# AAHKB20 Chemistry Study Guide & Questions

## 1. Avogadro's Number

Avogadro's number, or Avogadro's constant, is the number of particles found in one mole of a substance. It is the number of atoms in exactly 12 grams of carbon-12. This experimentally determined value is approximately $6.0221 \times 10^{23}$ particles per mole. Avogadro's number may be designated using the symbol L or NA. Note that Avogadro's number, on its own, is a dimensionless quantity.

## 2. Volume and Density

The properties of a material may be described in many ways. Any amount of any substance will have a volume. If you have two containers of water that are different sizes, they each hold a different amount, or volume, of water. The unit for volume is a unit derived from the SI unit of length and is not a fundamental SI measurement.

If two water samples have different volumes, they still share a common measurement: the density. Density is another measurement derived from SI basic units. The density of a material is defined as its mass per unit volume. In this example, each volume of water is different and therefore has a specific and unique mass. The mass of water is expressed in grams (g) or kilograms (kg), and the volume is measured in liters (L), cubic centimeters ($cm^3$), or milliliters (mL). Density is calculated by dividing the mass by the volume so that density is measured as units of mass/volume, often g/mL. If both water samples are at the same temperature, their densities should be identical, regardless of the samples' volume.

### The Variable Density of Water

Water itself is a complicated and unique molecule. Even if the pressure is consistent, water's density will change based on the temperature. Recall that the three basic forms of matter are solid, liquid and gas (ignore plasma for the time being). As a rule of thumb, almost all materials are more dense in their solid or crystalline form than in their liquid form; place the solid form of almost any material on the surface of its liquid form, and it will sink. Water, on the other hand, does something very special: ice (the solid form of water) floats on liquid water.

## 3. Phases of matter

There are four natural states of matter: Solids, liquids, gases, and plasma.

**Solids**
In a solid, particles are packed tightly together so they don't move much. The electrons of each atom are constantly in motion, so the atoms have a small vibration, but they are fixed in their position. Because of this, particles in a solid have very low kinetic energy. Solids have a definite shape, as well as mass and volume, and do not conform to the shape of the container in which they are placed. Solids also have a high density, meaning that the particles are tightly packed together.

**Liquids**
In a liquid, the particles are more loosely packed than in a solid and are able to flow around each other, giving the liquid an indefinite shape. Therefore, the liquid will conform to the shape of its container. Much like solids, liquids (most of which have a lower density than solids) are incredibly difficult to compress.

**Gases**
In a gas, the particles have a great deal of space between them and have high kinetic energy. A gas has no definite shape or volume. If unconfined, the particles of a gas will spread out indefinitely; if confined, the gas will expand to fill its container. When a gas is put under pressure by reducing the volume of the container, the space between particles is reduced and the gas is compressed.

**Plasma**
Plasma is not a common state of the matter here on Earth, but it may be the most common state of matter in the universe, according to the Jefferson Laboratory. Stars are essentially superheated balls of plasma.

## 4. pH Scale

A measure of acidity or alkalinity of water-soluble substances (pH stands for 'potential of Hydrogen'). A pH value is a number from 1 to 14, with 7 as the middle (neutral) point. Values below 7 indicate acidity which increases as the number decreases, 1 being the most acidic. Values above 7 indicate alkalinity which increases as the number increases, 14 being the most alkaline. This scale, however, is not a linear scale like a centimeter or inch scale (in which two adjacent values have the same difference). It is a logarithmic scale in which two adjacent values increase or decrease by a factor of 10.
For example, a pH of 3 is ten times more acidic than a pH of 4, and 100 times more acidic than a pH of 5. Similarly, a pH of 9 is 10 times more alkaline than a pH of 8, and 100 more alkaline than a pH of 7. Invented in 1909 by the Danish biochemist S. P. Sørensen (1869-1939).

## 5. Chemical Bonding

Molecules are held together by either covalent bonding or ionic bonding. Several types of non-metal elements exist only as molecules in the environment.

**Covalent**

A covalent bond is a chemical bond that involves the sharing of electron pairs between atoms. These electron pairs are termed shared pairs or bonding pairs, and the stable balance of attractive and repulsive forces between atoms, when they share electrons, is termed covalent bonding. **Nonpolar covalent bonds** are a type of bond that occurs when two atoms share a pair of electrons with each other. **Polar covalent bonding** is a type of chemical bond where a pair of electrons are unequally shared between two atoms. In a polar covalent bond, the electrons are not equally shared because one atom spends more time with the electrons than the other atom. In polar covalent bonds, one atom has a stronger pull than the other atom and attracts electrons.

**Ionic**

Ionic bonding is a type of chemical bond that involves the electrostatic attraction between oppositely charged ions and is the primary interaction occurring in ionic compounds. The ions are atoms that have lost one or more electrons (termed cations) and atoms that have gained one or more electrons (termed anions).his transfer of electrons is termed electrovalence in contrast to covalence. In the simplest case, the cation is a metal atom and the anion is a nonmetal atom, but these ions can be of a more complicated nature, e.g. molecular ions like NH4+ or SO42−. Basically, an ionic bond is the transfer of electrons from a metal to a non-metal for both atoms to obtain a full valence shell.

## 6. Physical & Chemical Changes

**Physical changes** are changes in which no chemical bonds are broken or formed. This means that the same types of compounds or elements that were there at the beginning of the change are there at the end of the change. Because the ending materials are the same as the beginning materials, the properties (such as color, boiling point, etc) will also be the same. Physical changes involve moving molecules around, but not changing them. Some types of physical changes include:

- Changes of state (changes from a solid to a liquid or a gas and vice versa)
- Separation of a mixture
- Physical deformation (cutting, denting, stretching)
- Making solutions (special kinds of mixtures)

As an ice cube melts, its shape changes as it acquires the ability to flow. However, its composition does not change. Melting is an example of a physical change. Since some properties of the material change, but the identity of the matter does not. Physical changes can further be classified as reversible or irreversible. The melted ice cube may be refrozen, so melting is a reversible physical change. Physical changes that involve a change of state are all reversible. Other changes of the state include vaporization (liquid to gas), freezing (liquid to solid), and condensation (gas to liquid). Dissolving is also a reversible physical change. When salt is dissolved into water, the salt is said to have entered the aqueous state. The salt may be regained by boiling off the water, leaving the salt behind.

**Chemical changes** occur when bonds are broken and/or formed between molecules or atoms. This means that one substance with a certain set of properties (such as melting point, color, taste, etc) is turned into a different substance with different properties. Chemical changes are frequently harder to reverse than physical changes. One good example of a chemical change is burning paper. In contrast to the act of ripping paper, the act of burning paper actually results in the formation of new chemicals (carbon dioxide and water, to be exact). Another example of chemical change occurs when water is formed. Each molecule contains two atoms of hydrogen and one atom of oxygen chemically bonded.

Another example of a chemical change is what occurs when natural gas is burned in your furnace. This time, before the reaction we have a molecule of methane, CH4CH4, and two molecules of oxygen, O2O2, while after the reaction we have two molecules of water, H2OH2O, and one molecule of carbon dioxide, CO2CO2. In this case, not only has the appearance changed, but the structure of the molecules has also changed. The new substances do not have the same chemical properties as the original ones. Therefore, this is a chemical change.

## 7. Physical & Chemical Properties

**Physical properties** are characteristics that scientists can measure without changing the composition of the sample under study, such as mass, color, and volume (the amount of space occupied by a sample).

**Chemical properties** describe the characteristic ability of a substance to react to form new substances; they include its flammability and susceptibility to corrosion. All samples of a pure substance have the same chemical and physical properties. For example, pure copper is always a reddish-brown solid (a physical property) and always dissolves in dilute nitric acid to produce a blue solution and a brown gas (a chemical property).

***Physical properties can be extensive or intensive.***

**Extensive properties** vary with the amount of the substance and include mass, weight, and volume. **Intensive properties**, in contrast, do not depend on the amount of the substance; they include color, melting point, boiling point, electrical conductivity, and physical state at a given temperature. For example, elemental sulfur is a yellow crystalline solid that does not conduct electricity and has a melting point of 115.2 °C, no matter what amount is examined (Figure 1.3.11.3.1). Scientists commonly measure intensive properties to determine a substance’s identity, whereas extensive properties convey information about the amount of the substance in a sample.

# 8. Chemical Mixtures

A mixture is a material system made up of two or more different substances, which are mixed but not combined chemically. A mixture refers to the physical combination of two or more substances in which the identities of the individual substances are retained. Mixtures take the form of alloys, solutions, suspensions, and colloids.

### Heterogeneous Mixtures

A heterogeneous mixture is a mixture of two or more chemical substances (elements or compounds), where the different components can be visually distinguished and easily separated by physical means.

### Homogenous Mixtures

A homogeneous mixture is a mixture of two or more chemical substances (elements or compounds), where the different components cannot be visually distinguished. The composition of homogeneous mixtures is constant. Often separating the components of a homogeneous mixture is more challenging than separating the components of a heterogeneous mixture.

Distinguishing between homogeneous and heterogeneous mixtures is a matter of the scale of sampling. On a small enough scale, any mixture can be said to be heterogeneous, because a sample could be as small as a single molecule. In practical terms, if the property of interest is the same regardless of how much of the mixture is taken, the mixture is homogeneous.

A mixture's physical properties, such as its melting point, may differ from those of its individual components. Some mixtures can be separated into their components by physical (mechanical or thermal) means.

# 9. Ions

Sometimes atoms gain or lose electrons.  The atom then loses or gains a "negative" charge. These atoms are then called ions. Positive Ion - Occurs when an atom loses an electron (negative charge) it has more protons than electrons and is named cation. Negative Ion - Occurs when an atom gains an electron (negative charge) it will have more electrons than protons and is named anion.

### Forming Ions

Ions can be formed by ionization, which is the process of a neutral atom losing or gaining electrons. Generally, the electrons are either added to or loss from the valence shell of an atom; the inner-shell electrons are more tightly bound to the positively charged nucleus and so do not participate in this type of chemical interaction.

Ionization generally involves a transfer of electrons between atoms or molecules. The process is motivated by the achievement of more stable electronic configurations, such as the octet rule, which states that most stable atoms and ions have eight electrons in their outermost (valence) shell. Polyatomic and molecular ions can also be formed, generally by gaining or losing elemental ions, such as $H^+$, in neutral molecules. Polyatomic ions are generally very unstable and reactive.

A common example of an ion is $Na^+$. Sodium has a +1 charge because sodium has eleven electrons. However, according to the octet rule, sodium would be more stable with 10 electrons (2 in its innermost shell, 8 in its outermost shell). Therefore, sodium tends to lose an electron to become more stable. On the other hand, chlorine tends to gain an electron to become $Cl^-$. Chlorine naturally has 17 electrons but it would be more stable with 18 electrons (2 in its innermost shell, 8 in its second shell, and 8 in its valence shell). Therefore, chlorine will take an electron from another atom to become negatively charged.