CHEMISTRY 11

UNIT 3: MATTER & INORGANIC NAMING

BOOK 2: MIXTURES & SEPARATION TECHNIQUES

Name: ____________   Block: _____
Table 2.2.2 Distinguishing Between Homogeneous and Heterogeneous Mixtures

<table>
<thead>
<tr>
<th>Material</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homogeneous mixture</td>
<td>a mixture that appears to be the same throughout.</td>
<td>e.g., CuSO₄(aq).</td>
</tr>
<tr>
<td>Heterogeneous mixture</td>
<td>doesn’t appear the same throughout. Some particles &gt; 1 μm.</td>
<td>trail may sand. CaCO₃ in water.</td>
</tr>
</tbody>
</table>

Solutions
A __________ is a type of homogeneous mixture in which the constituent chemical species do not aggregate to form any particles greater than 1 nm (nanometre).
A __________ is a minor component of the mixture, generally what has been dissolved.

The __________ is the major component of the mixture, generally what the solute was dissolved in.

Many chemicals are in __________ solution (dissolved in water).

Our lakes and rivers, our oceans, our drinks, our bodily fluids, and the bottles on the shelves of your laboratory are all __________ solutions.
Chemists denote that a chemical is in aqueous solution with “aq” in brackets after the formula (e.g., NaCl(aq)).

Solutions can be produced from materials in different phases (e.g., a solid can dissolve in a liquid). Regardless of the constituents’ phases when undissolved, a solution is a __________ phase, usually that of the solvent. If the solvent is a __________, it is melted to allow for mixing and then cooled to solidify the mixture.

Table 2.2.3 Examples of Solutions

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Solid</th>
<th>Liquid</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid</td>
<td>metal alloys</td>
<td>mercury in gold</td>
<td>hydrogen in palladium</td>
</tr>
<tr>
<td>Liquid</td>
<td>salt water</td>
<td>gasoline</td>
<td>oxygen in water</td>
</tr>
<tr>
<td>Gas</td>
<td>-</td>
<td>-</td>
<td>air</td>
</tr>
</tbody>
</table>

Colloids
A colloidal system consists of particles between 1 nm and 1 μm dispersed throughout a medium (Table 2.2.5). The particles of the __________ phase are large molecules (macromolecules) or aggregates of molecules that are invisible to the naked eye.

Unlike a solution, the colloid particles can be in a __________ phase than the dispersion medium in which they are suspended. Any mixture of __________ particles in a __________ liquid, regardless of how small the solid particles are, is a colloid or a __________ mixture.

If a liquid is translucent (gray), then it is a colloid or a __________ mixture.
**Homogeneous Mixtures**

If one or more of the components of a mixture are visible, then it is a heterogeneous mixture. The term “mechanical mixture” is often misused as an intended synonym for “heterogeneous mixture.”

A mechanical mixture is a mixture of components that are separated by mechanical means, i.e., by picking, sifting, shaking, spinning, pouring, skimming, etc.

This definition includes at least some mixtures of every class. For example, the components of colloids can be separated by mechanical means such as centrifugation (spinning) and ultra-filtration.

If the heterogeneous mixture has a dispersed phase and a continuous medium, then it is a coarse suspension or just a suspension.

**Colloids:** remain suspended indefinitely, but the larger mass of the suspended particles in suspensions causes them to settle out or sediment upon standing. The dispersed phase in a suspension is usually a solid. Examples of suspensions: silt in water, dust in air, and paint (pigments in a solvent).

The component particles are all visible, solid particles in some heterogeneous mixtures such as gravel.

**EXTENSION:** The Tyndall effect, also known as Willis–Tyndall scattering, is light scattering by particles in a colloid or else particles in a very fine suspension.

<table>
<thead>
<tr>
<th>Type of Mixture</th>
<th>Operational Definition*</th>
<th>Conceptual Definition**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>no</td>
<td>All particles are &lt; 1 nm.</td>
</tr>
<tr>
<td>Colloid</td>
<td>yes, no</td>
<td>Dispersed particles are between 1 nm and 1 μm. Particles comprising the medium are &lt; 1 nm.</td>
</tr>
<tr>
<td>Suspension</td>
<td>yes, yes</td>
<td>Dispersed particles are &gt; 1 μm.</td>
</tr>
</tbody>
</table>

* The operational definitions only provide methods of differentiating mixtures that have a liquid continuous medium.
** The sizes cited for the particles are only rough guidelines, not steadfast rules.
Review Questions

1. Name an element, a compound, and a mixture.

2. Is it easier to prove that elements are classified as "properties," or "compositions"? Why?

3. Elements, compounds, and mixtures can be classified as "properties," or "compositions.
   (a) Elements are classified as properties.
   (b) Compounds are classified as compositions.
   (c) Mixtures are classified as both properties and compositions.

4. Using only white circles, draw one element, one molecular compound, one ionic compound, one mixture of elements, and one mixture of compounds.

5. Classify each of the following as an element, a compound, a mixture, or a mixture containing only one type of atom.
   (a) Potassium fluoride
   (b) Egg nog
   (c) Can be decomposed
   (d) Can vary in proportions
   (e) Carbon
   (f) Seawater
   (g) Substance containing only one type of atom
   (h) Contains more than one substance

6. Classify each of the following elements as a metal, metalloid, or a non-metal.
   (a) Germanium
   (b) Calcium
   (c) Iodine
   (d) Xenon

7. Give four examples of physical properties of metals.
8. Complete the following table by classifying each of the compounds.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Organic or Inorganic</th>
<th>Binary or Non-Binary</th>
<th>Molecular or Ionic</th>
<th>Acid, Base, Salt or None of these</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaCl₂</td>
<td>Inorganic</td>
<td>Binary</td>
<td>Ionic</td>
<td>Salt</td>
</tr>
<tr>
<td>CH₃CH₂OH</td>
<td>Organic</td>
<td>Non-Binary</td>
<td>Molecular</td>
<td>None of these</td>
</tr>
<tr>
<td>NH₄ClO₃</td>
<td>Inorganic</td>
<td>Non-Binary</td>
<td>Ionic</td>
<td>Salt</td>
</tr>
<tr>
<td>KOH</td>
<td>Inorganic</td>
<td>Non-Binary</td>
<td>Ionic</td>
<td>Base</td>
</tr>
<tr>
<td>C₂H₆</td>
<td>Organic</td>
<td>Binary</td>
<td>Molecular</td>
<td>None of these</td>
</tr>
<tr>
<td>H₃PO₄</td>
<td>Inorganic</td>
<td>Non-Binary</td>
<td>Molecular</td>
<td>Acid</td>
</tr>
<tr>
<td>Ba(NO₃)₂</td>
<td>Inorganic</td>
<td>Non-Binary</td>
<td>Ionic</td>
<td>Salt</td>
</tr>
<tr>
<td>CO₂</td>
<td>Inorganic</td>
<td>Binary</td>
<td>Ionic</td>
<td>None of these</td>
</tr>
<tr>
<td>Al(OH)₃</td>
<td>Inorganic</td>
<td>Non-Binary</td>
<td>Ionic</td>
<td>Base</td>
</tr>
</tbody>
</table>

9. Suppose that chemists used names for compounds that could be organized into alternating rows. Would you use alternative names? Why or why not?

10. Why is no material truly homogeneous?

11. Is a mixture of O₂ and O₃ (two different forms of oxygen) a homogeneous mixture?

12. Identify each of the following species:
   (a) N₂    (b) O₂

   a. molecule   d. neutral atom
   b. neutral atom e. molecule
13. Complete the following table by checking (✓) the column that best describes each item.

<table>
<thead>
<tr>
<th></th>
<th>Solution</th>
<th>Colloid</th>
<th>Heterogeneous Mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>All particles are less than 1 nm in size</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Does not appear the same throughout</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Forms a sediment if left undisturbed</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Has a solute and a solvent</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Milk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exhibits the Tyndall effect</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Homogeneous mixture</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Coarse suspension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange juice with pulp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May be separated by centrifugation</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

14. To diagnose an ulcer, a doctor may have the patient’s gastrointestinal tract allowing it to be imaged using milk and a colloid? Explain.

15. Is dust a colloid or is it a suspension? Explain.

16. Correct each of the following sentences by replacing the underlined word with the correct word.

(a) Salt water is a denser substance than fresh water.
   - Salt water is a denser solution than fresh water.
   (Fresh water is not pure water. It also has substances dissolved in it.)

(b) The colloid particles were dissolved in water.
   - The colloid particles were dispersed in water.
Separating the Substances of a Mixture

Most naturally occurring objects and materials are *mixtures*. Our atmosphere, our natural water systems, and the ores and petroleum products (such as crude oil and natural gas) that we extract from the ground are mixtures. Just as a compound can be decomposed, a *mixture* can be UNCOMPARED, since the ingredients of a mixture are **NOT CHEMICALLY** combined; they retain their individual identities. The trick to separating the substances in a mixture is to pick a property that clearly differentiates the substances.

Laboratory technicians perform a tremendous number of separations daily in medical, forensic, and analytical chemistry laboratories to allow the substances in the mixtures to be identified. Large industrial-scale separations are performed around the world in commercial refineries (for sugar, oil, metal, etc.) to obtain the target substances for their useful properties, their intrinsic values, or more commonly to use the substances to produce useful mixtures of our own design.

In Chemistry 12, you'll examine a chemical separation technique called **selective precipitation**. In this course we restrict our studies to **physical** separations; those NOT INVOLVING CHEMICALS.

Physical separation techniques include *crystallization*, chromatography, *centrifugation*, *decantation*, *density separation*, *electrophoresis*, *evaporation*, *extraction*, *flocculation*, *filtration*, *freezing*, *magnetic separation*, *reverse osmosis*, and *sedimentation*.

Physical separations may be classified as **mechanical** or **non-mechanical**.

**Non-mechanical** means of separation include techniques that use **magnetism**, **dissolving**, or sticking to separate a mixture's components. **Mechanical means of separation** use **gravimetric**, **contact forces**, or motion to sort the components of a mixture. Terms such as picking, sifting, filtering, shaking, spinning, pouring, and skimming, describe the type of actions involved in mechanical separations.

**Density Separation**

To separate solid from liquid means to fall or sink to the bottom of a liquid. **Sediment** (noun) is matter that has fallen or sunk to the bottom of a liquid. A medium exerts an upward force called *buoyancy* on all objects immersed in it. As an object enters a fluid, it lifts the fluid it displaces. If the object is **less dense** than the fluid, then the object will float because it will displace a weight of fluid greater than its own weight. Density separation can be used to separate solids with different densities. The solids must be insoluble in the liquid media used to separate them. This technique is used to separate *plastics* of different densities. Although density separation separates the solid particles from each other, they are now mixed with the liquid used to separate them. The particles that **float** can be skimmed off the top of the liquid and dried. The particles that **sediment** can be separated from the liquid by **decanting** off the liquid or by **filtering** out the sediment. **Decanting** is carefully pouring off the liquid and leaving the sediment in the bottom of the original container.
Centrifugation
Another mechanical means of separation is centrifugation. Particles that would normally sink or rise still do so, just more rapidly. When you are in a car that turns a sharp corner you may be “thrown” sideways. It might seem as though a force pushed you against the door. This property is called inertia. The suspended particles in a mixture behave similarly in a centrifuge. As the tube changes its direction, the suspended particles initially maintain their linear motion. This process occurs continuously as the tube spins, directing the suspended particles to the bottom of the tube.

Non-Mechanical Means of Separation

Chromatography
Chromatography is one of the most widely used techniques in scientific research today. Researchers have been able to devise a chromatographic method for separating all but a few mixtures.

Chromatography separates the substances in a solution by having a flowing liquid or gas carry them at different rates through a stationary phase. The flowing liquid or gas is called the mobile phase. Each substance travels through the stationary phase at its own characteristic rate according to its relative affinities for the two phases. A substance that adheres strongly to the stationary phase but isn’t very soluble in the mobile phase travels slowly through the chromatogram. Conversely, a substance that adheres weakly to the stationary phase but is very soluble in the mobile phase travels quickly through the chromatogram.

There are many forms of chromatography: gas chromatography, column chromatography, thin layer chromatography, and paper chromatography.

In paper chromatography, the stationary phase is a strip or sheet of paper. The mobile phase in both forms of chromatography could be water, an organic solvent such as alcohol, or a mixture of solvents.

A drop of the solution to be separated is placed near the bottom of the sheet or plate and allowed to dry. Another drop of the solution is then placed on top of the first and also allowed to dry.

This process is repeated many times until there is a sufficient amount of each solute to produce a clear chromatogram. The bottom of the chromatogram is lowered into a pool of the solvent. Capillary action is the tendency of a liquid to rise in narrow tubes or be drawn into small openings. Capillary action results from the adhesive forces between the solvent molecules and those of the wicking material in combination with the cohesive forces between the solvent molecules themselves. Capillary action causes the solvent to rise up the stationary medium, between the paper fibers, past the deposit of solutes, and up the remainder of the paper or glass plate.

A substance’s $R_f$ (retention factor) for any particular system is defined as its flow speed relative to that of the mobile phase.

$$R_f = \frac{\text{distance the solute-float (cm)}}{\text{distance the solvent-float (cm)}}$$

A substance’s $R_f$ may help identify it or at least support its identification by more definitive means.
Distillation is any process that separates a mixture of substances by using their different vapor pressures or boiling points. Distillations require a heating device, a flask containing the original mixture, a condenser to cool and condense the vapours, and something to collect the condensed substances as they leave the condenser one after another. Distilled water is produced by boiling tap water, cooling its vapours, and then collecting the condensate or distillate. The impurities that were dissolved in the water remain as residue in the original flask.

Scientists have devised a method called fractional distillation in which the simple distillation (vaporizing and condensing) is repeated many times within the same device. After evaporating, the vapour enters a fractionating column. This may be a tube packed with glass fibres, a tube containing overlapping glass lips or plates, or simply coiled tubing as popularized by backwoods stills.

FYI...ADDITIONAL INFORMATION for the "KEEN BEANS":

The idea is to provide surfaces on which vapours can condense. At the hot vapours from below reheat the distillate, some compounds reconcentrate and travel farther up the column. At the same time, others with higher boiling points drip back in the opposite direction. This process is called reflux. The plates become progressively cooler as you move up the column. Each time the process is repeated, the distillate becomes richer in the liquid with the lower boiling point. The component liquids thus proceed at different rates up the fractionating column so as you move higher up, the mixture becomes increasing richer in the liquid with the lower boiling point. If the column is long enough, the liquid components may separate completely and enter the condenser one after the other. There are of course several variations on this same technique.

Distillation is an important laboratory and industrial process (Figure 2.3.6). Oil refineries employ distillation to separate the hundreds of different hydrocarbons in crude oil into smaller groups of hydrocarbons with similar boiling points. Chevron has an oil refinery in Burnaby and Husky has an oil refinery in Prince George. When distilling a single batch, as described and illustrated above, the temperatures within the column continuously change as the chemicals travel through the column much like solutes travelling up a piece of chromatography paper. By contrast, oil refineries continuously feed the vaporized crude oil mixture into large steel fractionating towers that electronically monitor and maintain a steady range of temperatures from 400°C at the bottom to 40°C at the top. Each compound rises until it reaches a section of the column that is cool enough for it to condense and be withdrawn from the column. For example, the gasoline fraction (meaning the fraction containing gasoline, itself a mixture) exits near the top of the tower at the 40°C to 110°C level.
Separating an insoluble solid

How could you separate an insoluble solid like sand from a mixture of sand and water?

It is easy to separate an ___________ solid by ________________ the mixture.
The insoluble solid cannot pass through the filter paper but the water can. The sand
that is trapped by the filter paper is called the __________. The water that passes
through the filter paper is called the __________.

Separating a soluble solid

How could you separate a soluble solid, like salt, from a seawater solution?

To separate a ___________ solid from a solution, ________________ can be used. The solution is
_______________ so that the water evaporates and leaves the dissolved solid
behind.

Separating immiscible liquids

Liquids that ___________ together are described as _________________.
Can you think of any examples of immiscible liquids?

On a small scale, immiscible liquids can be separated by simply removing the top layer using a ___________.
In laboratories, chemists use a ________________ to separate immiscible layers.

Separating miscible liquids

Liquids that ___________ together are described as _________________.
An example of this is water and alcohol – these two liquids mix together easily.

Can you think of any more examples of miscible liquids?

How could you separate a mixture of miscible liquids?
**Distillation**
The technique used to separate a liquid from a mixture is called distillation.

Distillation has three steps:
1. 
2. 
3. 

The solution is heated so that the liquid _____________ and is turned into a gas.
Everything else is left behind. The gas cools in the _______________ and turns back into a liquid, which can then be collected.

Could distillation be used to make seawater safe to drink?

---

**Chromatography**
Chromatography is used to _______________ of coloured or non-coloured substances that are _______________ in the same solvent. A spot of the mixture is placed on the same filter paper.

---

### How is a Chromatogram Produced?

<table>
<thead>
<tr>
<th>Stage 1</th>
<th><img src="image1.png" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 2</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>Stage 3</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>Stage 4</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
</tbody>
</table>
Identifying dyes in a mixture
Dots of single dyes are placed alongside a dot of ________________ mixture.
The solvent washes up the paper, and then the pattern of the dyes in the mixture can be compared with the single dyes.
Which dyes do the the following mixtures contain?
Example 1:  

Example 2:  

Match each technique to the substances it is used to separate

<table>
<thead>
<tr>
<th>Technique</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sieving</td>
<td>separating an insoluble solid from a liquid</td>
</tr>
<tr>
<td>filtering</td>
<td>separating solids of different sizes</td>
</tr>
<tr>
<td>distillation</td>
<td>separating a soluble solid from a liquid</td>
</tr>
<tr>
<td>evaporation</td>
<td>separating a mixture of two liquids</td>
</tr>
<tr>
<td>chromatography</td>
<td>separating a mixture of dyes</td>
</tr>
</tbody>
</table>

Which method could be used to separate each mixture?

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Substance to collect</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>glass and water</td>
<td>glass</td>
<td></td>
</tr>
<tr>
<td>sea water</td>
<td>salt</td>
<td></td>
</tr>
<tr>
<td>sea water</td>
<td>water</td>
<td></td>
</tr>
<tr>
<td>cooking oil and water</td>
<td>cooking oil</td>
<td></td>
</tr>
<tr>
<td>alcohol and water</td>
<td>alcohol</td>
<td></td>
</tr>
</tbody>
</table>

Assignment #8- Hebden pg 58-59 Questions #45-58 (odd)
All assignments are to be completed on a separate page with the assignment number & heading. Be sure to show FULL WORKING OUT for all homework.