature Conversion: Practice Problems

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

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 contains particles with the highest average kinetic energy?
1) $NO(g)$ at 40°C
2) $NO_2(g)$ at 45°C
3) $N_2O(g)$ at 30°C
4) $N_2O_3(g)$ at 35°C

Practice 38
Which water sample has molecules with the lowest average kinetic energy?

1) 2) 3) 4)

Practice 39
Which change in temperature is accompanied by the greatest increase in the 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.

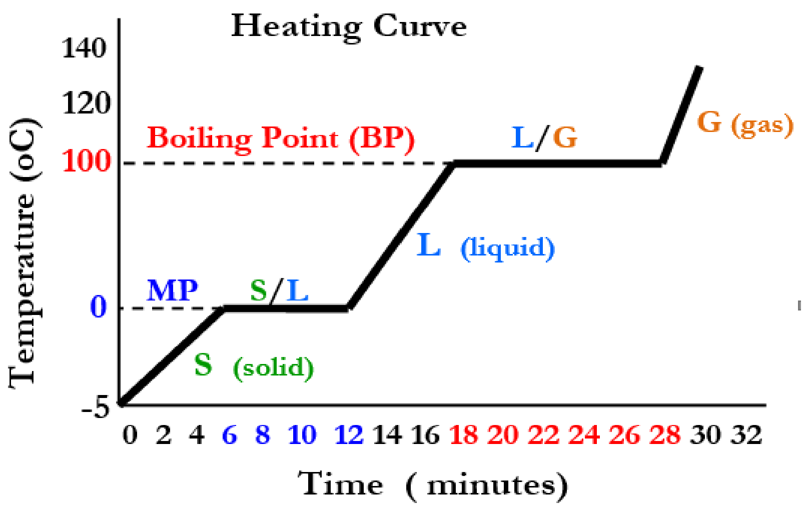
The two phase diagrams are the heating and cooling curves.

Heating curve:

- Shows changes of a substance starting with the substance in a more organized state (ex. from solid)
- Shows temperature changes 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)



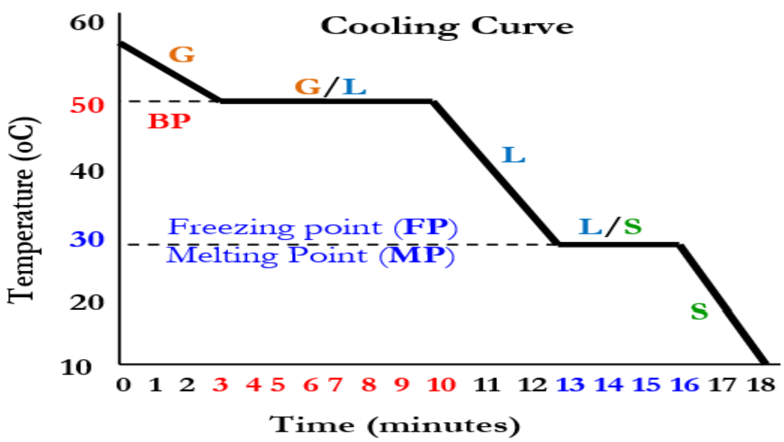
During segments S, L and G.

- One phase is present
- Temperature increases
- Kinetic energy increases
- Potential energy stays the same

During segments S/L and L/G

- Two phases are present
- Temperature stays the same
- Kinetic energy stays the same
- Potential energy increases

The substance represented by this curve is likely water.



During segments G, L and S.

- One phase is present
- Temperature decreases
- Kinetic energy decreases
- Potential energy stays the same

During segments S/L and L/G

- Two phases are present
- Temperature stays the same
- Kinetic energy stays the same
- Potential energy decreases

The substance represented by this curve is not water.

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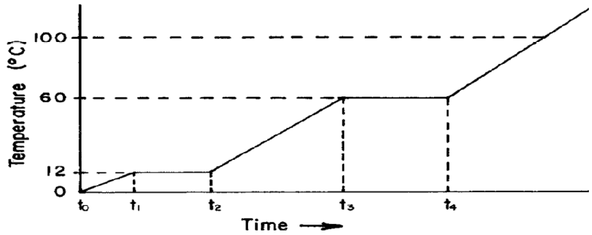
19. Phase Change Diagrams: Practice Problems

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

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.



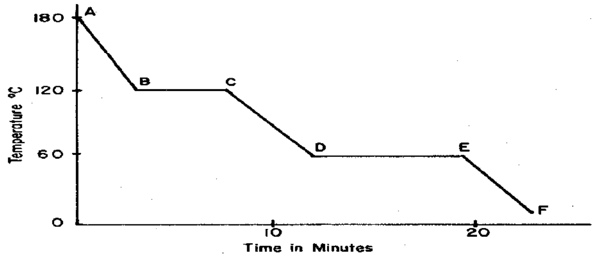
41. What is the melting point of this substance?
1) 0°C 3) 12°C
2) 60°C 4) 100°C

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 a phase change diagram.

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.



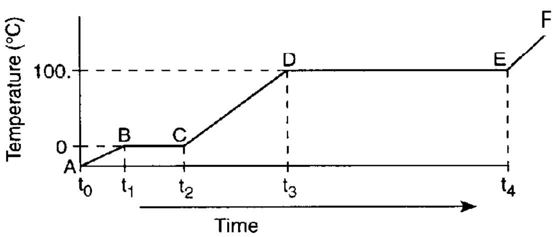
44. The liquid phase of the substance is represented by segment
1) BC 2) DE 3) CD 4) EF

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

Concept Task: Be able to relate energy to a 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 can the heat of fusion be determined?
1) t_0 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.

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

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

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 to 10 minute?
1) The kinetic energy increases and the potential energy remains constant.
2) The kinetic energy decreases and the potential energy remains constant.
3) The kinetic energy remains constant and the potential energy decreases.
4) Both the kinetic energy and the potential energy decrease.

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 the area or object of a higher temperature to the 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. If 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 by the substance.

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

20. Heat

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

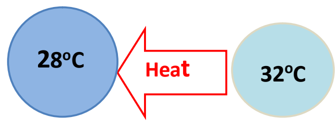
Joules and **calories** are the two most common units for measuring heat.

A **calorimeter** is a device that is used to measure the amount of heat energy involve during a physical and chemical change.

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 (takes in or 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 **low** temperature.*

21. Heat Flow and Temperature: Practice Problems

Concept Task: Be able to determine and describe the 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

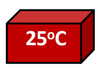
A solid material X is place in liquid Y. Heat will flow from Y to X when the temperature of

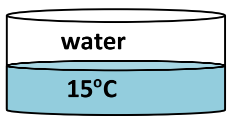
1) Y is 20°C and X is 30°C
2) Y is 10°C and X is 20°C
3) Y is 15°C and X 10°C
4) Y is 30°C and X is 40°C

Practice 53

Given the diagrams

Metal





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

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22. 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 constants one of the factors. The heat equations and heat constants for water are given on the Reference Tables.

Reference Table B
Heat constants for water

Specific Heat Capacity (**C**) of $H_2O(\ell)$	4.18 J/g°K
Heat of fusion (**H_f**)	334 J/g
Heat of Vaporization (**H_v**)	2260 J/g

Reference Table T
Heat Equations

$q = m \bullet \mathbf{C} \bullet \Delta T$

$q = m \bullet \mathbf{H_f}$

$q = m \bullet \mathbf{H_v}$

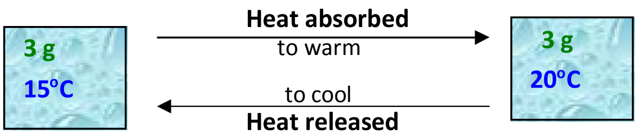
q is heat

m is mass

The notes below explain more about heat constants and equations.

23. 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 ΔT

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:

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

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

The **specific heat capacity (C)** of a substance is the amount of heat needed to change the temperature Of a one-gram sample of a substance by just one Kelvin.

The specific heat capacity (C) for water = 4.18 J/g•K

(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 Kelvin (1 K)
or
A one gram sample of water will absorb or release 4.18 Joules of heat energy to change temperature by just one Kelvin.

In heat equations, the specific heat capacity (C) is the 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 two temperatures.

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

24. 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 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 and liquid states can be calculated using the heat equation below:

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

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

The **heat of fusion (H_f)** of a substance is the amount of heat needed to melt a one-gram sample of a solid at a constant temperature.

The 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 its melting point.

In the equation above, the heat of fusion (H_f) is the 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.

25. 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:

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

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

The **heat of vaporization (H_v)** of a substance is the amount of heat needed to vaporize a one-gram sample of a liquid at a constant temperature.

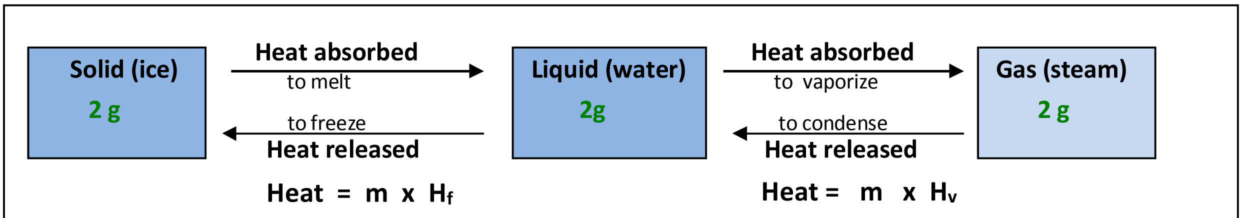
The heat of vaporization for water = 2260 J/g (See Reference Table B)

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 (H_v) is the 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.



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26. 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

Heat = m x C x ΔT

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

Example

How much heat is released by a 3.0-gram sample of water to change its temperature from 15°C to 10.°C ?
Show a numerical setup and the calculated result.

Step 1. Identify all known and unknown factors.

Known:
Mass = 3.0 g
ΔT = 15°C – 10.°C = 5.0°C
C = 4.18 J/g•°C *(for water – see Table B)*

Unknown
Heat = ?

Step 2: Write an equation, setup and solve

Heat = m x C x ΔT
Heat = 3.0 x 4.18 x 5.0 *numerical setup*
Heat = **63 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^{0} 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 a numerical setup and the calculated result.

Heat equation during melting phase change

Heat = m x H_f

Choose this equation if a heat problem 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 a numerical setup and the calculated result

Step 1: Identify all known and unknown factors.

Mass = 6 g
H_f = 334 J/g *(for water; see Table B)*

Heat = ?

Step 2: Write an equation, setup and solve

Heat = m x H_f
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?

`

Heat equation for vaporization phase change

Heat = m x H_v

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 5.00-gram sample of ammonia at its boiling point?

Show a numerical setup and the calculated result.

Step 1: Identify all known and unknown factors.

Mass = 5.00 g Heat = ?

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

Step 2: Write equation, setup and solve

Heat = m x H_v

Heat = 5.00 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 11 grams 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 a numerical setup and the calculated result

27. 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 was the final temperature of the water?

Show a 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 a numerical setup and the calculated result.

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Lesson 4 – Characteristics of Gases

Introduction

Gas behavior is influenced by three key factors: volume (space), pressure and temperature. The relationships between these three factors are the basis for 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 theory, gas laws, and gas law calculations.

28. Kinetic Molecular Theory (KMT) of an Ideal Gas

The **Kinetic Molecular Theory** explains behavior of an ideal gas.

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

Concept Facts: Study to memorize the characteristics below.

Summary of the Kinetic Molecular Theory of an ideal gas.

- A gases is composed of individual particles
- Distances between gas particles are large (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 a gas 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 a real gas. Therefore, real gases deviate from (do not behave exactly like) an ideal gas.

Reasons that a real gas behaves 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 particles are assumed to have no volume)

Gases that behave more like an ideal gas:

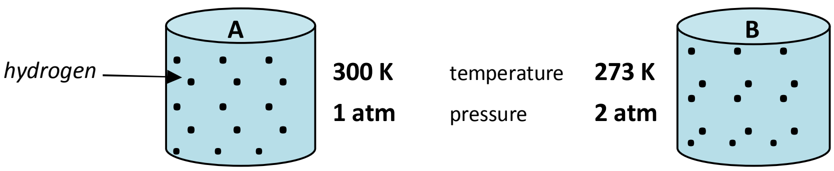
Real gases with small molecular masses behave more like an ideal gas.

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

Temperature and Pressure conditions that real gases behave more like an ideal gas:

Real gases behave more 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 .**

29. 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 an 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

30. 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 in which the gas occupies.

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 its 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 b101.3 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?

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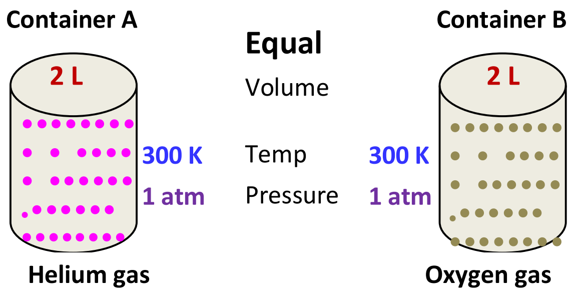
31. Avogadro's Law

Avogadro's Law states: Under the same conditions of temperature and pressure, gases of equal volume 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 helium gas molecules are counted in Container A and oxygen gas molecules are counted in Container B, ***the number of molecules of He in A will be the same as the number of molecules of O_2 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.

32. 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 and 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 the pressure on a gas decreases, volume increases proportionally. If pressure on a gas is halved, volume of the gas will double.
- As the pressure on a gas increases, volume decreases by the same factor. If pressure on a gas is doubled, volume of the gas will be half.

(see diagrams 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.

$$P_1 V_1 = P_2 V_2$$

P_1 = Initial pressure (atm or kPa)

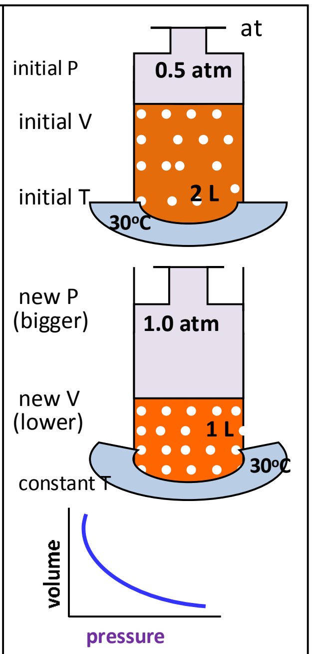
P_2 = New pressure (atm of kPa)

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 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.

33. Boyle's Law: Example and Practice Problems

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

Example

At constant temperature, what is the new volume of a 3.0 L sample of oxygen gas if its pressure is changed from 0.50 atm to 0.25 atm?

Show a numerical setup and the calculated result.

Step 1: Identify all known and unknown factors

V_1 = 3.0 L V_2 = ? (unknown)

P_1 = 0.50 atm P_2 = 0.25 atm

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

$$P_1 V_1 = P_2 V_2$$

$$(0.50)(3.0) = (0.25)(V_2)$$

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

numerical setup

$$6\ L = V_2$$

calculated result

Practice 81

The volume of 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 sample of 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 a numerical setup and the calculated result.

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34. Charles' Law: Volume – Temperature Relationship at Constant Pressure

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

Concept Facts: Study and remember the following relationships.

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

This fact can be expressed a few different ways:

- As temperature of a gas increases, volume increases proportionally. If temperature of a gas is doubled, volume will also double
- As temperature of a gas decreases, volume decreases by the same factor. If temperature of a gas is halved, volume will also be halved

(see diagrams 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)

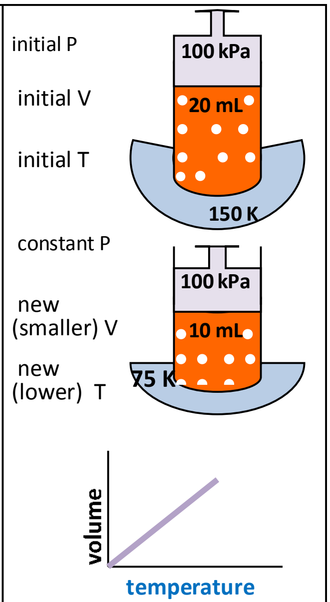
V_2 = New volume (mL or L)

T_1 = Initial Kelvin temperature (K)

T_2 = New Kelvin temperature (K)

According to Charles' law:

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



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

35. 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 a 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 the equation, setup, and solve

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

numerical setup

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

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

calculated result

840 K = T_2

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
2) 150. mL
3) 300. 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 a numerical setup and the calculated result.

36. Gay-Lussac's Law: Pressure – Temperature Relationship at Constant Volume

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

Concept Facts: Study and remember the following facts:

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

This fact can be expressed a few different ways:

- As temperature of a gas decreases, pressure decreases
  If temperature of a gas is halved, pressure will also be halved

- As temperature of a gas decreases, pressure increases
  If temperature of a gas is doubled, pressure of the gas will also double.

(See diagrams to the right)

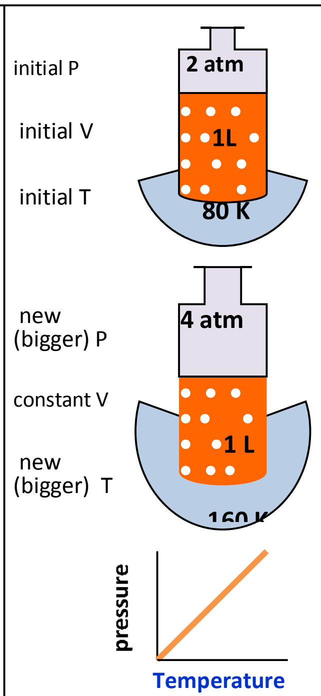
Gay-Lussac's law equation below can be used to calculate the new pressure of a gas when temperature of the gas is changed at constant volume.

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

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



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

37. 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 a 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 the 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
2) 0.1 atm
3) 0.8atm
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 a setup and the calculated result.

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38. 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 of the above gas law problems.

39. 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 a numerical setup and the calculated result.

Step 1: Identify all known and unknown factors

STP { V_1 = 100 mL, P_1 = 1 atm, T_1 = 273 K

V_2 = ? (unknown), P_2 = 0.5 atm, T_2 = 546 K

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

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

numerical setup

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

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

calculated result

400 mL = V_2

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

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

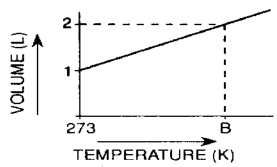
Practice 90

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 sets of characteristics that can be used to identify and classify matter. Two types of properties of matter are physical and chemical properties.
In this lesson, you will learn the differences between physical and chemical properties as well as the differences between physical and chemical changes of matter.

40. 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.*

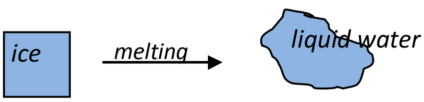
Intensive properties do not depend on sample size or amount. Melting, freezing and boiling points, density, solubility, color, odor, conductivity, luster, and hardness are *intensive properties.*

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

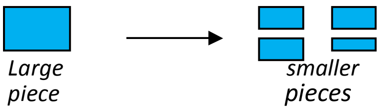
A **physical change** is a change of a substance from one form to another without changing its chemical composition.

Examples:

Phase change



Size change



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.

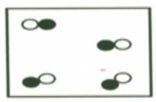
Practice 92
Which best describes a chemical property of sodium?
1) It is a shiny metal
2) It is smooth
3) It reacts vigorously with water
4) It is a hard solid

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

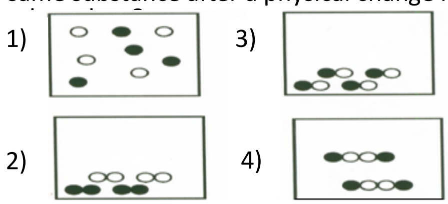
Practice 94
An example of a physical property of an element is the element's ability to
1) Form a compound
2) React with oxygen
3) React with an acid
4) Form an aqueous solution

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



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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 symbols for elements, compounds, and mixtures
2. Recognizing diagram representations for elements, compounds, and mixtures
3. Recognizing symbol representations for substances in different phases
4. Recognizing phase change equations
5. Determining substances with the 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 about these 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:

There are more than 100 known elements. Most of the elements are naturally occurring, while a few are artificially produced. The modern periodic table contains all known elements. These elements are arranged on the periodic table in order of *increasing atomic number.* Many important atomic structure information about each element can be found on the periodic table.

In this lesson you will learn about the arrangement of the elements on the periodic table.

1. Properties of the Modern Periodic Table

Concept Facts: Study to remember the following information about the periodic table.

- Elements are arranged in order of increasing atomic number
- Chemical properties of the elements are periodic functions of their atomic numbers
- 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)
- The majority of the elements exist as solids at room temperature
- Only two (mercury, Hg, and bromine, Br,) are liquids at room temperature
- Element symbol can be one (O), two (Na), or three (Uub) letters. The first letter is always a capital letter. The second and third letters are always lowercases.

The following information can be found in the box for each element on the Periodic Table.

O		Au
15.999	**Atomic mass**	196.967
-2	Selected oxidation states (charges)	+1 +2
O	**Element's symbol**	Au
8	**Atomic number**	**79**
2 – 6	Electron configuration	2 – 8 – 18 -32 -18 - 1

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

LOOKing Ahead ⇨ Topic 3 - Atomic Structure. You will learn to relate information on the periodic table to atomic structure.

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2. Groups and Periods

Elements on the periodic table are placed in groups and periods. Every element has a group number and a period number. For an example: Phosphorus (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 valence electrons and similar chemical properties
- There are eighteen (18) groups on the Periodic Table of the Elements

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 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

The **Periodic Law** states**:** Properties of the elements are periodic functions of their atomic numbers. In other words, arranging the elements in order of increasing atomic number allows elements with similar chemical properties to be 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 3) Atomic number
2) Phase 4) Atomic mass

Practice 2
The Periodic Table of the Elements contains elements that are
1) solids only 3) liquids and gases only
2) solid and liquids 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 3) Atomic mass
2) Oxidation state 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 3) Oxidation state
2) Valence electrons 4) Chemical properties

Practice 5
Majority of the elements on the Periodic Table are
1) Metals 3) Metalloids
2) Nonmetals 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 3) N, P and As
2) Be, N, O 4) Ba, Sr and Ca

Practice 8
Which two elements have the same number of occupied electron shells?
1) Mg and Be 3) Mg and O
2) Mg and Al 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 valence 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 main types of elements: metal, nonmetals, and metalloids.

Elements of one type have set of physical and chemical properties that are used to distinguish them from elements of the other types.

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

4. Types of Elements

Location of metals, metalloids, and nonmetals

metals | metalloids | nonmetals

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Ti	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Uuq	Uup	Uuh	Uus	Uuo
			La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Y b	Lu
			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

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 to remember these properties.

Malleable describes a solid that is easily hammered and flattened into a thin sheet. (Ex. Aluminum, Al)

Ductile describes a solid that is easily drawn into a thin wire. (Ex. Copper, Cu)

Brittle describes a solid that is easily broken or shattered into pieces when struck. (Ex. Sulfur, S)

Luster describes the shininess of a substance. (Ex. Gold, Au)

Conductivity describes the ability of heat or electricity to flow through a substance. (Ex. Copper, Cu)

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

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

Density describes the mass to volume ratio of an element.

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

See Table S

Ionic radius describes the size of the element after it has lost or gained electrons to become an ion.

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

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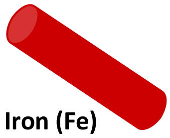
6. Metals

Metallic elements are located to the left of the periodic table**.**

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

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

Below are some general properties (characteristics) of metals.



Iron (Fe)

Concept Facts: Study to remember these properties.

- Almost all metals are solids at room temperature. The exception is mercury (Hg), which is a liquid metal.
- Solid metals are malleable and ductile. Many have high luster.
- Metals tend to have high heat (thermal) and electrical conductivity due to their *mobile valence 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 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 (+) ion is always smaller than the size of the neutral atom

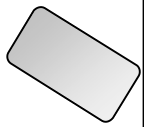
7. Metalloids

Metalloids are the seven elements located between the metals and 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 room temperature.



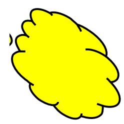
Tellurium (Te)

8. Nonmetals

Nonmetallic elements are located to the right of the periodic table.

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

Below are some general properties (characteristics) of nonmetals.



Sulfur (S)

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 or poor electrical and heat (thermal) conductivity
- Nonmetals tend to have high electronegativity values (because they attract and gain electrons easily)
- Nonmetals tend to have high ionization energy (which is why nonmetals do not lose electrons easily)
- Nonmetals gain electrons and form negative ions
- Radius of a nonmetal atom increases as it gains electrons and forms a negative ion
- The size of a negative (-) ion is always bigger than that of the neutral atom

9. Types of Elements: Summary of Properties

	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 the atom
Nonmetals	Solid Liquid Gas	Brittle Dull	Low	High	High	Gain electrons	- (negative)	Bigger than the atom
Metalloids	Solid only	Properties of metals and nonmetals	Low	varies	varies	Lose electrons	+ (positive)	Smaller than the atom

10. Types of Elements: Practice Problems

Practice 10
Elements that can be hammered into thin sheets are
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) Phosphorus
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 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) Phosphorus
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

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Lesson 3 – Group 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 valence electrons.

In this lesson you will learn properties that are shared by elements in each group.

11. The Periodic Table of the Elements

- Alkali metals (1)
- Alkaline earth metals (2)
- Transition metals (3-12)
- Halogens (17)
- Noble gases (18)
- Metals
- Metalloid elements
- Nonmetals

Group

	1	2	3	4	5	6	7	8	9
Period 1	1.007 +1 H 1 1								
Period 2	6.941 +1 Li 3 2-1	9.012 +2 Be 4 2-2							
Period 3	22.989 +1 Na 11 2-8-1	24.305 +2 Mg 12 2-8-2							
Period 4	39.09 +1 K 19 2-8-8-1	40.08 +2 Ca 20 2-8-8-2	44.9559 +3 Sc 21 2-8-9-2	47.88 +2 +3 +4 Ti 22 2-8-10-2	50.9414 +2 +3 +4 +5 V 23 2-8-11-2	51.996 +2 +3 +6 Cr 24 2-8-13-1	54.938 +2 +3 +4 +7 Mn 25 2-8-13-2	55.847 +2 +3 Fe 26 2-8-14-2	58.933 +2 +3 Co 27 2-8-15-2
Period 5	85.468 +1 Rb 37 2-8-18-8-1	87.62 +2 Sr 38 2-8-18-8-2	88.905 +3 Y 39 2-8-18-9-2	91.224 +4 Zr 40 2-8-18-10-2	92.906 +3 +5 Nb 41 2-8-18-12-1	95.94 +3 +6 Mo 42 2-8-18-13-1	(98) +3 +6 +7 Tc 43 2-8-18-14-1	101.07 +3 Ru 44 2-8-18-15-1	102.906 +3 Rh 45 2-8-18-16-1
Period 6	132.91 +1 Cs 55 2-8-18-18-8-1	137.33 +2 Ba 56 2-8-18-18-8-2	138.906 +3 La 57 -18-18-9-2	178.49 +4 Hf 72 -18-32-10-2	180.948 +5 Ta 73 -18-32-11-2	183.85 +6 W 74 -18-32-12-2	183.85 +4 +6 +7 Re 75 -18-32-13-2	190.2 +3 +4 Os 76 -18-32-14-2	192.22 +3 +4 Ir 77 -18-32-15-2
Period 7	(223) +1 Fr 87 -18-32-18-8-1	226.025 +2 Ra 88 -18-32-18-8-2	227.028 +3 Ac 89 -18-32-18-9-2	(261) Rf 104	(262) Db 105	(262) Sg 106	(272) Bh 107	(277) Hs 108	(276) Mt 109

Rare Earth metals

104.12 +3 Ce 58	140.908 +3 Pr 59	144.24 +3 Nd 60	(145) +3 Pm 61	150.36 +2 +3 Sm 62
232.038 +4 Th 90	231.036 +4 +5 Pa 91	238.029 +3 +4 +5 +6 U 92	237.029 +3 +4 +5 +6 Np 93	(244) +3 +4 +5 +6 Pu 94

Atomic mass	**30.973**	-3 +3 +5 Selected oxidation states
Element's symbol	**P**	
Atomic number	**15**	
Electron configuration	**2 – 8 – 5**	

Period	10	11	12	13	14	15	16	17	18
Period 1									4.002 0 **He** **2** 2
Period 2				10.81 +3 **B** **5** 2-3	12.011 -4 +2 +4 **C** **6** 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 3				26.981 +3 **Al** **13** 2-8-3	28.085 -4 +2 +4 **Si** **14** 2-8-4	30.973 -3 +3 +5 **P** **15** 2-8-5	32.06 -2 +4 +6 **S** **16** 2-8-6	35.453 -1 +1 +3 +5 +7 **Cl** **17** 2-8-7	39.948 0 **Ar** **18** 2-8-8
Period 4	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 +4 **Ge** **32** 2-8-18-4	74.921 -3 +4 **As** **33** 2-8-18-5	78.96 -2 +4 +6 **Se** **34** 2-8-18-6	79.904 -1 +1 +5 **Br** **35** 2-8-18-7	83.80 0 +2 **Kr** **36** 2-8-18-8
Period 5	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 6	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 +5 **Po** **84** -18-32-18-6	(210) +2 +4 **At** **85** -18-32-18-7	(222) 0 **Rn** **86** -18-32-18-8
Period 7	(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**

Series									
Lanthanide Series	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**
Actinide 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**

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12. Group 1: Alkali Metals

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

Properties (characteristics) of alkali metals are listed below.

Concept Facts: Study to remember these properties.

- One valence (outer shell) electron
- Form a positive one (+1) ion by losing one valence electron during bonding
- Very low electronegativity and very low ionization energy values.
- Found in nature in compounds, not as free elements, due to high reactivity
- Obtain 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**)
  - **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 room temperature.

13. Group 2: Alkaline Earth Metals

Alkaline earth metals are the elements in Group 2 of the periodic table.

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

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

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 by losing all two valence 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
  - **M**Y_2 is the general formula of a **Group 2** atom bonding with a Group 17 halogen (**Y**)
  - **M**O 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 room temperature.

14. Groups 3 – 12: Transition Metals

Transition metals are the elements in Groups 3 through 12 of the Periodic Table.
Properties of these elements vary widely. However, some 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 the 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, I_2)
- Each has seven valence electrons
- Very high electronegativity and high ionization energy values
- Form negative one (-1) ion by gaining one electron to fill their valence shells
- F and Cl are obtained from their fused salt (NaF, 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

  M**Y**$_2$ 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 metalloid

Group 17 Halogens	Group 18
F **9**	
Cl **17**	
Br **35**	
I **53**	
At **85**	

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16. Group 18: Noble Gases

Noble gases are the 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) elements (Ne, He, Kr…)
- All are gases are at STP.
- They all have full valence shells with eight electrons. Helium is full with its two electrons.
- They neither gain nor lose electrons because their valence shells are full
- They are very stable and are non-reactive (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)

Group 17	Group 18 Noble gases
	He **2**
	Ne **10**
	Ar **18**
	Kr **36**
	Xe **54**
	Rn **86**

17. Group Properties: **Summary Table**

Group number	*Group name*	*Types of elements in the group*	*Phases (at STP)*	*Valence 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) **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) **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. 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 a(n)

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

practice 25

The element in Group 17 Period 4 is a(n)

1) transition metal
2) halogen
3) alkali metal
4) 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 valence 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 an example 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 radius (size).
Trends in metallic and nonmetallic properties.
Trends in electronegativity and ionization energy.

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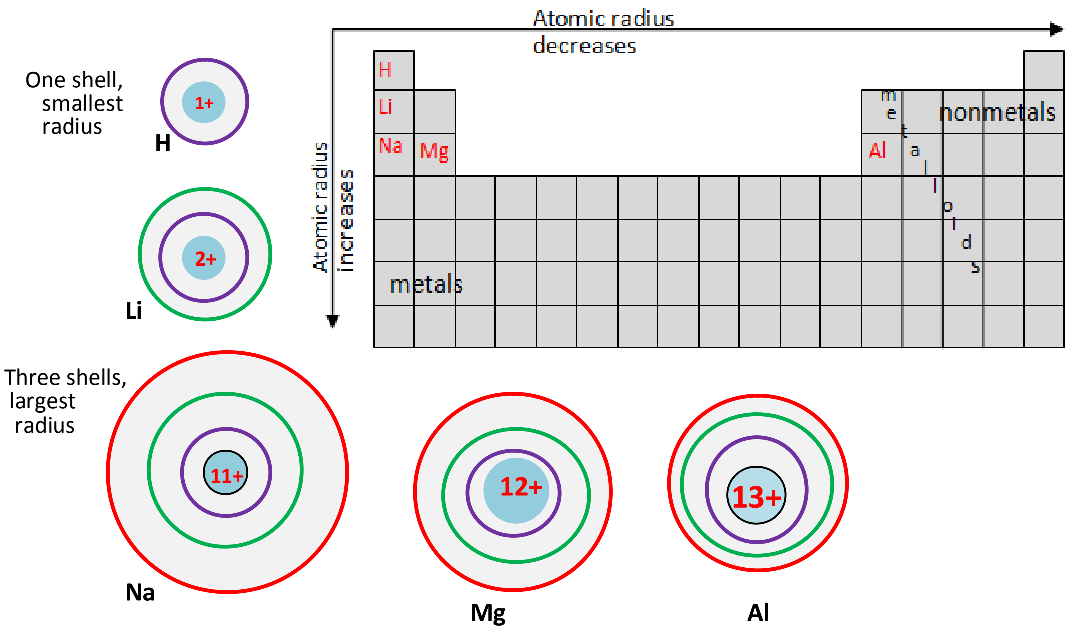
19. Trends in Atomic Size (Atomic Radius)

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.**
Trends in atomic radius that are found on the Periodic Table are as follow:

Concept Facts: Study to remember the following trends.

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

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



Smallest nuclear charge, largest radius (size)

Greatest nuclear charge, smallest radius (size)

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) Phosphorus, because it more electron shells
4) Phosphorus, because it has a smaller nuclear charge

21. Trends in Metallic and Nonmetallic Properties

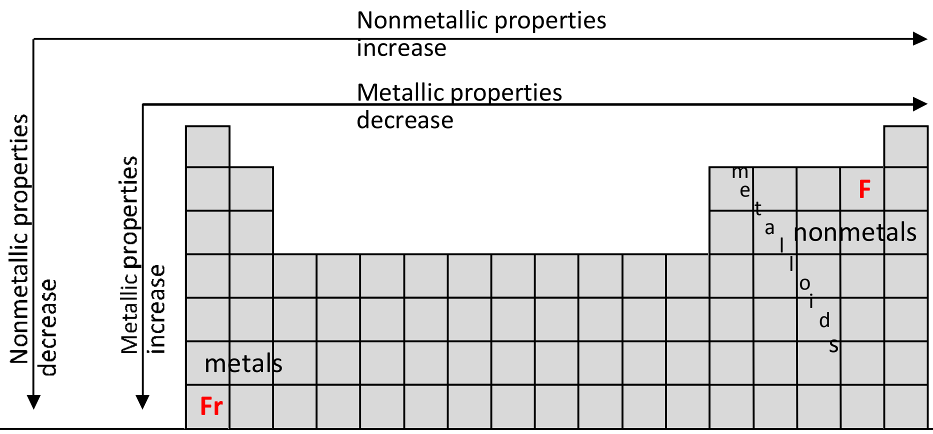
Trends in properties and reactivity vary between metals and nonmetals. The bottom left corner contains the most reactive metals. ***Francium*** is the most reactive of all metals. The top right corner contains the most reactive nonmetals. ***Fluorine*** is the most reactive of all nonmetals.

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

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23. Trends in Electronegativity and Ionization Energy

Electronegativity defines an atom's ability to attract (or gain) electrons from another atom during chemical bonding. The electronegativity value assigned to each element is relative to one another. The higher the electronegativity value, the more likely it is for the atom to attract (or gain) electrons and form a negative ion during bonding.

Fluorine (F) is assigned the highest electronegativity value of 4.0.

Francium (Fr) is assigned the lowest electronegativity value of 0.7.

This means that of all the elements, fluorine has the greatest tendency to attract (or gain) electrons. Francium has the least ability or tendency to attract electrons during bonding.

Ionization energy refers to the amount of energy needed to remove an electron from an atom. The ***first ionization energy*** is the energy to remove the most loosely bound electron from an atom. Ionization energy measures the tendency of (how likely) an atom to lose electrons and form a positive ion. The lower the first ionization energy of an atom, the easier (or the more likely) it is for that atom to lose its most loosely bound valence electron 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 allows them to lose their one valence electron 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 a full valence shell of electrons, a high amount of energy is required to remove any electron from their atoms.

Concept Facts: Study to remember the following trends.

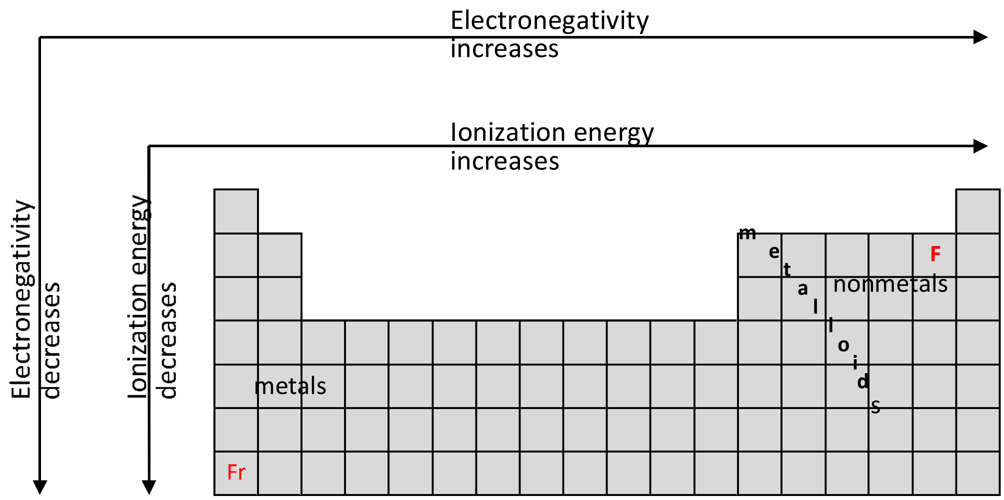
Top to **Bottom** down a **Group**: Electronegativity (tendency to gain or attract electrons) decreases.

Ionization energy (tendency to lose electrons) decreases

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

Ionization energy increases

NOTE: Electronegativity and ionization energy values for the elements are found on the Reference Table



24. Trends in Electronegativity and Ionization Energy: Practice Problems

Concept Task: Be able to determine which 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 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 phosphorus?

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

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

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

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

1) Calcium 3) Indium
2) Nitrogen 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 3) Cs, Na, Li
2) I, Br, Cl 4) C, B, Be

25. Allotropes

Allotropes refer to two or more different molecular forms of the same element in the same 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: Oxygen gas (O_2) and Ozone (O_3) are different molecular forms of oxygen. They have different chemical and different physical properties.

Carbon allotropes: Diamond, graphite, and fullerene are different molecular forms of carbon. They have different chemical and different physical properties.

Phosphorus allotropes: White, Red, and Black are all different forms of element phosphorus. They have different chemical and different physical properties.

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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 Law
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 element's name or symbol to group properties
7. Determining the element with the largest or smallest atomic radius
8. Determining the element that has the most or least metallic properties
9. Determining the element that has the most or least nonmetallic properties
10. Determining the element with the greatest or least tendency to attract electrons
11. Determining the element with the greatest or least tendency to lose electrons

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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 ratios
   4) consist of two or more substances

3. Which correctly describes particles of a substance in the gas phase?
   1) Particles are arranged in a regular geometric pattern and are far apart
   2) Particles are in a fixed rigid position and are close together
   3) Particles move freely in a straight path
   4) Particles 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/ g •°C. 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 ideal gases 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)*

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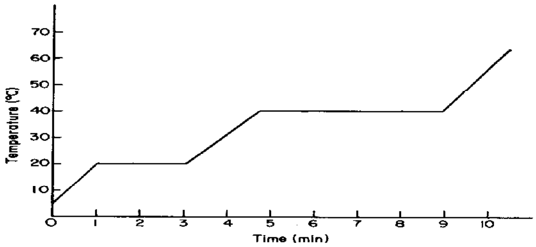
Day 1: Matter and Energy - Multiple Choices

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) does the substance's average kinetic energy remain 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 at 20°C 2) NO_2 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 the 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 J

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 kilopascals?
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) $6 \times \dfrac{3 \times 150}{1 \times 70}$

2) $6 \times \dfrac{3 \times 80}{1 \times 150}$

3) $6 \times \dfrac{3 \times 423}{1 \times 343}$

4) $6 \times \dfrac{3 \times 343}{1 \times 423}$

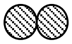
21. Given the balanced particle-diagram equation:

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 Response

Base 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.

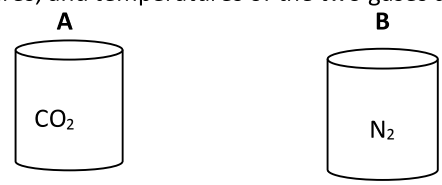
23. Draw a particle model that shows at least six molecules of liquid nitrogen. — 23.

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	B
V = 12.3 L	V = 12.3 L
P = 1.0 atm	P = 1.0 atm
T = 300. K	T = 300. K

Show work and answers here

26. How does the number of molecules of CO_2*(g)* in cylinder A compare 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.

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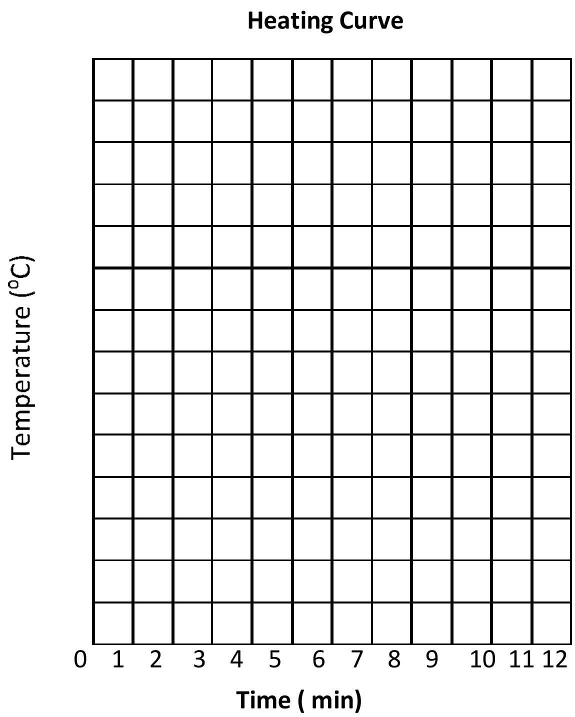
Day 1: Matter and Energy - Constructed Response

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

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 measured by
   1) density 2) ionization energy 3) heat of reaction 4) electronegativity

4. Which term represents the attraction one atom has for the electrons in a bond with another atom?
   1) electronegativity
   2) electrical conductivity
   3) first ionization energy
   4) mechanical energy

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 its phase at STP?
   1) Br is a liquid 2) F is a solid 3) I is a gas 4) Cl is a liquid

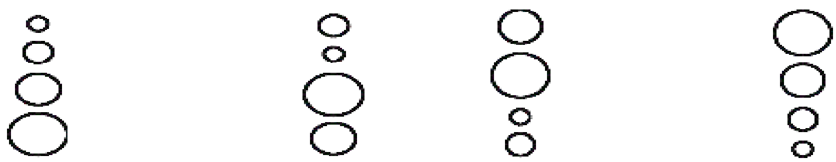
7. As the elements in Group 1 of the Periodic Table are considered in order of increasing atomic number, the atomic radius of each successive element increases. This is primarily due to an increase in the number of
   1) neutrons in the nucleus
   2) unpaired electrons
   3) valence electrons
   4) electron 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 an increase in atomic size
   2) increases due to a decrease in atomic size
   3) decreases due to an increase in atomic size
   4) decreases due to a decrease in atomic size

9. Which set of characteristics is true of elements in Group 2 of the Periodic Table?
   1) They all have two energy levels and have different chemical characteristics
   2) They all have two energy levels and share similar chemical characteristics
   3) They all have two valence electrons and share similar chemical properties
   4) They all have two valence electrons and have 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 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)

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Day 2: The Periodic Table - Multiple Choices

12. Elements strontium and beryllium both form a bond with fluorine with similar chemical formulas. 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 valence 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) phosphorus 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 → Ca → Mg
    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 electrons than phosphorus?
    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 Response

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.

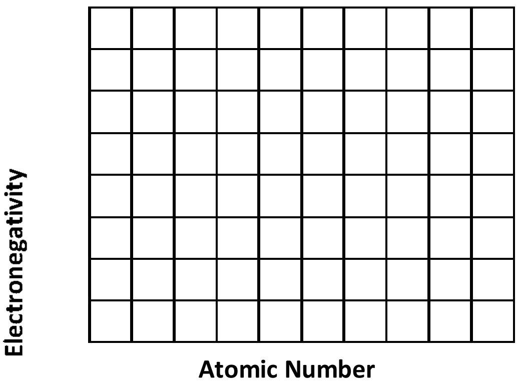
26. What is the phase of element M at STP? 26.

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 and atomic number on the x-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.

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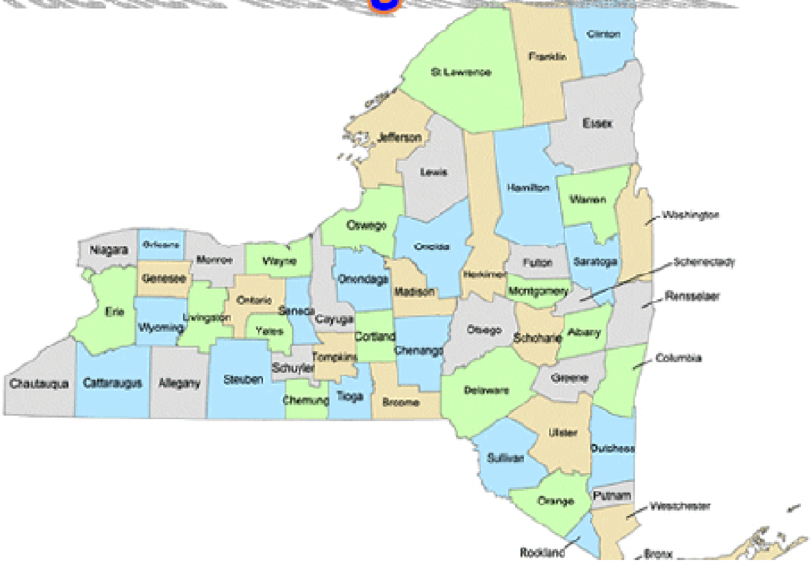
Days 13 through 16

Practice Regents Exams



NYS Chemistry

The Physical Setting

June 2014 and January 2015 Exams

C

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Reference Tables for Physical Setting/CHEMISTRY

2011 Edition

Table A
Standard Temperature and Pressure

Name	Value	Unit
Standard Pressure	101.3 kPa 1 atm	kilopascal atmosphere
Standard Temperature	273 K 0°C	kelvin degree Celsius

Table B
Physical Constants for Water

Heat of Fusion	334 J/g
Heat of Vaporization	2260 J/g
Specific Heat Capacity of $H_2O(\ell)$	4.18 J/g•K

Table C
Selected Prefixes

Factor	Prefix	Symbol
10^{3}	kilo-	k
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	μ
10^{-9}	nano-	n
10^{-12}	pico-	p

Table D
Selected Units

Symbol	Name	Quantity
m	meter	length
g	gram	mass
Pa	pascal	pressure
K	kelvin	temperature
mol	mole	amount of substance
J	joule	energy, work, quantity of heat
s	second	time
min	minute	time
h	hour	time
d	day	time
y	year	time
L	liter	volume
ppm	parts per million	concentration
M	molarity	solution concentration
u	atomic mass unit	atomic mass

Table E
Selected Polyatomic Ions

Formula	Name	Formula	Name
H_3O^+	hydronium	CrO_4^{2-}	chromate
Hg_2^{2+}	mercury(I)	$Cr_2O_7^{2-}$	dichromate
NH_4^+	ammonium	MnO_4^-	permanganate
$C_2H_3O_2^-$ / CH_3COO^-	acetate	NO_2^-	nitrite
CN^-	cyanide	NO_3^-	nitrate
CO_3^{2-}	carbonate	O_2^{2-}	peroxide
HCO_3^-	hydrogen carbonate	OH^-	hydroxide
$C_2O_4^{2-}$	oxalate	PO_4^{3-}	phosphate
ClO^-	hypochlorite	SCN^-	thiocyanate
ClO_2^-	chlorite	SO_3^{2-}	sulfite
ClO_3^-	chlorate	SO_4^{2-}	sulfate
ClO_4^-	perchlorate	HSO_4^-	hydrogen sulfate
		$S_2O_3^{2-}$	thiosulfate

Table F
Solubility Guidelines for Aqueous Solutions

Ions That Form *Soluble* Compounds	Exceptions
Group 1 ions (Li^+, Na^+, etc.)	
ammonium (NH_4^+)	
nitrate (NO_3^-)	
acetate ($C_2H_3O_2^-$ or CH_3COO^-)	
hydrogen carbonate (HCO_3^-)	
chlorate (ClO_3^-)	
halides (Cl^-, Br^-, I^-)	when combined with Ag^+, Pb^{2+}, or Hg_2^{2+}
sulfates (SO_4^{2-})	when combined with Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, or Pb^{2+}

Ions That Form *Insoluble* Compounds*	Exceptions
carbonate (CO_3^{2-})	when combined with Group 1 ions or ammonium (NH_4^+)
chromate (CrO_4^{2-})	when combined with Group 1 ions, Ca^{2+}, Mg^{2+}, or ammonium (NH_4^+)
phosphate (PO_4^{3-})	when combined with Group 1 ions or ammonium (NH_4^+)
sulfide (S^{2-})	when combined with Group 1 ions or ammonium (NH_4^+)
hydroxide (OH^-)	when combined with Group 1 ions, Ca^{2+}, Ba^{2+}, Sr^{2+}, or ammonium (NH_4^+)

*compounds having very low solubility in H_2O

Table G
Solubility Curves at Standard Pressure

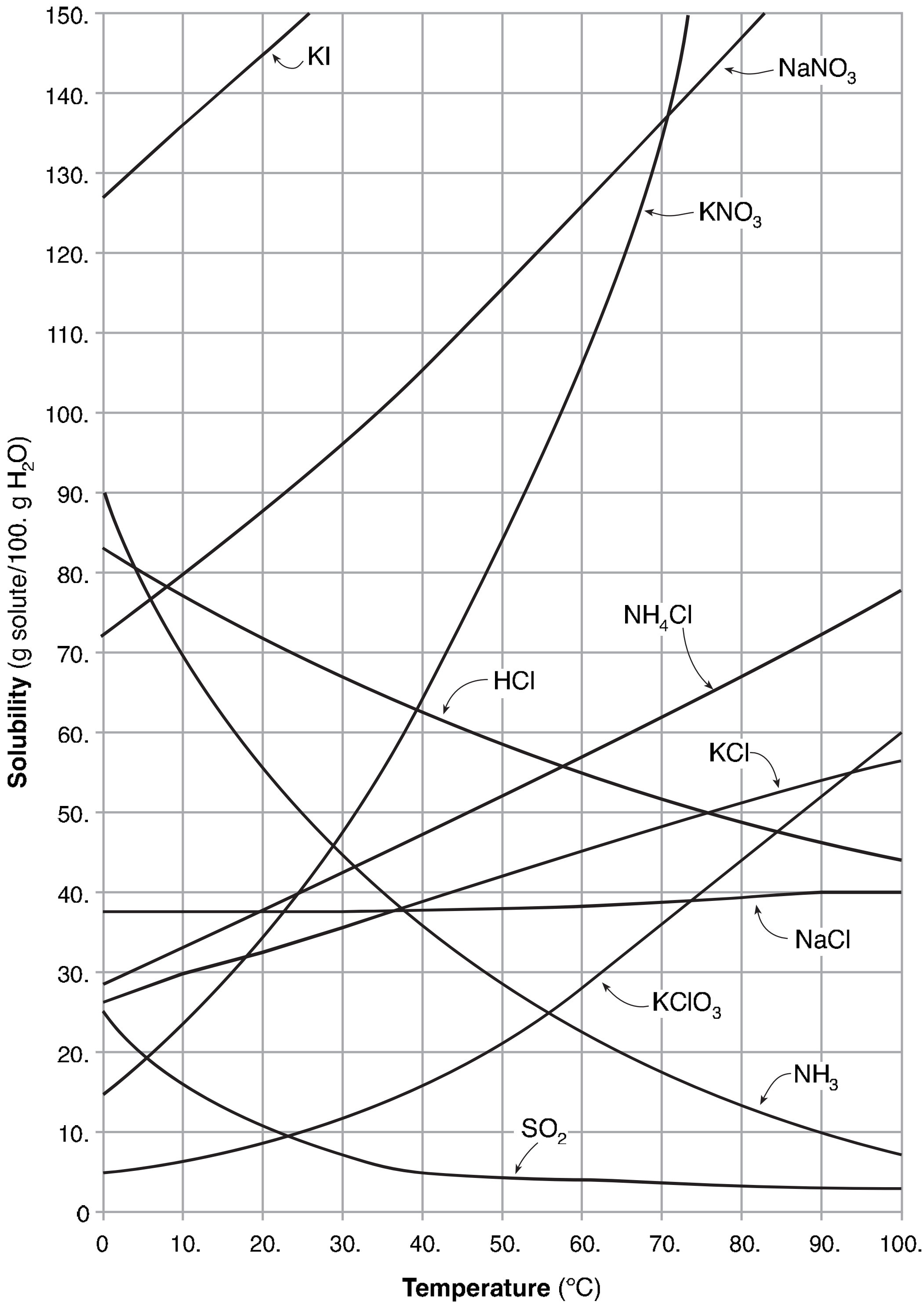


Table H
Vapor Pressure of Four Liquids

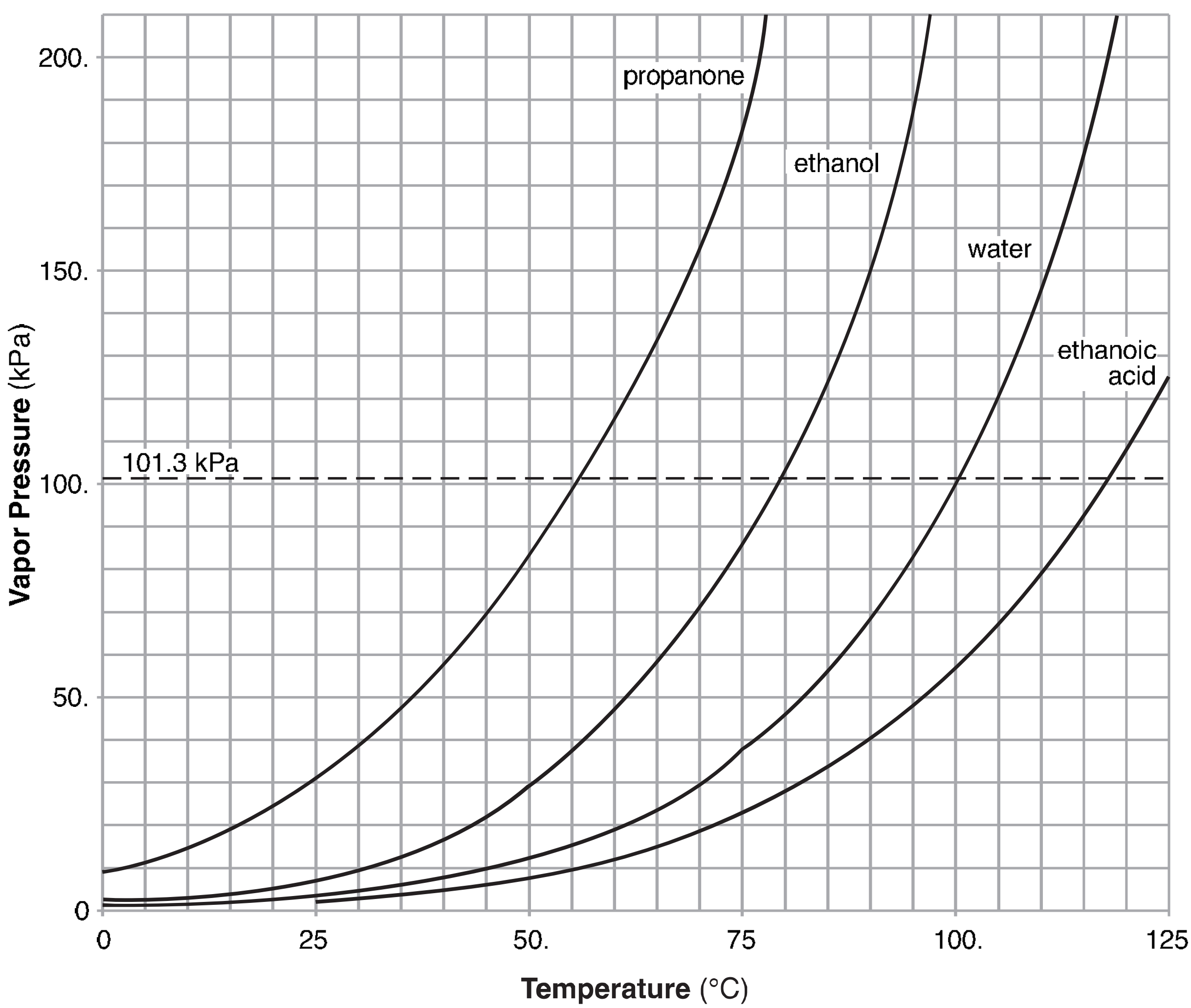


Table I
Heats of Reaction at 101.3 kPa and 298 K

Reaction	ΔH (kJ)*
$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(\ell)$	–890.4
$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(\ell)$	–2219.2
$2C_8H_{18}(\ell) + 25O_2(g) \longrightarrow 16CO_2(g) + 18H_2O(\ell)$	–10943
$2CH_3OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 4H_2O(\ell)$	–1452
$C_2H_5OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(\ell)$	–1367
$C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(\ell)$	–2804
$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$	–566.0
$C(s) + O_2(g) \longrightarrow CO_2(g)$	–393.5
$4Al(s) + 3O_2(g) \longrightarrow 2Al_2O_3(s)$	–3351
$N_2(g) + O_2(g) \longrightarrow 2NO(g)$	+182.6
$N_2(g) + 2O_2(g) \longrightarrow 2NO_2(g)$	+66.4
$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$	–483.6
$2H_2(g) + O_2(g) \longrightarrow 2H_2O(\ell)$	–571.6
$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$	–91.8
$2C(s) + 3H_2(g) \longrightarrow C_2H_6(g)$	–84.0
$2C(s) + 2H_2(g) \longrightarrow C_2H_4(g)$	+52.4
$2C(s) + H_2(g) \longrightarrow C_2H_2(g)$	+227.4
$H_2(g) + I_2(g) \longrightarrow 2HI(g)$	+53.0
$KNO_3(s) \xrightarrow{H_2O} K^+(aq) + NO_3^-(aq)$	+34.89
$NaOH(s) \xrightarrow{H_2O} Na^+(aq) + OH^-(aq)$	–44.51
$NH_4Cl(s) \xrightarrow{H_2O} NH_4^+(aq) + Cl^-(aq)$	+14.78
$NH_4NO_3(s) \xrightarrow{H_2O} NH_4^+(aq) + NO_3^-(aq)$	+25.69
$NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$	+3.88
$LiBr(s) \xrightarrow{H_2O} Li^+(aq) + Br^-(aq)$	–48.83
$H^+(aq) + OH^-(aq) \longrightarrow H_2O(\ell)$	–55.8

*The ΔH values are based on molar quantities represented in the equations. A minus sign indicates an exothermic reaction.

Table J
Activity Series**

	Metals	Nonmetals	
Most Active	Li	F_2	Most Active
↓	Rb	Cl_2	↓
	K	Br_2	
	Cs	I_2	
	Ba		
	Sr		
	Ca		
	Na		
	Mg		
	Al		
	Ti		
	Mn		
	Zn		
	Cr		
	Fe		
	Co		
	Ni		
	Sn		
	Pb		
	H_2		
	Cu		
	Ag		
Least Active	Au		Least Active

**Activity Series is based on the hydrogen standard. H_2 is *not* a metal.

Table K
Common Acids

Formula	Name
$HCl(aq)$	hydrochloric acid
$HNO_2(aq)$	nitrous acid
$HNO_3(aq)$	nitric acid
$H_2SO_3(aq)$	sulfurous acid
$H_2SO_4(aq)$	sulfuric acid
$H_3PO_4(aq)$	phosphoric acid
$H_2CO_3(aq)$ or $CO_2(aq)$	carbonic acid
$CH_3COOH(aq)$ or $HC_2H_3O_2(aq)$	ethanoic acid (acetic acid)

Table L
Common Bases

Formula	Name
$NaOH(aq)$	sodium hydroxide
$KOH(aq)$	potassium hydroxide
$Ca(OH)_2(aq)$	calcium hydroxide
$NH_3(aq)$	aqueous ammonia

Table M
Common Acid–Base Indicators

Indicator	Approximate pH Range for Color Change	Color Change
methyl orange	3.1–4.4	red to yellow
bromthymol blue	6.0–7.6	yellow to blue
phenolphthalein	8–9	colorless to pink
litmus	4.5–8.3	red to blue
bromcresol green	3.8–5.4	yellow to blue
thymol blue	8.0–9.6	yellow to blue

Source: *The Merck Index*, 14th ed., 2006, Merck Publishing Group

Table N
Selected Radioisotopes

Nuclide	Half-Life	Decay Mode	Nuclide Name
^{198}Au	2.695 d	β^-	gold-198
^{14}C	5715 y	β^-	carbon-14
^{37}Ca	182 ms	β^+	calcium-37
^{60}Co	5.271 y	β^-	cobalt-60
^{137}Cs	30.2 y	β^-	cesium-137
^{53}Fe	8.51 min	β^+	iron-53
^{220}Fr	27.4 s	α	francium-220
^{3}H	12.31 y	β^-	hydrogen-3
^{131}I	8.021 d	β^-	iodine-131
^{37}K	1.23 s	β^+	potassium-37
^{42}K	12.36 h	β^-	potassium-42
^{85}Kr	10.73 y	β^-	krypton-85
^{16}N	7.13 s	β^-	nitrogen-16
^{19}Ne	17.22 s	β^+	neon-19
^{32}P	14.28 d	β^-	phosphorus-32
^{239}Pu	2.410×10^4 y	α	plutonium-239
^{226}Ra	1599 y	α	radium-226
^{222}Rn	3.823 d	α	radon-222
^{90}Sr	29.1 y	β^-	strontium-90
^{99}Tc	2.13×10^5 y	β^-	technetium-99
^{232}Th	1.40×10^{10} y	α	thorium-232
^{233}U	1.592×10^5 y	α	uranium-233
^{235}U	7.04×10^8 y	α	uranium-235
^{238}U	4.47×10^9 y	α	uranium-238

Source: *CRC Handbook of Chemistry and Physics*, 91st ed., 2010–2011, CRC Press

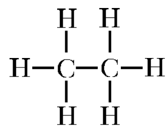
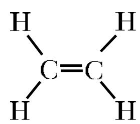
Table O
Symbols Used in Nuclear Chemistry

Name	Notation	Symbol
alpha particle	${}^{4}_{2}\mathrm{He}$ or ${}^{4}_{2}\alpha$	α
beta particle	${}^{0}_{-1}\mathrm{e}$ or ${}^{0}_{-1}\beta$	β^{-}
gamma radiation	${}^{0}_{0}\gamma$	γ
neutron	${}^{1}_{0}\mathrm{n}$	n
proton	${}^{1}_{1}\mathrm{H}$ or ${}^{1}_{1}\mathrm{p}$	p
positron	${}^{0}_{+1}\mathrm{e}$ or ${}^{0}_{+1}\beta$	β^{+}

Table P
Organic Prefixes

Prefix	Number of Carbon Atoms
meth-	1
eth-	2
prop-	3
but-	4
pent-	5
hex-	6
hept-	7
oct-	8
non-	9
dec-	10

Table Q
Homologous Series of Hydrocarbons

Name	General Formula	Examples	
		Name	Structural Formula
alkanes	C_nH_{2n+2}	ethane	
alkenes	C_nH_{2n}	ethene	
alkynes	C_nH_{2n-2}	ethyne	H—C≡C—H

Note: n = number of carbon atoms

Table R
Organic Functional Groups

Class of Compound	Functional Group	General Formula	Example
halide (halocarbon)	$-F$ (fluoro-) $-Cl$ (chloro-) $-Br$ (bromo-) $-I$ (iodo-)	$R-X$ (X represents any halogen)	$CH_3CHClCH_3$ 2-chloropropane
alcohol	$-OH$	$R-OH$	$CH_3CH_2CH_2OH$ 1-propanol
ether	$-O-$	$R-O-R'$	$CH_3OCH_2CH_3$ methyl ethyl ether
aldehyde	$-\overset{O}{\overset{\Vert}{C}}-H$	$R-\overset{O}{\overset{\Vert}{C}}-H$	$CH_3CH_2\overset{O}{\overset{\Vert}{C}}-H$ propanal
ketone	$-\overset{O}{\overset{\Vert}{C}}-$	$R-\overset{O}{\overset{\Vert}{C}}-R'$	$CH_3\overset{O}{\overset{\Vert}{C}}CH_2CH_2CH_3$ 2-pentanone
organic acid	$-\overset{O}{\overset{\Vert}{C}}-OH$	$R-\overset{O}{\overset{\Vert}{C}}-OH$	$CH_3CH_2\overset{O}{\overset{\Vert}{C}}-OH$ propanoic acid
ester	$-\overset{O}{\overset{\Vert}{C}}-O-$	$R-\overset{O}{\overset{\Vert}{C}}-O-R'$	$CH_3CH_2\overset{O}{\overset{\Vert}{C}}OCH_3$ methyl propanoate
amine	$-\overset{\vert}{N}-$	$R-\overset{R'}{\overset{\vert}{N}}-R''$	$CH_3CH_2CH_2NH_2$ 1-propanamine
amide	$-\overset{O}{\overset{\Vert}{C}}-\overset{\vert}{N}H$	$R-\overset{O}{\overset{\Vert}{C}}-\overset{R'}{\overset{\vert}{N}}H$	$CH_3CH_2\overset{O}{\overset{\Vert}{C}}-NH_2$ propanamide

Note: R represents a bonded atom or group of atoms.

Periodic Table of the Elements

KEY

Atomic Mass → 12.011	−4 +2 +4 ← Selected Oxidation States
Symbol → **C**	
Atomic Number → 6	
Electron Configuration → 2-4	

Relative atomic masses are based on $^{12}C = 12$ (exact)

Note: Numbers in parentheses are mass numbers of the most stable or common isotope.

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1.00794 +1 −1 **H** 1 1																	4.00260 0 **He** 9 2
2	6.941 +1 **Li** 3 2-1	9.01218 +2 **Be** 4 2-2											10.81 +3 **B** 5 2-3	12.011 −4 +2 +4 **C** 6 2-4	14.0067 −3 −2 −1 +1 +2 +3 +4 +5 **N** 9 2-5	15.9994 −2 **O** 9 2-6	18.9984 −1 **F** 9 2-7	20.180 0 **Ne** 10 2-8
3	22.98977 +1 **Na** 11 2-8-1	24.305 +2 **Mg** 12 2-8-2											26.98154 +3 **Al** 13 2-8-3	28.0855 −4 +2 +4 **Si** 14 2-8-4	30.97376 −3 +3 +5 **P** 15 2-8-5	32.065 −2 +4 +6 **S** 16 2-8-6	35.453 −1 +1 +5 +7 **Cl** 17 2-8-7	39.948 0 **Ar** 18 2-8-8
4	39.0983 +1 **K** 19 2-8-8-1	40.08 +2 **Ca** 20 2-8-8-2	44.9559 +3 **Sc** 21 2-8-9-2	47.867 +2 +3 +4 **Ti** 22 2-8-10-2	50.9415 +2 +3 +4 +5 **V** 23 2-8-11-2	51.996 +2 +3 +6 **Cr** 24 2-8-13-1	54.9380 +2 +3 +4 +7 **Mn** 25 2-8-13-2	55.845 +2 +3 **Fe** 26 2-8-14-2	58.9332 +2 +3 **Co** 27 2-8-15-2	58.693 +2 +3 **Ni** 28 2-8-16-2	63.546 +1 +2 **Cu** 29 2-8-18-1	65.409 +2 **Zn** 30 2-8-18-2	69.723 +3 **Ga** 31 2-8-18-3	72.64 +2 +4 **Ge** 32 2-8-18-4	74.9216 −3 +3 +5 **As** 33 2-8-18-5	78.96 −2 +4 +6 **Se** 34 2-8-18-6	79.904 −1 +1 +5 **Br** 35 2-8-18-7	83.798 0 +2 **Kr** 36 2-8-18-8
5	85.4678 +1 **Rb** 37 2-8-18-8-1	87.62 +2 **Sr** 38 2-8-18-8-2	88.9059 +3 **Y** 39 2-8-18-9-2	91.224 +4 **Zr** 40 2-8-18-10-2	92.9064 +3 +5 **Nb** 41 2-8-18-12-1	95.94 +6 **Mo** 42 2-8-18-13-1	(98) +4 +6 +7 **Tc** 43 2-8-18-13-2	101.07 +3 **Ru** 44 2-8-18-15-1	102.906 +3 **Rh** 45 2-8-18-16-1	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	114.818 +3 **In** 49 2-8-18-18-3	118.71 +2 +4 **Sn** 50 2-8-18-18-4	121.760 −3 +3 +5 **Sb** 51 2-8-18-18-5	127.60 −2 +4 +6 **Te** 52 2-8-18-18-6	126.904 −1 +1 +5 +7 **I** 53 2-8-18-18-7	131.29 0 +2 +4 +6 **Xe** 54 2-8-18-18-8
6	132.905 +1 **Cs** 55 2-8-18-18-8-1	137.33 +2 **Ba** 56 2-8-18-18-8-2	138.9055 +3 **La** 57 2-8-18-18-9-2	178.49 +4 **Hf** 72 *18-32-10-2	180.948 +5 **Ta** 73 -18-32-11-2	183.84 +6 **W** 74 -18-32-12-2	186.207 +4 +6 +7 **Re** 75 -18-32-13-2	190.23 +3 +4 **Os** 76 -18-32-14-2	192.217 +3 +4 **Ir** 77 -18-32-15-2	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 +1 +3 **Tl** 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 -18-32-18-6	(210) **At** 85 -18-32-18-7	(222) 0 **Rn** 86 -18-32-18-8
7	(223) +1 **Fr** 87 -18-32-18-8-1	(226) +2 **Ra** 88 -18-32-18-8-2	(227) +3 **Ac** 89 -18-32-18-9-2	(261) +4 **Rf** 104	(262) **Db** 105	(266) **Sg** 106	(272) **Bh** 107	(277) **Hs** 108	(276) **Mt** 109	(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

	140.116 +3 +4 **Ce** 58	140.908 +3 **Pr** 59	144.24 +3 **Nd** 60	(145) +3 **Pm** 61	150.36 +2 +3 **Sm** 62	151.964 +2 +3 **Eu** 63	157.25 +3 **Gd** 64	158.925 +3 **Tb** 65	162.500 +3 **Dy** 66	164.930 +3 **Ho** 67	167.259 +3 **Er** 68	168.934 +3 **Tm** 69	173.04 +2 +3 **Yb** 70	174.9668 +3 **Lu** 71
	232.038 +4 **Th** 90	231.036 +4 +5 **Pa** 91	238.029 +3 +4 +5 +6 **U** 92	(237) +3 +4 +5 +6 **Np** 93	(244) +3 +4 +5 +6 **Pu** 94	(243) +3 +4 +5 +6 **Am** 95	(247) +3 **Cm** 96	(247) +3 +4 **Bk** 97	(251) +3 **Cf** 98	(252) +3 **Es** 99	(257) +3 **Fm** 100	(258) +2 +3 **Md** 101	(259) +2 +3 **No** 102	(262) +3 **Lr** 103

*denotes the presence of (2-8-) for elements 72 and above

**The systematic names and symbols for elements of atomic numbers 113 and above will be used until the approval of trivial names by IUPAC.

Source: *CRC Handbook of Chemistry and Physics*, 91st ed., 2010–2011, CRC Press

Table S
Properties of Selected Elements

Atomic Number	Symbol	Name	First Ionization Energy (kJ/mol)	Electro-negativity	Melting Point (K)	Boiling* Point (K)	Density** (g/cm^3)	Atomic Radius (pm)
1	H	hydrogen	1312	2.2	14	20.	0.000082	32
2	He	helium	2372	—	—	4	0.000164	37
3	Li	lithium	520.	1.0	454	1615	0.534	130.
4	Be	beryllium	900.	1.6	1560.	2744	1.85	99
5	B	boron	801	2.0	2348	4273	2.34	84
6	C	carbon	1086	2.6	—	—	—	75
7	N	nitrogen	1402	3.0	63	77	0.001145	71
8	O	oxygen	1314	3.4	54	90.	0.001308	64
9	F	fluorine	1681	4.0	53	85	0.001553	60.
10	Ne	neon	2081	—	24	27	0.000825	62
11	Na	sodium	496	0.9	371	1156	0.97	160.
12	Mg	magnesium	738	1.3	923	1363	1.74	140.
13	Al	aluminum	578	1.6	933	2792	2.70	124
14	Si	silicon	787	1.9	1687	3538	2.3296	114
15	P	phosphorus (white)	1012	2.2	317	554	1.823	109
16	S	sulfur (monoclinic)	1000.	2.6	388	718	2.00	104
17	Cl	chlorine	1251	3.2	172	239	0.002898	100.
18	Ar	argon	1521	—	84	87	0.001633	101
19	K	potassium	419	0.8	337	1032	0.89	200.
20	Ca	calcium	590.	1.0	1115	1757	1.54	174
21	Sc	scandium	633	1.4	1814	3109	2.99	159
22	Ti	titanium	659	1.5	1941	3560.	4.506	148
23	V	vanadium	651	1.6	2183	3680.	6.0	144
24	Cr	chromium	653	1.7	2180.	2944	7.15	130.
25	Mn	manganese	717	1.6	1519	2334	7.3	129
26	Fe	iron	762	1.8	1811	3134	7.87	124
27	Co	cobalt	760.	1.9	1768	3200.	8.86	118
28	Ni	nickel	737	1.9	1728	3186	8.90	117
29	Cu	copper	745	1.9	1358	2835	8.96	122
30	Zn	zinc	906	1.7	693	1180.	7.134	120.
31	Ga	gallium	579	1.8	303	2477	5.91	123
32	Ge	germanium	762	2.0	1211	3106	5.3234	120.
33	As	arsenic (gray)	944	2.2	1090.	—	5.75	120.
34	Se	selenium (gray)	941	2.6	494	958	4.809	118
35	Br	bromine	1140.	3.0	266	332	3.1028	117
36	Kr	krypton	1351	—	116	120.	0.003425	116
37	Rb	rubidium	403	0.8	312	961	1.53	215
38	Sr	strontium	549	1.0	1050.	1655	2.64	190.
39	Y	yttrium	600.	1.2	1795	3618	4.47	176
40	Zr	zirconium	640.	1.3	2128	4682	6.52	164

Atomic Number	Symbol	Name	First Ionization Energy (kJ/mol)	Electro-negativity	Melting Point (K)	Boiling* Point (K)	Density** (g/cm^3)	Atomic Radius (pm)
41	Nb	niobium	652	1.6	2750.	5017	8.57	156
42	Mo	molybdenum	684	2.2	2896	4912	10.2	146
43	Tc	technetium	702	2.1	2430.	4538	11	138
44	Ru	ruthenium	710.	2.2	2606	4423	12.1	136
45	Rh	rhodium	720.	2.3	2237	3968	12.4	134
46	Pd	palladium	804	2.2	1828	3236	12.0	130.
47	Ag	silver	731	1.9	1235	2435	10.5	136
48	Cd	cadmium	868	1.7	594	1040.	8.69	140.
49	In	indium	558	1.8	430.	2345	7.31	142
50	Sn	tin (white)	709	2.0	505	2875	7.287	140.
51	Sb	antimony (gray)	831	2.1	904	1860.	6.68	140.
52	Te	tellurium	869	2.1	723	1261	6.232	137
53	I	iodine	1008	2.7	387	457	4.933	136
54	Xe	xenon	1170.	2.6	161	165	0.005366	136
55	Cs	cesium	376	0.8	302	944	1.873	238
56	Ba	barium	503	0.9	1000.	2170.	3.62	206
57	La	lanthanum	538	1.1	1193	3737	6.15	194
Elements 58–71 have been omitted.								
72	Hf	hafnium	659	1.3	2506	4876	13.3	164
73	Ta	tantalum	728	1.5	3290.	5731	16.4	158
74	W	tungsten	759	1.7	3695	5828	19.3	150.
75	Re	rhenium	756	1.9	3458	5869	20.8	141
76	Os	osmium	814	2.2	3306	5285	22.587	136
77	Ir	iridium	865	2.2	2719	4701	22.562	132
78	Pt	platinum	864	2.2	2041	4098	21.5	130.
79	Au	gold	890.	2.4	1337	3129	19.3	130.
80	Hg	mercury	1007	1.9	234	630.	13.5336	132
81	Tl	thallium	589	1.8	577	1746	11.8	144
82	Pb	lead	716	1.8	600.	2022	11.3	145
83	Bi	bismuth	703	1.9	544	1837	9.79	150.
84	Po	polonium	812	2.0	527	1235	9.20	142
85	At	astatine	—	2.2	575	—	—	148
86	Rn	radon	1037	—	202	211	0.009074	146
87	Fr	francium	393	0.7	300.	—	—	242
88	Ra	radium	509	0.9	969	—	5	211
89	Ac	actinium	499	1.1	1323	3471	10.	201
Elements 90 and above have been omitted.								

*boiling point at standard pressure

**density of solids and liquids at room temperature and density of gases at 298 K and 101.3 kPa

— no data available

Source: *CRC Handbook for Chemistry and Physics*, 91st ed., 2010–2011, CRC Press

Table T
Important Formulas and Equations

Density	$d = \frac{m}{V}$	d = density m = mass V = volume
Mole Calculations	number of moles = $\frac{\text{given mass}}{\text{gram-formula mass}}$	
Percent Error	% error = $\frac{\text{measured value} - \text{accepted value}}{\text{accepted value}} \times 100$	
Percent Composition	% composition by mass = $\frac{\text{mass of part}}{\text{mass of whole}} \times 100$	
Concentration	parts per million = $\frac{\text{mass of solute}}{\text{mass of solution}} \times 1000000$	
	molarity = $\frac{\text{moles of solute}}{\text{liter of solution}}$	
Combined Gas Law	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$	P = pressure V = volume T = temperature
Titration	$M_AV_A = M_BV_B$	M_A = molarity of H^+ M_B = molarity of OH^- V_A = volume of acid V_B = volume of base
Heat	$q = mC\Delta T$ $q = mH_f$ $q = mH_v$	q = heat H_f = heat of fusion m = mass H_v = heat of vaporization C = specific heat capacity ΔT = change in temperature
Temperature	K = °C + 273	K = kelvin °C = degree Celsius

Glossary and Index

A

Absolute Zero (9)
0 K or -273°C; the temperature at which all molecular movements stop.

Accelerator (223)
a device which gives charged particles sufficient kinetic energy to penetrate the nucleus.

Acid, Arrhenius (141, 142)
a substance that produces H^+ (hydrogen ion, proton) or H_3O^+ (hydronium) ion as the only positive ion in solutions.

Acid , Alternate Theory (143)
a substance that donates H+ (hydrogen ion, proton) in acid-base reactions.

Activation energy (154)
minimal amount of energy needed to start a reaction.

Addition reaction (193, 194)
organic reaction that involves the adding of hydrogen atoms (or halogen atoms) to a double or a triple bond.

Addition polymerization (193, 196)
the joining of monomers (small unit molecules) with double bonds to form a polymer (a larger unit) molecule.

Alcohol (184)
an organic compound containing the hydroxyl group (-OH) as the functional group.

Aldehyde (186)
an organic compound containing the $-\overset{\overset{\displaystyle O}{\|}}{C}-H$ as the functional group.

Alkali metal (36)
an element in Group 1 of the Periodic Table.

Alkaline Earth metal (36)
an element in Group 2 of the Periodic Table.

Alkane (180, 181)
a saturated hydrocarbon with all single bonds and general formula of C_nH_{2n+2}

Alkene (180, 181)
an unsaturated hydrocarbon with a double bond and general formula of C_nH_{2n}

Alkyl group (190)
a hydrocarbon group (found as a side chain) that contains one less H atom than an alkane with the same number of C atoms.

Alkyne (180, 183)
an unsaturated hydrocarbon with a triple (≡) bond and general formula of C_nH_{2n-2}

Allotropes (43)
two or more different forms of the same element that have different formulas, structures, and properties.

Alloy
a homogeneous mixture of a metal with another element (often another metal.)

Alpha decay (226)
a nuclear decay that releases an alpha particle.

Alpha particle (223)
a helium nucleus, $^{4}_{2}He$

Amide (88)
an organic compound formed from a reaction of an organic acid with an amine.

Amine (188)
an organic compound that has $-\overset{|}{N}-$ (nitrogen) as its functional group.

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